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COMPUTATIONAL TRACKING AND MONITORING FOR EFFICIENCY ENHANCEMENT OF SOLAR BASED REFRIGERATION

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ABSTRACT

The primary source of our energy is the sun. The growing demand for energy throughout the world has caused great importance to attach to the exploration of new sources of energy. And also there is currently a widespread need around the world to reduce the emission of the green house gases. One such process which still contributes to global warming is the household refrigeration process. This can be avoided if the process works on non-conventional energy. This process involves activated carbon and methanol as the refrigerant mixture to produce the refrigeration effect. Parabolic trough is used to focus the sun's energy for heating up of the water. An embedded based tracking system is built, in which a computational control program is loaded. The tracking kit is fitted with the parabolic trough so as to improve its efficiency. This solar adsorption system can be an adequate replacement for the conventional refrigeration process as it does not contribute to environmental pollution. This system when implemented along with a tracking device shows an increase in performance of over 50%. Moreover as this refrigeration system involves only installation costs and minimal working costs, it reduces the expenses on conventional refrigeration system by around 40% on monthly basis. This process can be implemented for various applications like preserving the vaccines, dairy products and for other perishable food items.

KEYWORDS
solid adsorption refrigeration, refrigerant mixture, computer programming, parabolic trough, activated carbon

INTRODUCTION

Sunlight is a source of energy regarded as an alternative source of energy along with other alternative source such as hydrogen and natural gas. Solar energy is a vital that can make environment friendly energy more flexible, cost effective and commercially widespread. The two methods in which solar energy can be utilized is by using photovoltaic cells and by concentrating solar power.

Although photovoltaic source are widely used today in many applications such as battery charging, water heating system, satellite power system, and others, they remain a distant dream for peasants and lower middle class people as their installation cost is pretty much high.

So the method of concentrating solar energy has to be implemented in variety of present day processes so as to address the needs of the poor people around the world. One such process is the solar adsorption refrigeration system.

Various researches around the world have shown that adsorption refrigeration technology has a promising potential for competing with conventional vapor compression and absorption refrigeration techniques. When this process is done by means of non-conventional energy sources, not only it will become an affordable system but also as a system which is environment friendly. So the solar powered adsorption refrigeration systems can be used as an alternative to the conventional refrigeration systems.

The solar energy is concentrated by means of a parabolic trough. The purpose of using parabolic trough is to get the ray reflection of light at the highest efficiency and to get the source of energy at the maximum value. The development of this system is as an alternative of power source and also to utilize the source from the sun at the highest efficiency from morning until afternoon.

WORKING PRINCIPLE

The principle behind this refrigeration system is the normal adsorption cycle. The absorption cycle is similar to the compression cycle, except for the method of raising the pressure of the refrigerant vapor as in [1].

In the absorption system, the compressor is replaced by an absorber which dissolves the refrigerant in a suitable liquid, a liquid pump which raises the pressure and a generator which, on heat addition, drives off the refrigerant vapor from the high-pressure liquid.

The basic principle applied in collecting the energy from the sun is to focus the light falling on trough onto a glass tube fitted at the middle of it. This is done by designing a parabolic shaped trough having a particular focal point. A control program is written to control the trough movement according to the input from the light sensors fitted on the trough.. Thus the trough is aligned to move along the sun.

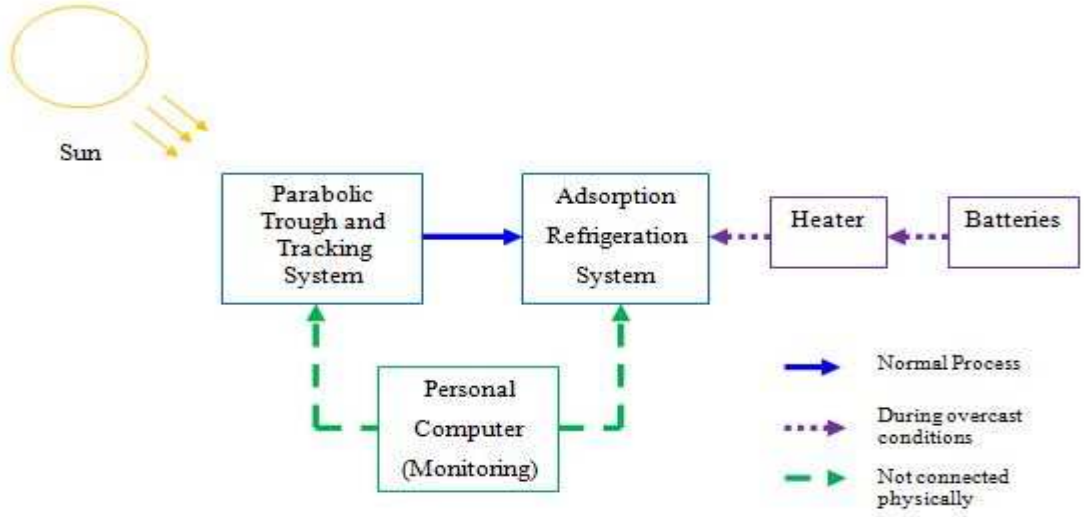
EXPERMENTAL SETUP

The solar adsorption refrigeration system consists mainly of three units is shown in fig.1 and they are as follows.

