"Experimental Investigations of Parabolic Dish with Conical Coil Receiver Using Therminol-55"

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Abstract

The solar cooking is the alternate method of cooking to reduce consumptions of fossil fuels. An affordable, energy efficient solar cooking technology is much need due to increase in the cost of fossil fuels. This paper presents an experimental analysis of the heat transfer enhancement of solar parabolic dish truncated helical coil receiver. The parabolic solar dish with conical coil receiver is experimentally tested to find the thermal characteristics and the instantaneous efficiency of the heat transfer fluids like water and Therminol 55.

Keywords - Parabolic dish, Truncated helical coil, Therminol 55, Water.

Introduction

Cooking, heating and lighting are the basic energy needs of domestic consumers. Hence it is necessary to satisfy them with clean and efficient fuel like LPG for cooking and heating demands whereas electricity for lighting purpose. But in India even today about 90% of Indian rural people do not have access to modern cooking fuels and it drops down to 33% in urban area [1]. About 90% of energy consumed by the poor is used to satisfy their cooking demands and electricity is used mainly for lighting purpose [2]. Studies reveal that it requires only about 35 kg of Liquefied petroleum Gas (LPG) per person per year to cook his three meals thereby reducing their dependency on solid fuel [3]. Hence the need of the hour is to find out an energy source which is locally available and good enough to satisfy the energy demand of the needy people. As of now the use of fossil and biomass fuels has produced large amounts of environmental pollution due to the emission of harmful gases as combustion byproducts. Which also results in increase of carbon dioxide in the atmosphere from fossil fuel combustion is believed by some to be the main source of global warming.

Renewable sources play important role in sustainable development and the environmentally friendly energy sources. Among the renewable energy sources, solar energy is considered the most abundant and a viable option for thermal energy applications. Solar energy has been a huge potential solution to these needs. The power intercepted by the earth from the sun is estimated at about $1.8x\ 10^{11}$ MW. In fact, the sun provides enough energy in one hour to supply the earth with its energy needs for a whole year. When considering thermal applications of solar energy, solar cooking presents the best option and the most promising appliance for solar thermal energy. Solar cookers provide many advantages, including fuel economy, reduction in greenhouse gas emission, firewood utilization saving, lower cost and high durability, among others. However, in many parts of the world, especially in developing countries wood and fossil fuel based cooking energy resources still predominate with the highest share of global energy consumption in the residential sector. This situation creates serious ecological problems, such as deforestation; economical and health problems are also consequences of firewood use. On the other hand, the global demand for cooking energy is expected to increase with the increasing human population over in the upcoming years. Currently, renewable energy sources supply about 14% of the total world energy demand, and their potential will play an important role in the world's future. The development of solar cooking systems in the near future will also help to resolve the existing problems with the technology like long duration cooking, uncontrolled temperatures, tracking strategies, and thermal storage techniques, etc. and thereby, overcome the barriers to the dissemination of the solar cookers. Many opportunities exist to promote the future potential of solar cookers, so more research attempts must be carried out to increase their efficiency and thus enhance their current performance.

In this paper an effort has been made to identify the best possible heat transfer fluid (HTF) for cooking applications using solar truncated helical coil based dish type collector is studied. The performance test is conducted for dish collector using Water and Therminol-55 as HTF in the same atmospheric condition.

Materials and Methods

This system operates on the principle of concentrating the incident solar radiation into small enclosures via dish collector. The solar receiver or the enclosure is located at the focal point or focal line of the dish collector. A Solar dish system consists of a dish with a reflective materials and a receiver located at the focal point of the dish. The Solar dish type collector supported by stand. The solar radiation incidents on the dish are reflected toward the focal point of the dish where the receiver is located. Highly concentrated solar radiations enter the receiver and significantly increase the temperature of the receiver and the receiver fluid. The receiver is designed in the form of helical tube structure as given in Figure 2 (b). The helical tube consists of heat transfer fluid which circulates the system with the help of pump. The heat transfer fluid absorbs heat and transfer heat to cooker which is placed inside the household. The pump operates with help of the battery and it is charged by the PV source.

