An Analytical Investigation on the Performance of Solar Water Heater Made Form Cold Drink Cans

Kumar Abhishek*, Kandarp Mehta, Prashant Mishra, and Indrajit Mukhopadhyay

***Abstract*—**This paper deals with the theoretical as well as the practical results achieved of a solar water heater made up from cold drink cans. In order to heat small amount of water, we have designed and implemented a solar heating model for Gandhinagar, Gujarat (23°9' 23"N 72° 40'2" E). The design concept is to capture and concentrate incident solar radiation by using cold drink cans which replaces the conventional design. EES software was used to calculate the theoretical efficiency. The cold drink cans solar water heater is based on thermosyphon effect which is used in many solar water heater .It makes use of the circulation of water based on density: hot water which is less dense, move upwards and the cold water, which is denser, moves down. Testing of the actual model showed that it is able to heat 30°C above the ambient temperature. Once implemented, such proposed produce will be able to provide hot water with no negative environmental effect and minimal maintenance requirement. It is estimated that a $1m^2$ is enough to heat water upto 20 LPD which is sufficient for a small family.

***Keywords*—** Solar thermal, solar water heater, testing & performance, tropical region (INDIA)

I. Introduction

INDIA is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun [1]. India benefits from a sunny climate, in particular in the north-west region, which receives some 5.5kWh/m^2 solar energy daily .The annual global radiation varies from 1600 to 2200 kWh/m^2 [2], which is comparable with radiation received in the resources [3].At present grid connected fuel mix is 63% fossil thermal, 3% nuclear, 25% hydroelectric and 9% from other renewable resources, whereas rid connected solar generation capacity is a mere 2 MW [4]. About 5,000 trillion kWh per year of solar energy is incident over India's land area with nearly all of India receiving an average 5.5 Wh/m^2/day. The abundant solar radiation, clean character of solar energy, high cost of fossil fuel costs of fossil fuel and negative emission consequences along with large requirements for process heat below 250^0 C are the key drivers of strong focus of development of solar thermal application in India. The use of solar concentrator to meet he process heat requirement of community, industrial and commercial establishment is an emerging and exciting market opportunity in India. Recently, however, the Indian Government has launched the Jawaharlal Nehru Solar Mission (JNNSM) Staring form January 2010 which targets 2000 MW of grid connected solar power 2012, a new policy directive through its national Action Plan on climate Change. One of which eight national missions, namely the National Solar Mission, proposes substantial investment in R&D and infrastructure to increase the share of solar energy within the total energy mix [5].

Research shows that the life cycle environmental sustainability of solar thermal system using life cycle assessment (LCA). Though most of these works has been carried out for nations like USA, UK, and Europe where annual solar irradiation is much more suitable for application of solar thermal technology [6-11]. In recent years, with the theme of promoting environmental protection, solar water heater is more concerned as it uses non polluting solar energy and reduces the use of fossil fuels which makes a great contribution of global warming.

Kumar Abhishek is with the School of Solar Energy ,Pandit Deendaayal Petroleum University ,Gandhinagar, Gujarat , India (corresponding author's phone:+919662531003; e-mail: abhishek.kmts12@pdpu.ac.in).

II. Background

Solar energy is a sustainable, green energy provided for free from the sun. It can be utilised in producing electricity through photo voltaic cells (PV) and capture of heat through solar thermal technologies (CST). Utilization of solar energy for domestic use has been of interest since the 18^{th} century. It was in the 1790s when *Horace de Saussure* observed that boiling temperature can be obtained under glass covering a box. It was from then since that concept of solar water heater evolved from. Water heaters can be mainly classified as: active and passive. Active ones integrate pump which adds on auxiliary consumption as well as construction cost. Passive systems use natural water circulation which makes is less expensive.

Solar water heating (SWH) use radiation from the sun to heat solar collectors, and then transfer the heat to water. As in conventional storage tank water heating systems, SWH systems also store the heated water for future use. Because hot water demand is typically greater in the morning or late evening and does not coincide with times of maximum solar radiation. Most commons ones are flat plate collector and (FPC) and evacuated tube collector (ETC). A typical flat plate solar collector (Fig. 1) is mounted on the roof. It consists of a black metal absorber plate in aluminium housing with a glass

cover plat. Evacuated tube collector (Fig. 2) has a row of glass tube that may contain small metal pipes that act as heat absorbers.

