FEASIBILITY OF A SOLAR COOKER IN OFF SUNSHINE HOURS USING PCM AS THE SOURCE OF HEAT

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ABSTRACT

Present box type solar cooker is only successful in sunshine hours. In the present research work, a solar cooker has been developed which can work even during Non-Sunshine hours and can be installed in the kitchen itself. In the present work, the system a system has been developed where heat is transferred to cooking material in solar cooker in non-sunshine hours from Acetamide, a PCM, which store energy during Sunshine hours. PCM is heated by hot water which is heated in a flat plate collector using annular evacuated glass tubes. It was possible to achieve the temperature of 63.6°C during non-sunshine hours and was enough to cook the food stuff.

KEYWORDS

Solar cooker, Phase changing material, evacuated glass tubes, Heat transfer fluid.

1. INTRODUCTION

Box type solar cooker marketed by UrjaVikas Nigam, which runs on Green house effect, are only successful during Sunshine hours. An effort has been made to develop a solar cooker, which can work even during Non-sunshinehours[4]. It will conserve conventional energy and reduce the polluting emissions. It is also a step towards to achieve the target of 1,00,000MW of Solar energy based electric power generation, set by Govt. of India by 2022. In the present work, a commercial grade Acetamide has been used as Phase Changing Material[1] to store heat energy during sunshine hours. During the off sunshine hours, the same material is used to heat food stuff in the solar cooker. PCM was heated by hot water, heated in flat plate collector using evacuated annular glass tubes. It was possible to get maximum temperature of 63.6°C in the solar cooker.

2. EXPERIMENTAL SETUP

Experimental setup is shown in figure 1. It consists of the following main parts:-

a) Evacuated Annular tube collector
b) Solar cooker
c) Phase change material (PCM)
d) Reflector
e) Heat transfer fluid