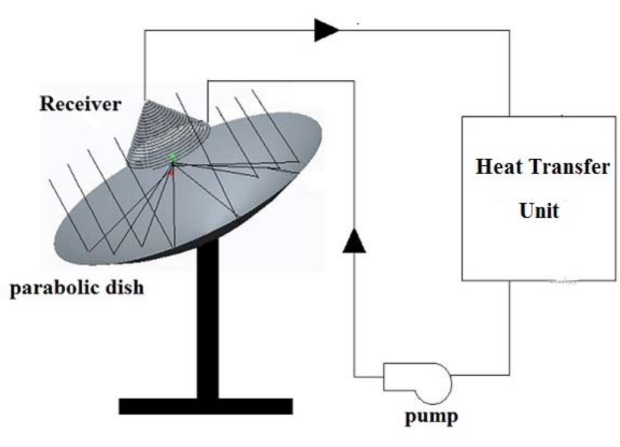

Figure .1 Schematic of Parabolic dish with conical coil receiver setup

Figure .2 (a) Photographic view of Schematic of Parabolic dish with conical coil setup (b) Receiver coil

The following are the deliberations made for the design of the ACS IES-15 stove:

- A family of two adults and two children are considered
- Quantity of meal estimated is one per person per day

Some important calculations used to design the solar dish collector are as follows and the detailed design parameters used to construct the truncated helical coil dish collector are also given in the Table 1.

The amount of energy needed to make a meal for the four members family is estimated to be about Qn =1000 kJ.

Table 1. Cooking load calculations

PARAMETERS	SYMBOLS	VALUE
Heat energy required to cook rice	Q_{rice}	378 kJ
Heat energy required to cook dhal	Q_{dhal}	564.3 kJ
Total heat energy required to cook (3 members)	Q_{total}	1000 kJ
Collector area	A_c	1 m^2
Efficiency of solar cooker	η	40%
Cooking time	t	2 hrs

Table 2. Specification of Parabolic Dish collector

PARAMETERS	SYMBOLS	VALUE
Aperture diameter	D_a	1.13 m
Half acceptance angle	φ	18.48°
Rim angle	ψ_{rim}	71.57°
Focal length	f	0.392 m
Receiver area	A_r	0.1 m^2
Radius of the cone base	R	0.178 m
Arc length	L	1.22 m
Height of the dish collector	h	0.204

Therminol and its properties

It has been proven that the fluids having low specific heat have the higher heat gain. Therminol is available in different grades and the selection is based on the flash point and its operating temperature limits. Selvakumar et al [4] has conducted the experiment on evacuated tube based solar parabolic trough collector system using Therminol D-12 as HTF to utilize low sunshine during morning and evening time. G. Kumaresan et al [5] suggested that Therminol-55 is the best heat transfer fluid for short flow length and cooking applications. Different grades of therminol and their working temperatures are shown in Figure 3. Therminol 55 has the flash point of 177°C and fire point of 218°C (ASTM D-92) is an inexpensive and easily available heat transfer fluid. The other fluid properties like density are closer to that of water. From the above observations, Therminol 55 is selected as heat transfer fluid for the truncated helical coil based solar dish collector system. Table 1 shows the thermo-physical properties of water and Therminol-55.

Table 3. Thermo physical properties of Heat Transfer Fluids

Property	**Water**	**Therminol 55**
Kinematic viscosity @ 40^0 C	0.657 mm^2 /s (cSt)	36.8 mm^2 /s (cSt)
Density @ 20^0 C	1000 kg/m^3	875 kg/m^3
Thermal conductivity @ 27^0 C	0.6012W/mK	0.1276 W/mK
Flash point	-	193^0 C
Fire point	-	238^0 C
Boiling point @ 1013 mbar	100 ^{0}C	351^0 C
Coefficient of thermal expansion	-	$0.00096/^0$ C
Specific heat capacity @ 27^0 C	4.187 kJ/kg K	1.83 kJ/kg K

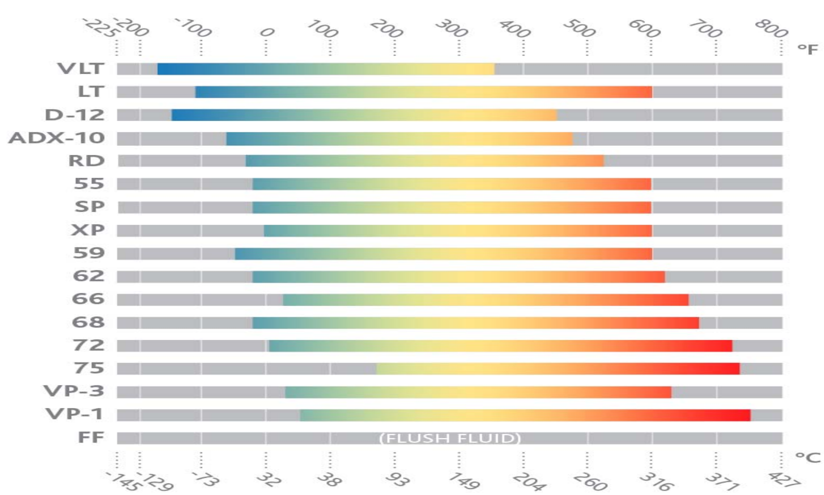

Figure .3 Different grades of Therminol [6]