Fig.1 FPC

Fig. 2 ETC

EES is an acronym for Engineering Equation Solver. The basic function provided by EES is the solution of a set of algebraic equation. EES can also solve differential equation, equations with complex variables, do optimization, provide linear and non linear regression and generate publication-quality plots.

The working model was programmed in the EES so that theoretical efficiency could be found out of the SWH system developed. A program is with actual data was written in the EES software and the theoretical parameter were calculate with some assumptions (Fig. 3) shows the program window of EES.

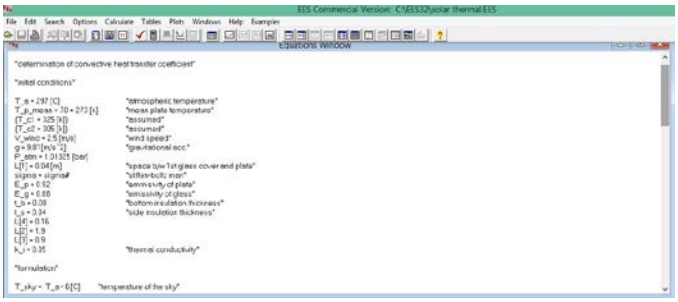

Fig. 3 Program window of EES

III. Objective

As household-income rises domestic energy consumption also increases. The use of air condition, hot water heater etc causes an ever increasing use of energy. Access to cheap and easy water using free solar energy would be beneficial to countries with low house hold income. Such devices would be very efficient in countries near the equator which have access to solar energy throughout the year. There are also health benefits associated when water heated using solar energy.. As people are less exposed to toxins and pollutants released using traditional burning fuels.

The paper presented herewith is to develop a method to utilize the waste material in order to heat from the sun to heat water for domestic consumption. We are not going to focus much on the theoretical modelling part rather practical model is being our prime concern. The final model would be an affordable solar water heater for low and medium income group people.

IV. Material and Methodology

Material

Most of residential SWH systems contain five components:

(i) Solar thermal collector (s)-flat lat plate and evacuated tube are the most typical. For the same we require cold drink cans.

(ii) Heat transfer system- piping valves for liquid. Since its a natural one no pump, fans and heat exchanger is necessary. Copper pipes were used in the SWH system and external to it PVC pipes.

(iii) Storage tank- to store the water and to make the thermal energy demand when solar radiation is not available. For this purpose we made use of 20L lubricant bucket.

Methodology

1. Firstly the collected cold drink cans were washed and cleaned properly.
2. Holes were drilled in the cold drink cans. (Fig 4) shows the drilled hole in the cold drink can.

Fig. 4 Drilled holes in cold drink cans

3. These cans were connected back to back so that appropriate length is achieved. One line called as one strings
4. The cans were painted black with two to three layer of black painting. It is done to make it a good collector of solar energy.(Fig.5) depicts the painting process carried out.

Fig.5 painting process being carried out

5. Copeer pipes are inserted in the drilled out holes in the cold drink cans. Water would flow in these pipes, getting heated by absorbing heat . (In our earlier attempt we tried to flow water directly in the cans but there were leakages.)
6. The strings are connected with the pipe fittings and clamped inside the wooden box (Fig 6) shows the wooden box. Thermal insulation is provided on the sides on the wooden box from inside.

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Fig. 6 Wooden box with thermal insulation

7. A galvanised iron sheet is on the sun facing side to reflect the radiation. (fig. 7) Shows the complete assembly inside the wooden box.

Fig. 7 Working model of SWH system made up of cold drink cans

V. WORKING MODEL

A. Solar water heater configuration

The configuration of solar water heater is illustrated in Fig. 6.The collector is mounted vertically so that no special requirement is there for the it. The array of Making in possibilities for just hanging on the walls.