- The Parabolic Trough and Tracking Kit
- The Adsorption Refrigeration Setup
- The Backup and Monitoring Devices

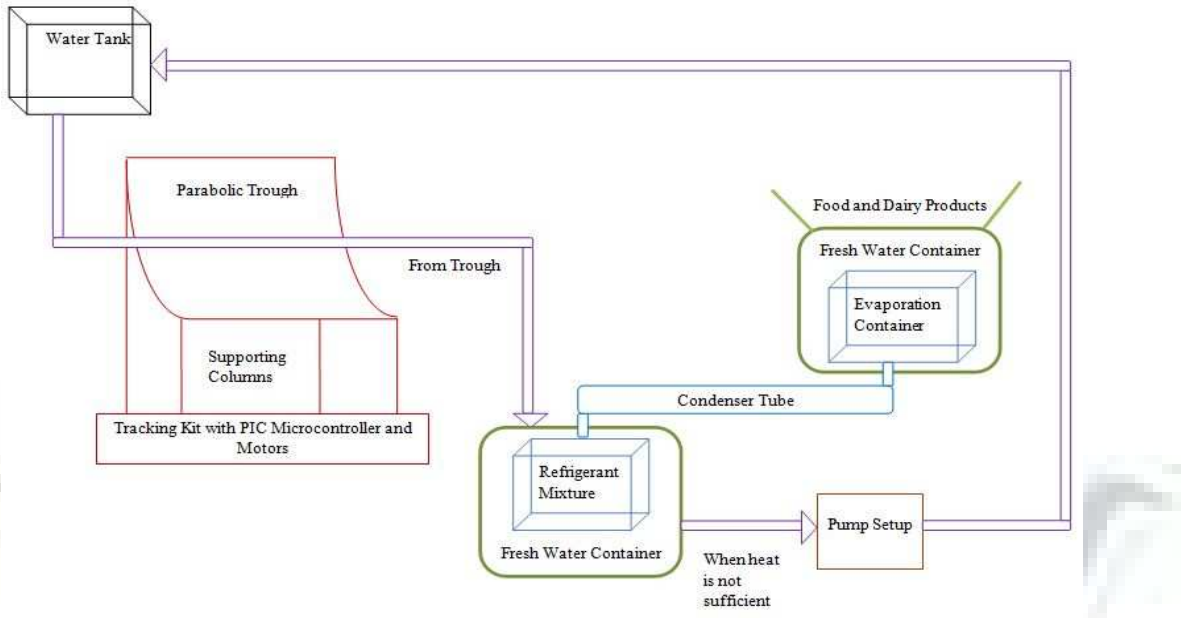
The parabolic trough is made from a plain stainless steel sheet. The angle at which the plain sheet must be bent can be found out using software called Parabola Calculator. The stainless steel dimensions are entered and the software determines the focal length of the parabola. The parabolic trough is fitted with a tracking device to reposition it according to the movement of the sun as in [3] and [4].

FIG. 1: BLOCK DIAGRAM OF THE SOLAR ADSORPTION REFRIGERATION SYSTEM



The proposed model of the process is shown in fig.2. The tracking kit consists of a pair of LDR's fitted on either side of the parabolic trough. It senses the light rays and depending upon the intensity of the light, the resistance value changes. This signal is sent to the microcontroller. Depending on the control program, the controller triggers the driver circuit which actuates the motor and moves the parabolic trough according to the sun's position as in [5].

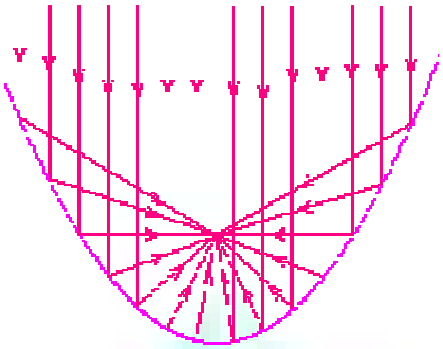
FIG. 2: MODEL OF THE SOLAR ADSORPTION REFRIGERATION SYSTEM



The tracking kit consists of a PIC microcontroller, a driver circuit and a power supply circuit. The PIC microcontroller is loaded with an Embedded C program. This program is written so as to move the trough according to the light input sensed by the LDR's. The focusing of the trough is shown in fig.3. The program is written in software called MPLAB IDE.

MPLAB IDE is a Windows OS based Integrated Development Environment for the PIC microcontrollers. The chip is loaded with the program and it can also be erased and re-written.

