Design and Development of a Uni-Directional Solar Collector for Producing Hot Water & Steam

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Abstract— Science is basically "passive" observation of the universe, as it exists to generate knowledge. Engineering is making use of that knowledge to meet human needs by creating machine, systems, process and technologies that have not previously existed. Design and manufacturing are the synthetic part of engineering practice. Manufacturer has received a lot of attention recently for very good economic reasons. The use of renewable energy resources is increasing rapidly. Following this trend, the implementation of large area solar arrays is to be considered. Due to energy drivers that include uncertainty in oil prices and environmental concerns, effective management of energy system is a priority. Energy policy can focus on three areas to improve energy system like renewable energy supply, efficiency improvement and demand reduction. The solar collectors used in the solar heating plants are flat plate solar collectors and compound parabolic solar collector. If the solar irradiance is high the volume flow rate is high, if the solar irradiance is low the volume flow rate is low. When the efficiency of a solar collector is determine often only one volume flow rate. The flat plate solar collector is the simplest form of solar energy collector. It has been widely and efficiency used in many low temperature application in the field of solar energy utilization. This paper emphasis on the maximum utilization of solar power as energy. It can be most often used at various locations such as house and industry. The additional advantage of this project is it can be used as portable solar collector.

Keywords-*component; solar energy, uni-directional solar collector, flat plate collector*

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I. INTRODUCTION

Sun is the source of one of renewable energy knows as solar energy. Solar energy is a basic need of living plants and human being on the earth. It is intermittent in nature, eco-friendly and non-polluting energy. It is freely available throughout the world, particularly in India. Solar energy can be used for direct conversion into electricity (by photovoltaic conversion) and into thermal energy. The flat plate collector is the heart of any solar energy collection system designed for operation in the low temperature range (ambient-60^{o} C) or in the medium temperature range (ambient-100^{o} C). It is used to absorb solar energy, convert it into heat and then to transfer that heat to a stream of liquid or gas. It absorbed both the beam and diffuse radiation, and is usually planted on the top of a building or other structures. It does not require tracking of the sun and requires little maintenance.(7)

In this paper we are trying to make unique equipment for domestic and industrial purpose for producing hot water and steam. Mostly in the domestic and industrial application for producing hot water and steam flat plate collector and evacuated solar collector use in day to day life.(7)

But problem with flat plate collector and evacuated solar collector is that only get maximum intensity of sun ray during afternoon session and minimum efficiency during morning time. Problem with compound parabolic collector its required motor and sensor for tilting process according to the sun direction. Maximum efficiency during afternoon time and low efficiency at Morning & Evening hours when sunray's inclined with panel. To overcome the above problem we suggested new modified design for flat-plate collector that is uni-directional solar collector for producing hot water and steam throughout day with maximum intensity.(8)

II. OBJECTIVE

The primary objectives of this study can be summarized as follows:

1. Maximum Intensity: - The primary objective of this Paper is to provide uni-directional solution for flat plate collector. They must collect maximum intensity of light throughout day.

2. Application of renewable energy technologies in such communities can reduce the initial cost of flat plate collector.

III. CONSTRUCTION

A modified uni-directional solar collector as shown in figure No-1. Its consist of the absorber plate, tubes fixed to the absorber plate through which the liquid to be heated flows, the transparent cover and the collector box. The absorber plate is usually made from a thin metal sheet ranging in thickness from 0.2 to 0.7 mm, while the tubes, which are also of metal, and range in diameter from 1 to 1.5 cm. They are soldered, brazed or pressure bonded to the bottom of the absorber plate with the pitch ranging from 5 to 12 cm. In same designs, the tubes are bonded to the top or are in-line and integral with the absorber plate. The most commonly used both for the absorber plate and the tubes, is copper. The header pipes, which lead the liquid in and out of the collector and distribute it to the tube, are made of the same metal as the tubes and have slightly larger diameters 2 to 2.5cm.(7)

The cover should be made of a material which is highly transparent to incoming solar radiation and at the same time, opaque to long wavelength re-radiation emitted by the absorber plate. Toughened glass of 4 or 5mm thickness is the most favored material. The type of glass is able to withstand thermal shock as well as the impact of objects which may fall on the collector face. The usual practice is to have one cover with spacing ranging from 1.5 cm to 3cm between the cover