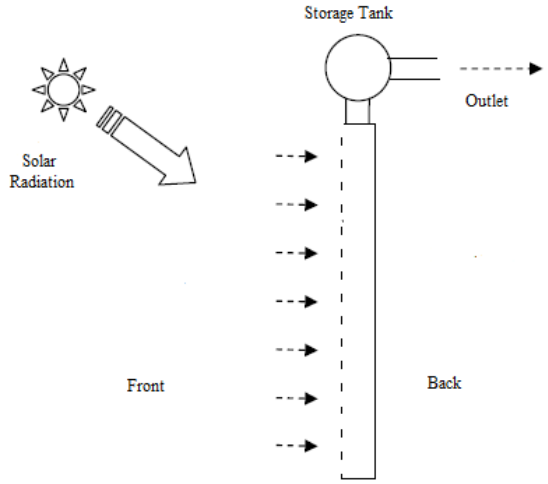

Fig. 8 Configuration of the proposed model

B. Assumptions:

(i) The Absorber and plate temperature and black plate temperature are assumed to be throughout their respective surfaces i.e. Isothermal. While mostly there are non-isothermal.

(ii) The water flow is assumed homogeneous and ideal

(iii) Convection losses from the absorber plate to the ambient air are considered negligible.

(iv) One Dimensional condition is considered. The absorber is considered to be diffuse,(i.e. one without directional characteristics) and gray (i.e. one independent of wavelength) for all absorbed and emitted radiation.

(v) Flow reversal through the absorber is assumed to be negligible. In actual practice flow reversal is driven by buoyancy and wind.

(vi) The absorber is considered circular throughout the array. But in reality they are not circular at the joints between the two cans.

VI. TESTING AND RESULTS

The heat transfer method is used to study the performance of the solar water heater i.e. collector. With the stable water temperature 25±2^{o}C and inlet velocity of flow 70 (kg/h), was stopped when the difference in inlet and outlet water temperature was less than 1^{o}C after working hours. It was found for the Gandhinagar, Gujarat, India location *(23^{o}9' 23"N 72^{o} 40'2" E)* the developed model was able to heat about 20 LPD water over a whole day duration. For the sake of simplicity, the water flow rate, water inlet temperature, ambient temperature, and wind speed are all assumed to be constant. Though these parameters affect the performance of the collector.

VII. CONCLUSION

The result suggests that the proposed design of solar water heater made of cold drink cans is successful and can be

practically implemented. Manufacturing is the main contribution to environmental impacts harnessing the solar energy from the waste material would be actual sustainability. The proposed model makes access to a cheap and easy water heating device using free solar energy would be beneficial to countries with low house hold income.

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REFERENCES

[1] K.S. Reddy, G.Veershetty, Viability analysis of solar parabolic dish stand-alone power plant for Indian conditions. *Applied Energy* 102 (2013); 908–922
http://dx.doi.org/10.1016/j.apenergy.2012.09.034

[2] Government of India, Ministry of New and Renewable Energy, *Annual Report*, 2005-2006.

[3] R.B. Grover, S. Chandra, Scenario for growth of electricity in India. *Energy Policy* 2006;34(17):2834-47.
http://dx.doi.org/10.1016/j.enpol.2005.04.021

[4] B. Buragohain, P. Mahanta, V.S.Moholkar. Biomass gasification for decentralized power generation: the Indian perspective. *Renewable and Sustainable Energy* Reviews 2010;14(1):73-92.
http://dx.doi.org/10.1016/j.rser.2009.07.034

[5] Government of India. National action plan on climate change. 2008.

[6] Y. Hang,Qu M, F. Zhao, Ecnomic and environmental life analysis of solar hot water system in United States, *Energy Build* 2012;45:181-8
http://dx.doi.org/10.1016/j.enbuild.2011.10.057

[7] F. Ardente, G. Beccali, M. Cellura, V. Lo Brano. Life cycle assessment of a solar thermal collector: sensitivity analysis, Energy and environmental balances. *Renewable Energy* 2005; 30:109-30
http://dx.doi.org/10.1016/j.renene.2004.05.006

[8] G. Tislingiridis, G. Martinopoulos, N. Kyriakis. Life cycle environmental impact of a thermosyphonic domestic solar water system in comparison with electrical gas water heating. *Renewable Energy* 2004; 29:1227-88

[9] R.H. Crowford, G.J.B.D. Treloar. Comparative greenhouse gas emission analysis of domestic hot water systems. Build Res Inform 2003; 31:34-7.
http://dx.doi.org/10.1080/09613210210160800

[10] ISO. ISO 14040-Environmental management-lifecycle assessment-principles and framework; 2006, Geneva.

[11] P. Hernandez, P. Kenny. Net energy analysis of domestic solar water heating installations in operation. *Renew Sustain Energy* Rev 2012; 16:170-7
http://dx.doi.org/10.1016/j.rser.2011.07.144