Results and Discussion

The results obtained from the experimental investigations of the dish collector truncated coil receiver is discussed and presented in detail. In forced mode the HTF is circulated by the pump with the flow rate of 0.004 kg/s. Flow rate is measured and fixed by the jar filling method. In this experiment both

Water and Therminol-55 were taken as heat transfer fluid. The various results obtained from the experiment are discussed in detail as follows:

Outlet Temperature

Experiment is conducted using water with mass flow rate of 0.04 kg/s and average wind velocity of 2.5 m/s. Figure 4 shows that the variation of radiation, outlet temperature, inlet temperature and wind velocity with respect to time of the day. The maximum outlet temperature of 69^{o}C reaches at 12.30 p.m for water as HTF.

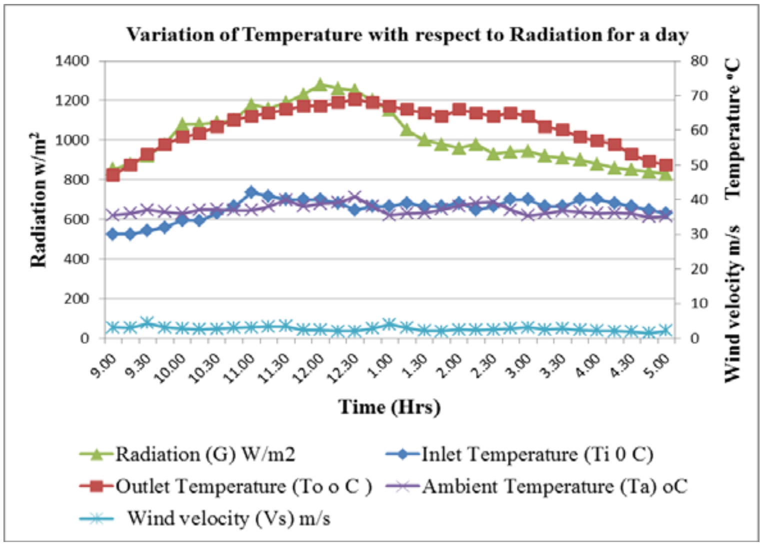

Figure 4. Outlet temperature plot (Water as HTF)

The same experiment if repeated for Therminol-55 as HTF with mass flow rate of 0.04 kg/s and average wind velocity of 4.6 m/s. Figure 5 shows that the variation of radiation, outlet temperature, inlet temperature and wind velocity with respect to time of the day. The maximum outlet temperature of Therminol-55 reaches about 86^{o}C at 12.30 p.m.