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and absorber plate. The bottom and sides are usually by mineral wool, rock wool or glass wool with a covering of aluminum foil and has a thickness ranging from 2.5 cm to 8 cm. The whole assembly is contained within the box according to proposed design as shown in figure no.1 below.(7,8)

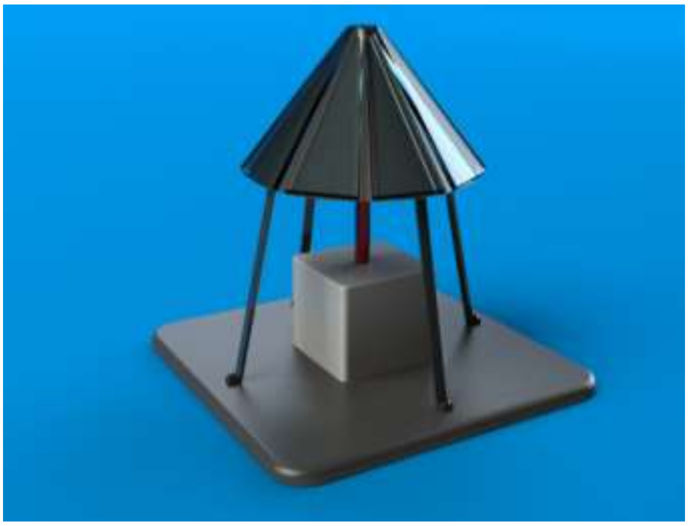


Figure No.1.
Proposed Design of Uni-Directional solar Collector

IV. WORKING

A proposed design of uni-directional solar collector as shown in figure no.1. It consists of an absorber plate on which the solar radiation fall after coming through a transparent cover (made of glass). The absorbed radiation is partly transferred to a liquid flowing through tubes which are fixed to the absorber plate or are integral with it. This energy transfer is the useful gain. The remaining part of the radiation absorbed in the absorber plate is lost by convection and re-radiation to the surrounding from the top surface, and by conduction through the back edges helps in reducing the conduction heat loss. The liquid most commonly used is water. A uni-directional collector is usually held tilted in a fixed position on a supporting structure.(4)

In order to reduce the heat lost by re-radiation from the top of the absorber plate of a uni-directional solar collector, it is usual to put a selective coating on the plate. The selective coating exhibits the characteristic of a high value of absorptivity for incoming solar radiation and a low value of emissivity for out-going re-radiation. As a result, the collection efficiency of the uni-directional solar collector is improved. (1)

V. EQUATIONS AND DESIGN CALCULATION

A. Solar Collector

A solar collector is the heart of any solar energy collection system. Solar collector is a device for collecting solar radiation and transfer the energy to a fluid a fluid passing in contact with it. Utilization of solar energy requires solar collectors. The solar energy collector, with its associated absorber, is the essential component of any system for the conversion of solar radiation energy into more usable form (e.g. heat or electricity). This designed for operation in the low temperature range (ambient-60^0C) or in the medium temperature range (ambient-100^0C). Its absorbs both the beam and the diffuse radiation, and usually planted on the top of a building or other structures. It does not require tracking of the sun. (2)

A solar collector consists of the following components.

- Glazing, this may be one or more sheet of glass or some other diathermanous material.
- Tubes, fines, passages or channels are integral with the collector absorber plates or connected to it, which carry the water air or other fluid.
- The absorber plate, normally metallic or with a black surface, although a wide variety of the material.
- Insulation, which should be provided at the back and sides to minimize the heat losses. Standard insulating material such as fiber glass or styro-foam.
- The casing or containers which enclose the other components and protect them from weather.

