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Residential Solar Cooker

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Abstract- Energy has become the utmost necessity of our life. It is required from dawn to dusk to fuel the world. Energy is scattered everywhere around the Earth. Man has always desired to capture it and use it for mankind. One of the most important sources of energy is solar energy. Several methods of capturing solar energy and its usage are practised. The intensity of solar rays is immense and ways are still being discovered to harness the full potential of the rays. Focussing the rays to a point will cause generation of heat. Transferring the energy towards cooking is one such method. Usually a solar cooker is a device that is placed in the open ground under direct sunlight. This causes inconvenience to the users. Recent developments are in progress to make it possible to cook under shelter harnessing energy from the solar rays.

There is extensive potential in the solar rays yet to be harnessed. The existing methods, apart from being inefficient in transferring energy, it fails to store the heat effectively. Introduction of Phase Change Materials (PCM) has done the trick of harnessing sun's energy to cook. By doing so the heat energy storing efficiency is increased and thereby effectively increases the process of cooking. With prices of LPG elevating, using this method proves to be cost effective and energy conserving. Unlike induction stoves, the residential solar cooker uses energy from the solar rays and is cost effective. In the absence of sunlight, the PCM setup still increases the efficiency of heating the utensils.

Index Terms- Sheltered solar cooking, Phase Change Material (PCM), Effective heating, Less fuel consumption, User friendly, Cost effective cooking, Eco friendly.

I. Introduction

The present day systems to cook food using solar rays promise heating at the expense of our convenience. This idea deals with this problem to make the energy harnessing a more user friendly process. The usage of solar cookers is not more widely used because of its major disadvantages. The most prominent problem arising in this method is the seasonal changes.

The intensity of the solar rays is unpredictable and often plays truant during rainy and winter seasons. The harnessed energy is transferred and poorly stored. This reduces the overall efficiency of the device. The time required to cook the food is increased because of lacking in heat storage.

To overcome these major problems, a new design has been devised to heat efficiently using the sunny days and as well as the other dusky situations. This device not only transfers energy efficiently and stores it for continuous usage. The PCM material layered around the vessel stores heat effectively and heats up the vessel. This helps in reducing the fuel consumption to a greater extent during non-sunny days. The harnessed energy is not liberated thus assuring fast heating process.

II. Existing Systems

A. Box Cookers

Box cookers are the most common type made for personal use. They consist of an enclosed inner box covered with clear glass or plastic, a reflector, and insulation. There is a wide variety of patterns and plans that can be adapted to work with available materials. While they do not heat quickly, they provide slow, even cooking. Box cookers are very easy and safe to use, and fairly easy to construct.

B. Panel Cookers

Panel cookers are flat reflective panels which focus the sunlight on a cooking vessel without the inner box common in box cookers. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds.

C. Parabolic Cookers

Parabolic cookers reach higher temperatures and cook more quickly than solar box cookers, but are harder to make and use. Parabolic cookers require more precision to focus the sunlight on the cooking vessel. If the sunlight is not focused exactly on the cooking vessel, the food will not cook. When the parabolic oven is used, the temperature must be watched so the vessel does not overheat, burning the food. The risk of burns and eye injury is greater with homemade parabolic designs. While they provide excellent results when used correctly, they are not easy to build at home and require great care to use.

III. Description

The system consists of two tanks T2 and T3 where T2 is storage tank and T3 is tank which collects water outlet from cooker .Flat plate collector (1) uses solar energy and transfer heat to water. The container is surrounded by PCM and water. It is considered that an 8 litre cooker is enough to cook for a family of four.

