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Feasibility Study of Solar Thermal Integration to Community Cooking Systems

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Abstract*: Cooking is a prime requirement for people, all over the world. Cooking accounts for the major share of energy consumption in developing countries. Conventional cooking requirement is met through fuel wood which resulted in deforestation, increased costs of fuels and adverse environmental effects. The major source of conventional cooking is LPG which is getting increased day-by-day and it leads to carbon dioxide emission in the environment. Solar cooking is simplest, safest, and a convenient way to cook food without consuming fuels. Solar cooking is done by various types of solar cookers such as parabolic, box type and indirect type using steam cooker. But, this concept is used usually for large community level. Many researchers have been worked on solar box type cooker or large scale paraboloidal dish type cooker. So, for medium scale community where 150 to 250 people can be served such as mid-day meal schools, orphanages, old age homes, and governmental canteens is limited. The compound parabolic concentrator (CPC) based solar thermal cooking is convenient. The medium temperature range solar concentrator is useful in medium scale applications. The indirect cooking is done by steam on large scale using parabolic dish collector, parabolic trough collectors which is costly to medium scale community. The compound parabolic concentrator is presently used for hot water generation in the storage tank. In the storage tank water temperature is rise to more than 90°C daily, which can be used for cooking application as the sensible heat source. Cooking needs sensible and latent heat to boil food completely and hence sensible heat is supplied using compound parabolic concentrator heat source while for further latent heat is supplied by an electric boiler. The combination of electric boiler and solar CPC collector hot water is used for cooking. The hot water is getting more than 80°C for cooking at morning as it is stored in insulated tank inside the kitchen. After using such hybrid solution at NCL canteen for cooking, around 34% saving on cost of LPG obtained which corresponds to around 57% of LPG reduction. Further, more than 30% saving on carbon dioxide emission is possible due to this hybrid solution for the College canteen.

***Keywords*: Solar Thermal Integration, Community Cooking Systems.**

1. Introduction

India is consuming energy at rate of about one third of the world energy consumption. The primary energy demand of world is increasing around 2% annually. Man has used energy at an increasing rate for his sustenance and well-being since time immemorial. Primitive man required energy primarily in the form of food. The conventional cooking is carried out using firewood, woodchips on challahs, LPG cooking, Kerosene, etc. [1]. The main requirement for cooking is sensible heating and latent heating of water. After, man discovered fire, his energy needs got increased as he started to make use of wood and other biomass to heat for cooking. Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11} M W, which is larger than the present commercial need on earth. Solar energy is the most promising unconventional energy resource. There are various solar thermal modules that can be used to obtain high temperature water [2].

The latent heat requirement is normally satisfied using electric boiler instead of LPG. These solar collectors are classified on the basis of temperature, capacity and design [3]. Out of all these collectors, for low-medium temperature process heat applications Compound Parabolic Collectors (CPC) are most suitable. A potential capacity of CPC is to obtain operating temperatures near to (or higher than) the boiling point of water generally in the range from 80-130ºC. The CPC is used for heating water in the storage tank at a laboratory setup is explained in chapter three. There are three panels used for heating storage tank water of capacity two hundred litre. From his storage tank, water is passed to cooking vessel. In cooking vessel, water volume is heated along with storage tank water by indirect contact. An important domestic thermal application is that of cooking. For medium scale community, where 150 to 250 people can be served such as mid-day meal in schools, orphanages, old age homes, governmental canteens. The major Indian style cooking items include rice, dal, legumes, and potatoes, tea, which require hot water. That hot water (or sensible heat) can be utilized medium temperature range solar thermal collector and compound parabolic concentrator.

2. Experimental methodology

A. *Experimental set up*

The experimental setup is used for storage tank water heating and cooking vessel water heating. The schematic diagram of experimental setup is shown in the Fig. 1 and 2. The experimental setup consists of three CPC panels, storage tank, cooking vessel, expansion tank and temperature sensors, data acquisition system, centrifugal pump, etc.

Fig. 1. Typical schematic of experimental setup


Fig. 2. Typical schematic of experimental setup

3. Results and discussions

A. Temperature data analysis

Experiments were performed at the college canteen. During November 2018 to April 2019 for continuous heating of water. For different months, the temperature data were extracted through data acquisition system as, explained in chapter three. RTD (pt100) temperature sensors are mounted in the pipeline and inside the storage tank. From these temperature sensors, signal pass to data logger and through data logger, it is communicated to computer system. In the computer, output is obtained in the excel sheet format which is used for data analysis. Compound parabolic concentrators are used to heat the storage tank water using copper tube heat exchanger. Continuous heating is done for six months [5].

The corresponding temperature rise with respect to the solar intensity is then plotted for those experiments. Figs. 3 to 6, shows the temperature variation with respect to time of the day. As the solar irradiance is increased day-by-day, there is rise in temperature of storage tank water. From the month of November itself, water temperature obtained is around 78°C and in April the maximum water temperature obtained is around 106°C. In month of December, solar radiation was not uniform or more as compared to November, it was a cloudy day, and hence the temperature did not reach more than that in November. But, still in cloudy days, temperature is getting around 74°C. Fig.7, show the maximum temperature of water obtained in the storage tank for six months. For month of November to February, the maximum water temperature is getting around at 4PM and at 2PM, 3PM for the month of March and April, respectively.