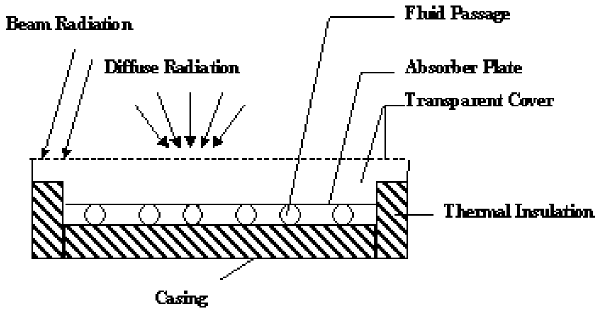


Fig. 2: cross section view of solar collector

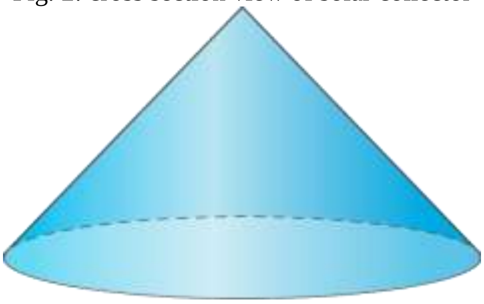
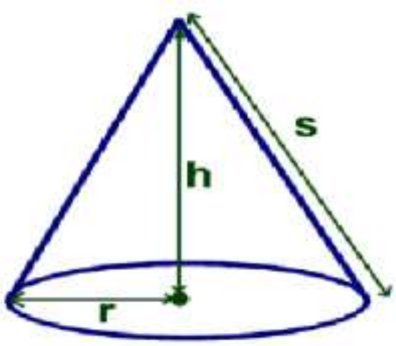


Fig. 3: View of unidirectional solar collector

Surface area



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r=radius of base=2.175 feet

h=height of collector=2.12 feet

s=length of slant=3 feet

Calculation:-

$A=\pi rl+\pi r^2$

$l=\sqrt{r^2+h^2}$

$A=\pi r(r+\sqrt{r^2+h^2}) = \pi*2.17*(2.17+\sqrt{2.12^2+2.175^2})$

$\approx 35.37987\ ft^2$

$m^2=\frac{ft^2}{10.764}$

$=3.2859\ m^2$

B. Hot Water Tank

Hot water storage tanks have an additional outlet and inlet connected to and from the collector. In this tank hot water will be stored and utilized according to requirement.

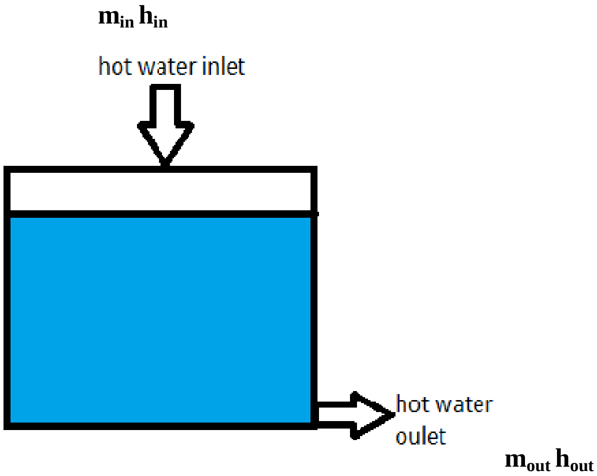

Fig. 4: Front view of hot water tank

Height of tank= 1 feet

Width of tank= 1 feet

Length of tank= 1.5 feet

Calculation:

Volume= length(L)* Width (W)* Height (H)

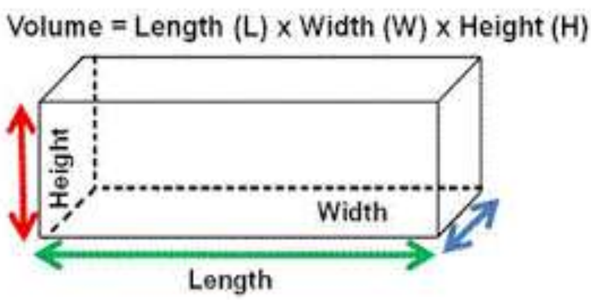

Table 6: Dimensional View of tank

Measurement	Tank Capacity
Liters	42
M^3	0.0
Galons (UK)	9
Galons (US)	11
BBL(USOil)	0.3
Cu.ft	1

Table 6: Calculation table for hot water tank.

C. Absorbed Radiation (S):

$$S = I_b R_b(\tau\alpha)_b + I_d(\tau\alpha)_d\left(\frac{1+\cos\beta}{2}\right) + \rho_g(I_b+I_d)(\tau\alpha)_g\left(\frac{1-\cos\beta}{2}\right)$$

$$(1+\cos\beta/2),(1-\cos\beta/2)$$

Are the view factors from the collector to the sky and from the collector to the ground, respectively. The subscripts b,d, and g represent beam, diffuse, and ground , respectively. $(\tau\alpha)$ is transmittance and absorptance product.Rb is the ratio of beam radiation on the tilted surface to that on a horizantal surface at any time.