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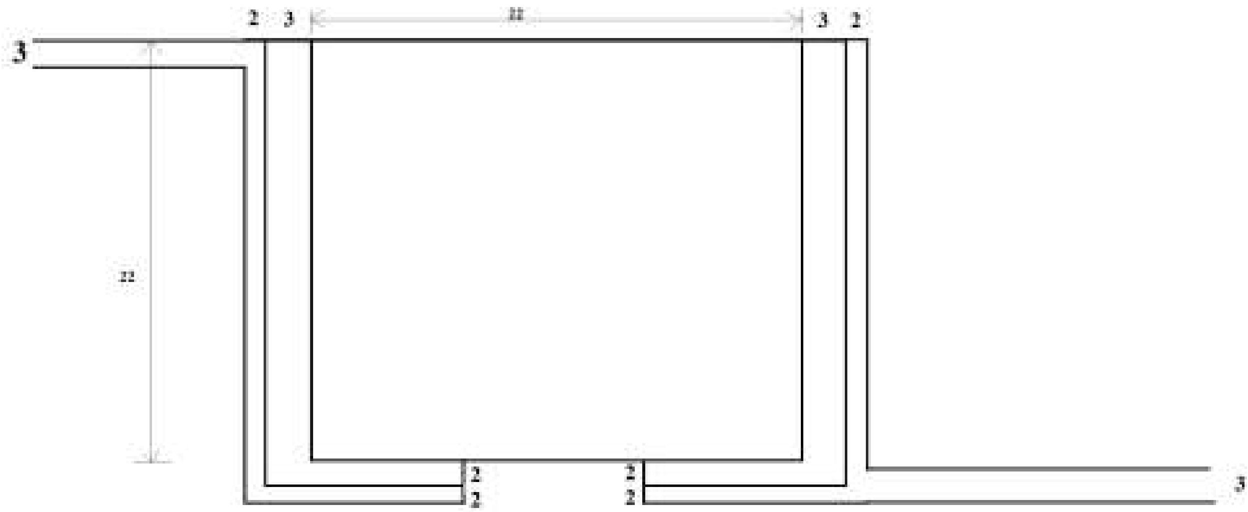
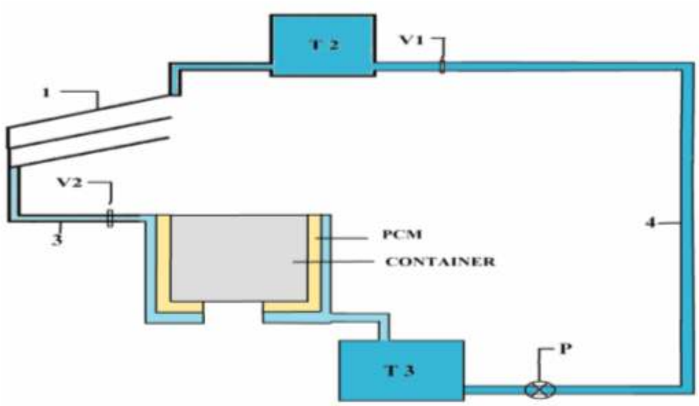


All dimensions are in centimeter

The dimensions of the container was designed as a cylinder with a diameter of 22cm, a height of 22cm.The surface of the container is copper coated for better heat transmission. The container is surrounded by a layer of PCM of thickness 3cm. There is provision for placing the container over a burner as per the usual domestic gas stove used. The component material were selected as,



Insulated pipeline:	SIB with PVC
Cooking vessel (inner):	Copper coated
Ordinary pipeline:	Mild steel
Cooking vessel (outer):	Cera glue alp coated stainless steel.

A ¼1/4hp motor is used to circulate the water facilitating heat transfer. Valves V1 and V2 are to control the flow rate and adjust the cooking temperature respectively. The PCM material used is Paraffin wax whose latent heat is 180K J/Kg K, melting point is 1300F. The thermal conductivity of the material is 0.21 W/m K.

IV. Working

Water is pumped into the tank T2 by means of motor. The Valve V1 is generally kept open slightly, so that the fluid flow will be laminar. The laminar flow is maintained so that the water will attain temperature of 90^{o}C (approx.) {Note: This temperature is attained only in summer days in Tropical region}.