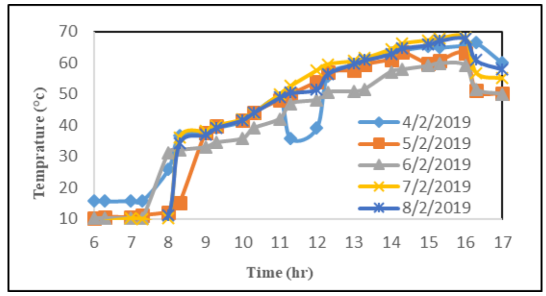

Fig. 3. Storage tank water temperature variation (February)

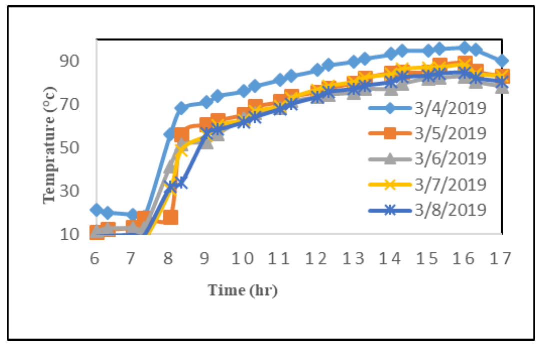

Fig. 4. Storage tank water temperature variation (March)

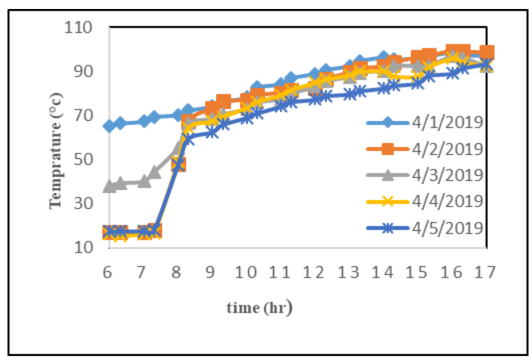

Fig. 5. Storage tank water temperature variation (April)

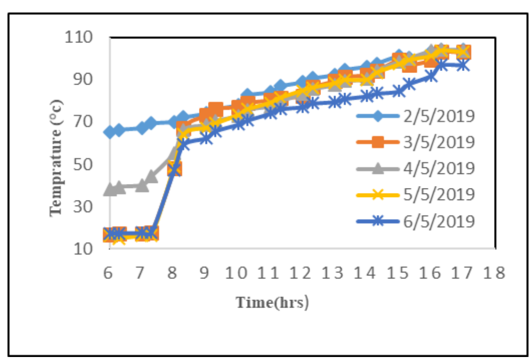

Fig. 6. Storage tank water temperature variation (May)

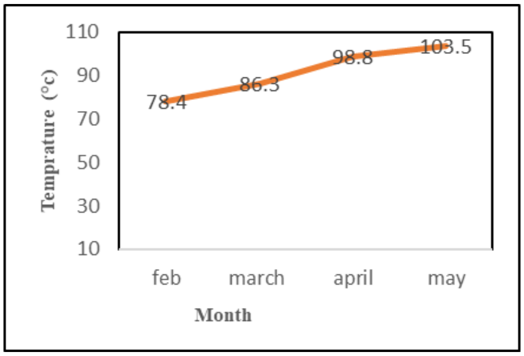

Fig. 7. Storage tank water temperature in particular month (maxi)

4. Energy consumption

A. cooking section

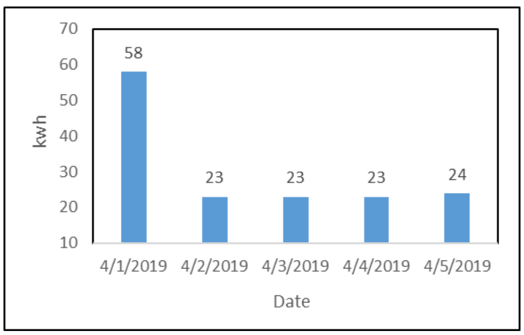

Fig. 8. Energy consumption per day

Energy consumption: The energy consumption by geyser is measured using an energy meter. The above Fig. 8 shows the energy consumption of washing section geyser. As seen in Fig. 7, for cooking section, about 25kWh electrical energy was used per day. So, as per Pune electricity tariff (Non-Domestic) of MSEDCL'S (Maharashtra state electricity distribution co. Ltd) is Rs.10 per unit. According to this tariff, the cost estimated for geyser load is Rs. 250 per day. (Assuming, that, 25 units of electricity is used on an average per day).

5. Conclusions

Corresponding to sunny days more than 75°C water temperature is achievable in the storage tank during November 2018 to May 2019.The maximum water temperature obtained in the storage tank is around 106°C with a flow rate of 4.7LPM in the April month. While the maximum temperature obtained in the cooking vessel is 95°C, which shows that indirect type of cooking is not possible [5]. The maximum temperature is obtained at 4PM during daytime. The average CPC efficiency achieved is about 35 to 40%. Using a hybrid solution in the canteen cooking section, around 57% of LPG consumption is reduced, 26% of energy is saved, and 30% CO_2 emissions is reduced [6]. Also using the hybrid solution in canteen cooking section, on an average Rs. 448/- per day is saved on fuel, which is around 34% cost saving per day. In the washing section, Rs. 250/-per day are saved from geyser consumption.

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