D. Collector Heat Removal Factor (FR):

$$F_R=\frac{\dot{m}C_p}{A_cU_L}\left[1-\exp\left(-\frac{A_cU_L}{\dot{m}C_p}\right)\right]$$

m' = Fluid mass flow rate, kg/s

Cp = Fluid specific heat, J/kg °C

The quantitiy FR is equavialent to the effectiveness of a conventional heat exchange, which is defined as the ratio of the actual heat transfer to the maximum possible heat transfer. The maximum possible useful energy gain (heat transfer) in a solar collector occurs when the all whole collector is at the inlet fluid temperature; heat losses to the surroudings are than at a minimum.

E. Overall Heat Loss Coefficient (UL):

UL=UTOP+UBOTTOM+UEDGE,W/M²K

UL is the collector overall loss coefficient and it is equal to the sum of the top, bottom,and edge loss coefficients.

F. Collector Efficiency:

$$Q_U = m' C_P (T_O - T_i)$$

Where;

m' = Fluid mass flow rate, kg/s

Cp = Fluid specific heat, J/kg°C

Useful gain enerrgy equation

$$Q_u = A_c F_R \left[G_T (\tau\alpha) - U_L (T_i - T_a) \right]$$

Where $(\tau\alpha)$ is a transmittance-absorptance product that is weighted according to the proportions of beam, diffuse, and ground reflected radiation on the collector.

G. Instantaneous Efficiency:

$$n_i = \frac{Q_u}{A_c G_T} = F_R (\tau\alpha) - \frac{F_R U_L (T_i - T_a)}{G_T}$$

That is

$$n_i = \frac{m' C_p (T_0 - T_i)}{A_c G_T}$$

VI. EXPERIMENTAL SETUP

The experiments were carried out in April, May and June, in the Nagpur area. The tilt angle of the collector is for practical reasons it was set at 45° throughout the experiments. Due to this, the solar radiation incident on the collector never exceeded 600 w/m^2.

The radiation intensity incident on the outer glazing surface was measured by pyranometer. The temperatures were measured with calibrated temperature sensors. Ambient temperature and wind velocity was measured by a meteorological set. The experimental set-up allowed us to study the development of the unidirectional solar collector steady state and the collector performance (the energy balance on the collector under steady state condition; the collector efficiency and the overall heat loss coefficient of the collector as a function of the operational temperature).

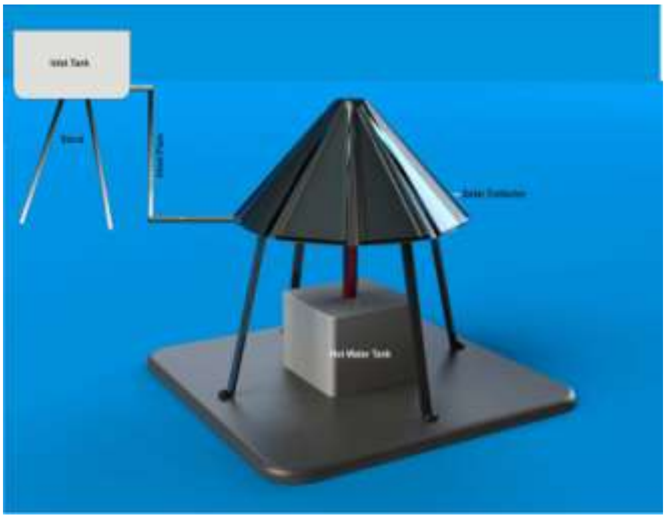

Figure 7: Experimental model of unidirectional solar collector

VII. CONCLUSION

In the current work a uni-directional solar collector is design to absorbed maximum solar intensity of solar sun ray thought out day. The performance of uni-directional solar collector is obtained by testing the manufactured uni-directional. It is expected to reach better performance by improving the design and manufacturing processes.

The conclusion of this Paper is to provide uni-directional solution for flat plate collector. They must collect maximum intensity of solar radiation throughout day. Application of uni-directional solar collector cause maximum utilization of renewable energy for producing hot water and steam

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