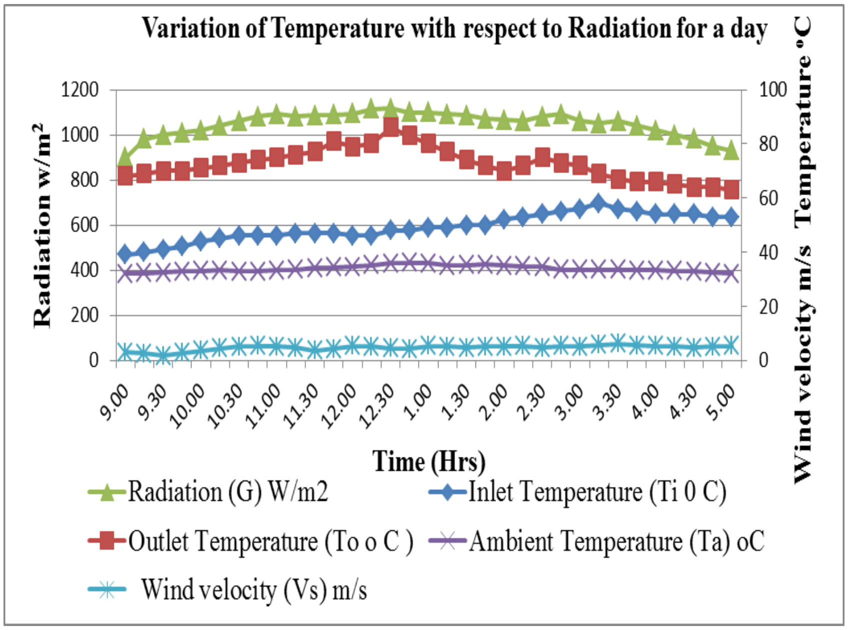

Figure 5. Outlet Temperature plot (Therminol 55 as HTF)

Hence, the outlet temperature of Therminol-55 is high when compered to water as HTF. This is due to low specific heat capacity of Therminol-55 as shown in Table 3.

Heat Gain

The heat gain of the system gradually increases and decreases with respect to the solar radiation are shown in the Figure 6. The maximum heat gain of 600 W attained for water as HTF at 12.30 p.m.

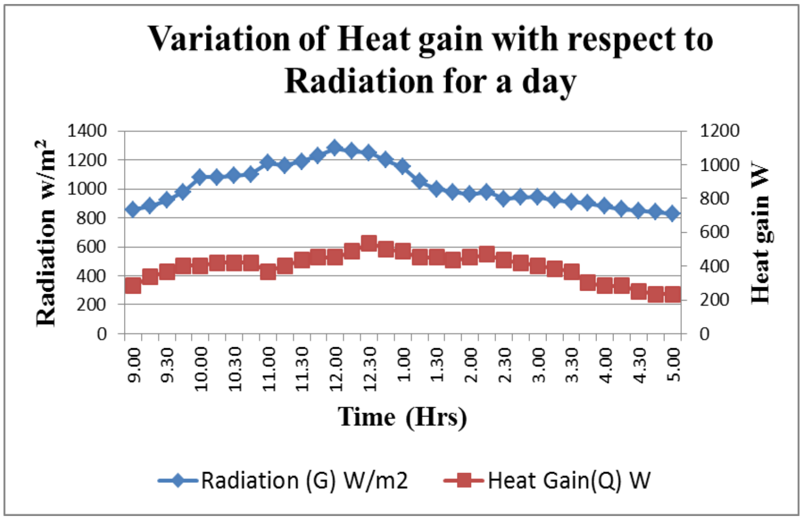

Figure 6. Heat gain (Water as HTF)

The maximum heat gain of 380W attained for Therminol-55 as HTF at 12.30 p.m is shown in Figure 7.

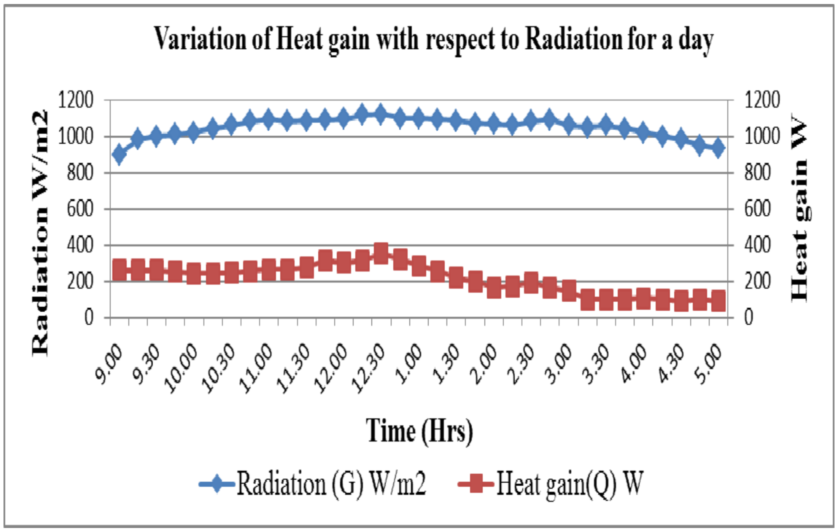

Figure 7. Heat gain (Therminol 55 as HTF)

Therfore the overal heat gain of water is very high when compered to Therminol-55 as HTF. The reason is due to thermal conductivity of water is high than Therminol-55 as shown in Table 3.

Efficiency

The efficiency of the truncated helical coil dish collector varies over time and is reached maximum between 1.00 to 3.30 p.m. The highest efficiency of 48% is recorded for Water at 2.30 pm is shown in Figure 8.