The water from storage tank T2 is passed through the inlet of flat plate collector. Since flat plate collector absorbs Sun's radiation and converts light energy into heat energy, the heated water is allowed to pass through the pipeline (3). The hot water is circulated through outer cooking vessel.

Since the outer cooking vessel contains PCM, the latent heat of condensation of water is absorbed by the PCM, thus gets heated it. Thus latent heat of fusion of PCM is obtained from the latent heat of condensation of water. Since latent heat of PCM is transferred to the cooking vessel which is copper coated since copper is having good thermal conductivity, the food can be cooked easily. Foods can be cooked more effectively if it is covered with an insulating lid while cooking.

Thus the circulated water comes out of outlet pipeline and is collected in the tank T3. Generally the hot water in the tank T3 is pumped to tank T2 by means of the motor. The hot water is again circulated and this process continues till cooking ends. This circulation increases the efficiency of system.

V. Calculations

A. Calculation for output heat from flat plate collector:

The total output heat is calculated by

$$Q_{Out} = m_{water} * C_{p,\ water} * (T_{out,\ water} - T_{in\ ,water})$$

Calculation for fluid flow:

Steady flow is maintained by using valve V1.

c = constant
$dc/dt = 0$
$Re = (\rho_w * c * d_p) / \mu$ = Inertia force / Viscous force

Since laminar flow is maintained,

$Re < 2000$
$\mu = \tau / (dc/dy)$
$Q_{discharge} = A_p * c$
$Q_{discharge} = \pi * (d_{p2} / 4) * c$

But $Q_{discharge} = V_{tank} / t_{tank}$

$t_{tank} = V_{tank} / Q_{discharge}$

Calculation for PCM:

$Q_{water} = m_{water} * C_{p, water} * dT_{water}$
$Q_{water} = m_{water} * C_{p, water} *$
$(T_{pcm} - T_{out, water})$
$m_{t, water} = V_{t,water} * \rho_w / 3600$
$V_{t,water} = C_{v2} * A_p$
$Nu = h_{water} * D_h / k_{water}$
$k_{copper} = 401$ W/m K.
$dc/dt = 0$

$Re = (\rho_w * c * d_p) / \mu$ = Inertia force / Viscous force

Since laminar flow is maintained,

$Re < 2000$
$\mu = \tau / (dc/dy)$
$Q_{discharge} = A_p * c$
$Q_{discharge} = \pi * (d_{p2} / 4) * c$

But $Q_{discharge} = V_{tank} / t_{tank}$
$t_{tank} = V_{tank} / Q_{discharge}$

***Motor*:**

Motor used = ¼ hp=0.1864 W
Let us assume that we are using this for 4 hours per day.
No. of hours usage per month= 120 hours
Power consumed per day=0.1864*4=0.7456W
Power consumed per month=0.7456 □= 23W
Cost consumed per unit = Rs.5/-
Total cost consumed per month = Rs.115/-

Induction Stove:

Induction stove power usage= 250*10=2.5KW

Let us assume that we are using 2 hours per day.
No. of hours usage = 60 hours.
Power consumed per day= 5KW
Power consumed per month = 150KW
Total cost per month = Rs.750/-

Cost efficiency = cost of induction stove for power consumption/ cost of motor for power consumption
= 750/115
= 6.5

VI. Results

Considering the above assumptions made, it is inferred that we are reducing the cost to 6.5 times than that of induction stove. We can save about Rs.10000/- per year.

VII. Conclusion

Nowadays cooking has become the major source for global warming. If we consider a home using LPG stove it produces a lot of polluted air. By using the above stated technique, we can save LPG by a considerable amount, thereby reducing the heat rejected to atmosphere. This in turn reduces the global warming effect.

Thus this device can be used extensively in the domestic as well as industrial applications to immediate effect. Further proper designing of the vessel can make it more efficient in usage and for multi-purpose tasking.

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