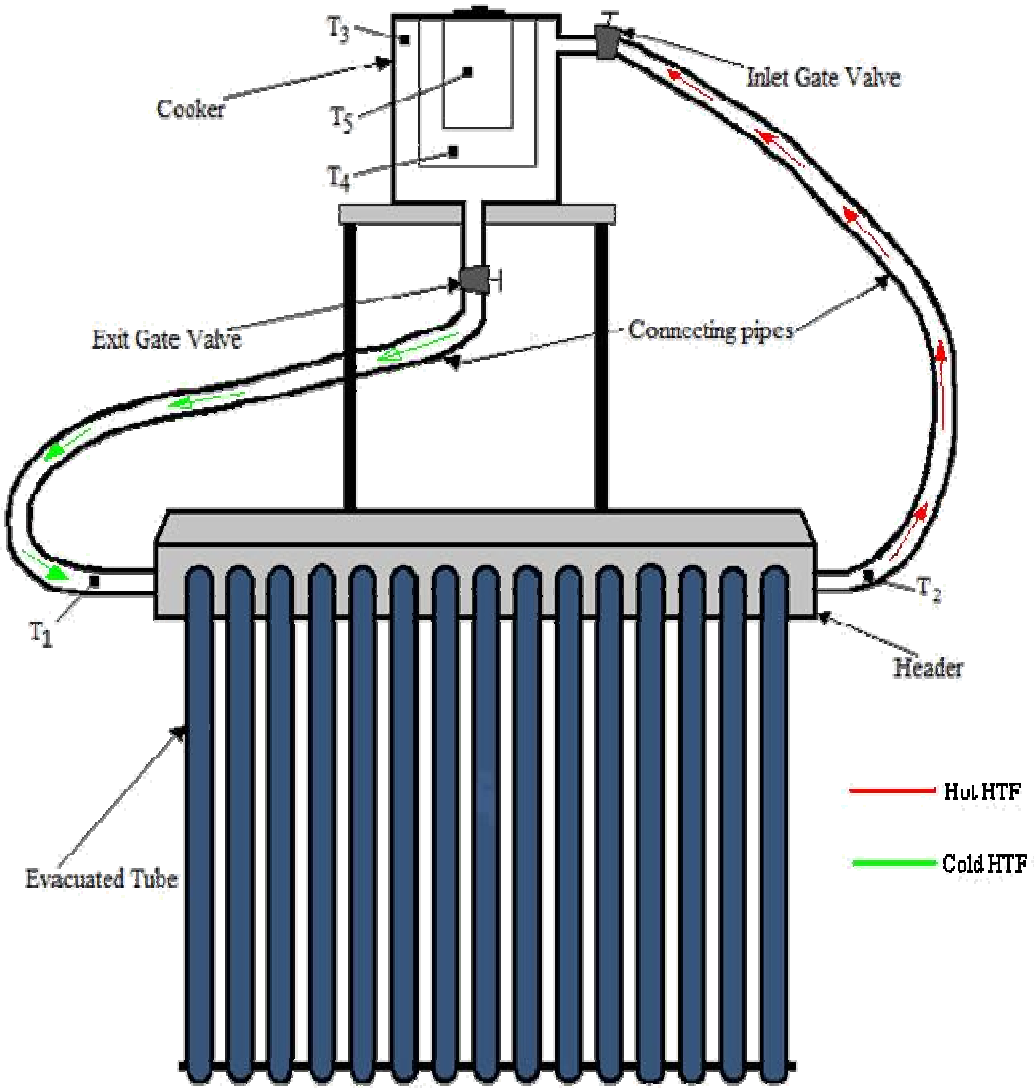


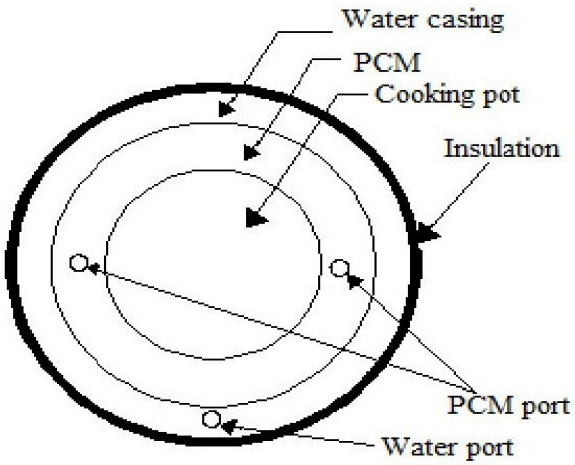
Figure 1 Schematic diagram of Experimental setup

a) Evacuated Annular tube collector:

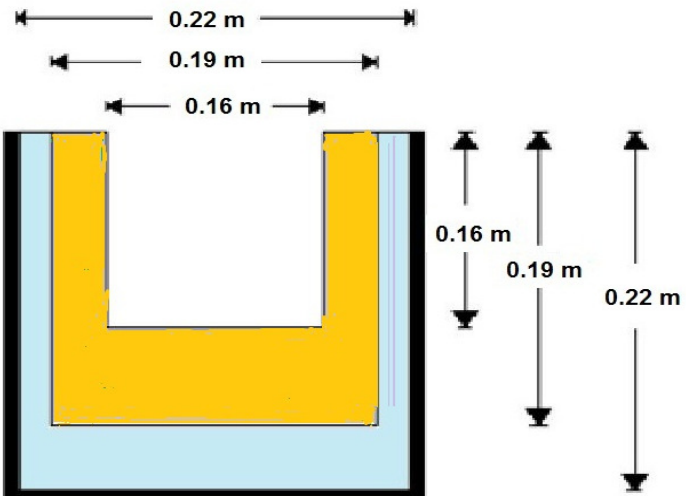
It consists of fifteen evacuated annular glass tubes of 1.5m in length. The diameter of outer glass tube and coated absorber tube are 0.0047m and 0.0037m respectively. A vacuum of ($P \leq 5x10^{-2}Pa$) was created between outer and absorber glass tube. Vacuum was created to check the heat loss by convection. Absorber tube is coated with Selective coating of Aluminum Nitride to absorb solar radiations to a higher extent. A steel sheet was used below the tubes as a reflector to reflect the sun radiations and absorber tube. This flat plate collector was used to heat water as Heat transfer fluid (HTF).

b) Solar Cooker:

Construction details of solar cooker have been shown in figure 2.



a) Top View of Solar cooker



b) Side view of Solar cooker

Figure 2: Schematic diagram of solar cooker (a) Top view of cooker (b) Side view of cooker

Solar cooker is made of 3 hollow coaxial cylindrical vessels of steel having dia. of 0.22m, 0.19m and 0.16m respectively. In the outer vessel, water flows as heat transfer fluid. The center vessel is stuffed with 3kg of commercial grade Acetamide to act as PCM[11]. Allowances are given with in the middle vessel for volumetric expansion of PCM. Inner vessel is used to keep the food stuff to be cooked with air tight lid. Two safety valves are also provided for PCM unit and working fluid.

c) Phase change Material (PCM):

A PCM[1] could be a substance with high heat of fusion that is capable of storing and releasing large amount of energy. Heat is absorbedwhen PCM changes its phase from Solid to Liquid and Heat is released on Reverse phase change. A PCM [3] should have high melting temperature, high latent heat of Fusion, high specific heat, high density and non-toxic. The thermo physical properties of Acetamide are given as below in Table 1.