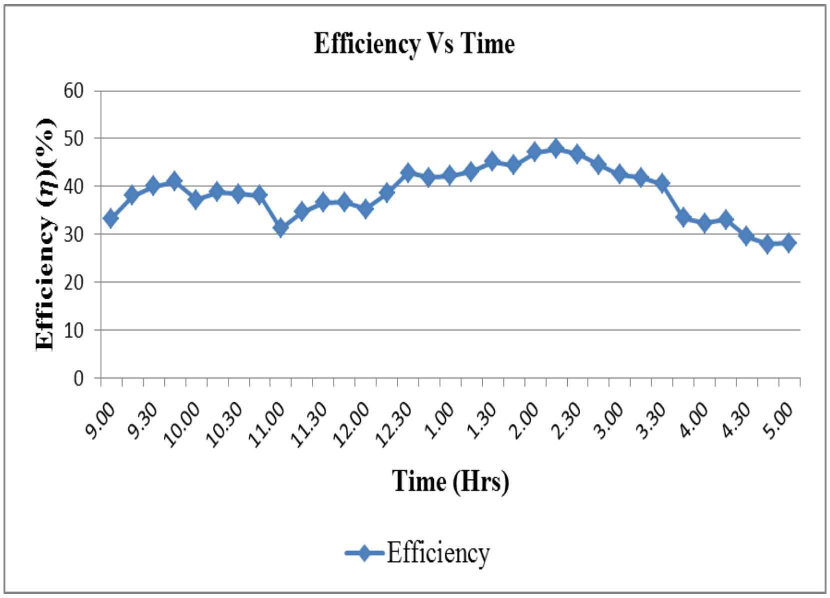

Figure 8. Efficiency of dish collector (Water as HTF)

Similarly the efficiency of the truncated helical coil dish collector various with time and is reached maximum between 12.00 to 1.00 p.m for Therminol-55. The highest efficiency of 33% is recorded for Therminol-55 as HTF at 12.30 pm is shown in Figure 9.

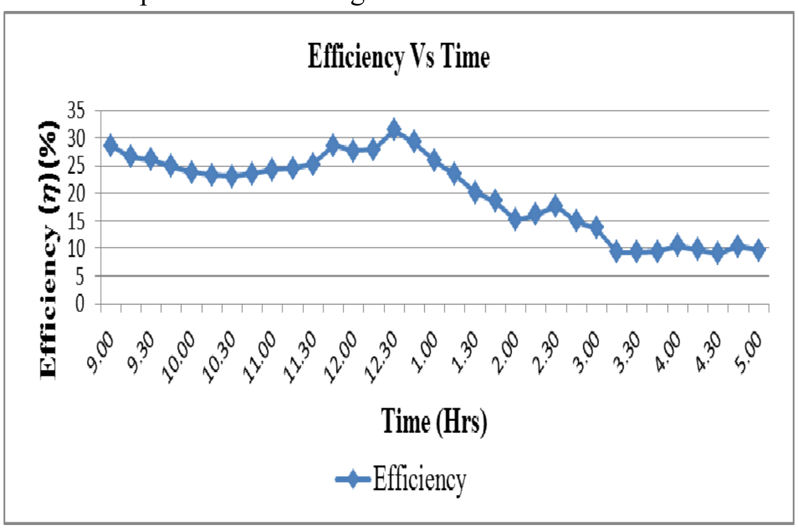

Figure 9. Efficiency of dish collector (Therminol 55 as HTF)

Further, research and development can be extended in order to reduce the heat losses by incorporating lightweight composite insulating materials around the receiver can increase the efficiency of the collector.

Conclusion

Over the decade, intensive research is going in the field of solar energy for various household applications. In this paper a special type of conical coil truncated coil receiver is studied and constructed. The parabolic dish is designed in such a way that to concentrate the solar radiation in to the receiver. The designed conical coil truncated receiver is experimentally analyzed with various heat transfer fluids like water and Therminol 55. The result shows that efficiencies of Therminol 55 is lower than that of water

HTF is due to variation in specific heat capacity and thermal conductivity. The maximum efficiency of water is 48% and for Therminol-55 it is about 33% has been attained. But the maximum temperature received for Therminol-55 is considerably high when compared to water as HTF. From the results it can be concluded that the Therminol-55 is the best HTF medium for cooking applications.

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