Table1: Thermo physical properties of commercial grade Acetamide[1].

Melting point of Acetamide (commercial grade)	79℃
Latent heat of fusion of Acetamide (commercial grade)	263 kJ/kg
Specific heat of Acetamide	1.94 kJ/kg℃
Density of Acetamide	1.159g/cm^3

d) Reflector:

A steel sheet as reflector has been used below the evacuated tubes to reflect sun radiations on absorber tubes. Steel sheet of size 1.55m x 1.00m with reflectivity of 82% was used.

e) Heat Transfer Fluid[14]**:**

Water having specific heat of 4.187kJ/kgK was used as Heat transfer fluid to PCM during Sun shine hours.

3. WORKING MECHANISM

During sun shine hours, water as heat transferring fluid gets heated and circulates in the system due to convection. This water transfers heat to phase changing material, placed around solar cooker. Phase changing material (PCM) absorbs heat by changing its phase from solid to liquid. During the non-sunshine hours this stored heat in PCM is used to heat the food stuff in solar cooker. Heat transferred is enough to cook the food stuff in cooking vessel.

5. RESULTS AND DISCUSSION

Experiments were conducted in the second week of June in the premises of UIETKurukshetra. Solar cookware was loaded in the morning at 10hrs and at 16hrs in the evening with 400gms of water and 200gms of rice as cookery load. Gate valves were closed at 16 hrs to check the flow heat transferring fluid. Temperatures were noted at inlet to header (T_1), outlet to header (T_2) of flat plate collector, heat transferring fluid i.e. water (T_3) around solar cookware, PCM Temperature (T_4), and food stuff (T_5) being cooked. Thermocouples (RTD- PT100) were used to measure the temperatures. Readings were taken with time interval of 30 minutes and are tabulated as shown in table 2.

Table 2:Information of ambient temperature, HTF temperatures, PCM temperatures with time and solar intensity in case of both gate valves open throughout discharging of PCM and water as heat transfer fluid.

Time (hr)	Solar Intensity (W/m^2)	T(Ambient) (°C)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	T5 (°C)
9:00	540	27.5	45.3	58.7	51	43.2	21
9:30	591	29	49.4	63	56	48.6	39.3
10:00	660	29.5	54.2	64.5	58.6	53.5	48
10:30	770	30	59.3	69.6	62.8	58.8	56.2
11:00	828	31.4	63.9	73.8	66.1	63.4	60.5
11:30	856	33.3	68.8	77.9	71.8	68.8	65.9
12:00	892	34.1	74.3	79.8	73.5	71.2	69.8
12:30	907	34.2	79.8	83.4	78.7	73.8	72.1
13:00	930	34.5	84.3	86.7	82.2	78.6	76.3
13:30	877	34	88.5	93.5	86.9	84.2	82.1
14:00	812	33.5	85.6	90	83.5	82.5	-
14:30	742	33.4	82	88.4	83	81.9	-
15:00	657	33	78.5	85.6	81.6	80.1	-
15:30	605	32.9	77.6	83.9	80.5	79.8	33.2
16:00	525	32.6	74.3	80.3	77.3	76.4	45.6
16:30	415	32.4	71.3	77.6	75.2	74.2	58.6
17:00	301	32	70.6	76.4	73.1	71.2	61.2
17:30	246	31.6	68.1	74.1	71.3	69.8	64.5
18:00	153	30.7	65.4	71.5	69.7	66.8	63.6

From the results it was found that maximum temperature at the different points during sunshine hours and non-sunshine hours were as given below:

Table 3- Maximum temperature during sunshine hours and non-sunshine hours

Temperature	During Sunshine hours (°C)	During Non-sunshine hours (°C)
T_1	88.5	74.3
T_2	93.5	80.3
T_3	86.9	77.3
T_4	84.2	76.4
T_5	82.1	63.6

From the experimental results, it is evident that at 18hrs, temperature in the cookware was 63.6°C and that was enough to cook the rice in approximately 2hours.

5. CONCLUSION

Present Conventional box type of solar cooker [21] can be used only in the sunshine hours. Moreover, continuous attention is required in cooking hours. In the present research work, a solar cooker has been developed which can work in non-sunshine hours and cooker portion even can be placed in the kitchen itself.

In the present work, a combination of solar cooker, Phase changing material (PCM), heat transferring fluid and solar plate collector was used. It has been investigated that system will work successfully in non-sunshine hours. Experimental analysis reveals that a temperature up to 63.6 $^{\circ}$C can be obtained at 1800 hours, enough to cook the rice. If solar cooker is placed in kitchen, no regular attention is required. Apart from that, lot of conventional fuel can be saved and lot of lives can be saved from Indoor pollution.

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