FIG. 3: THE FOCUSING ACTION OF THE PARABOLIC TROUGH



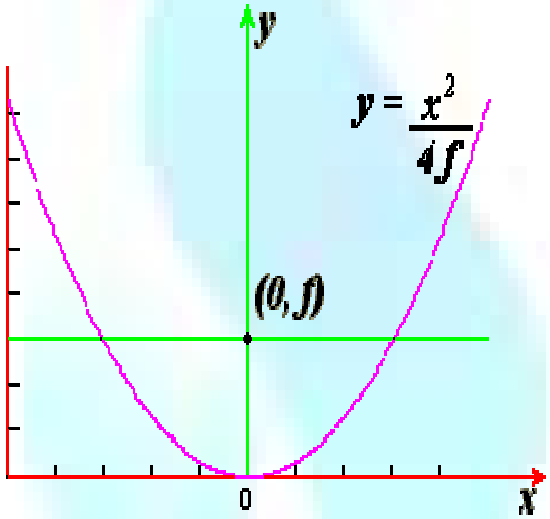
The parabolic trough is made of stainless steel and its focusing angle is determined using software called Parabola Calculator. The dimensional values are entered in it, and the software calculates the focal point.

The general equation of a parabola is:

$y = a.x^2$, where a is a constant.

For a parabola with a focal length of f; $a = 1/(4f)$

FIG. 4: DESIGN OF FOCAL POINT OF THE PARABOLA



The axis of the parabola is coincident with the y-axis and the focus is located at (0, f) as shown in fig.4.

The adsorption refrigeration consists mainly of a refrigerant container and a condenser. The refrigerant mixture used for this process is Activated Carbon (Adsorbent) and Methanol (Refrigerant).

Activated carbon is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption as in [8]. Methanol, also called as Methyl Alcohol, has the molecular formula of CH_3OH.

The refrigerant mixture is kept in a small container surrounded by another container called the storage container. The water which is heated through the parabolic trough is stored in that container. The heated water transfers the heat onto the refrigerant mixture which starts evaporating and the vapor is stored inside the condenser tube. The condenser tube is surrounded by a tray having fresh water.

The vaporized refrigerant mixture tries to return to its original state; the liquid state. Thus by absorbing the heat from the fresh water in the tray, it attains the liquid state; thereby converting the fresh water into ice.

This is the basic working principle of the adsorption refrigeration system. The activated carbon can adsorb a large amount of methanol vapors in ambient temperature and desorbs it at a higher temperature of around 100° C.

During the daytime, the container is heated up and the methanol is desorbed from the activated carbon. In desorption, the liquid methanol adsorbed in the charcoal heats up and vaporizes. The methanol vapor condenses and is stored in the condenser tube.

After some time, when the temperature decreases to the ambient temperature, the charcoal adsorbs the methanol from the condenser tube. The liquid methanol in the condenser tube vaporizes and absorbs the heat from the water contained in the trays surrounding it as in [9]. The backup kit consists of a heater and a rechargeable battery for power supply.

The backup kit is used when the day is darkened and foggy. During such overcast conditions the battery supplies power to the heater. The heater heats up the water to the sufficient temperature and the process continue normally without any interruption.

The monitoring devices include noting down the temperature of the water, checking the temperature of ice formation and the positioning of the parabolic trough. The exact values have to be tabulated and can be used for further modifications to the process.

ALGORITHM OF THE REFRIGERATION PROCESS

Step 1: The water tank is filled with water

Step 2: The water is passed in a zigzag manner through the focal point of the parabolic trough

Step 3: The sensors detect the position of the sun and sends the input to the microcontroller.

Step 4: The controller triggers the driver circuit and controls the motor.

Step 5: The motor rotates the trough according to the movement of the sun.

Step 6: The water is heated and it is stored in a storage container

Step 7: Is the temperature of water sufficient? If Yes, go to Step 8 else Step 1.

Step 8: The Adsorption Process starts; the surrounding hot water heats up the refrigerant mixture

Step 9: The methanol vaporizes and stored in a condenser tube

Step 10: After sometime, the methanol gets back to its liquid state by forming ice in the tray

EXPERIMENTAL RESULTS

The solar powered refrigeration system working on adsorption effect is subjected to three different experimental analysis and the data obtained through various measurements are tabulated for clear understanding. One is based on the temperature at focal point at different time while using tracking and non-tracking and another is based on the temperature of water at various time intervals, while the final table analyzes the different refrigerant mixtures and their boiling point.

TABLE 1: TEMPERATURE MEASUREMENT ON THE FOCAL POINT OF THE PARABOLIC TROUGH

Timeline	Temperature in °C Without Tracking	Temperature in °C With Tracking
6 a.m.	18	18
7 a.m.	20	22
8 a.m.	22	25
9 a.m.	25	29
10 a.m.	26	33
11 a.m.	28	36
12 p.m.	30	40
1 p.m.	31	43
2 p.m.	32	45
3 p.m.	28	44
4 p.m.	26	40
5 p.m.	23	36
6 p.m.	21	32

TABLE 2: TEMPERATURE MEASUREMENT OF THE WATER STORED IN THE CONTAINER

Timeline	Temperature in °C
6 a.m.	15
7 a.m.	18
8 a.m.	20
9 a.m.	22
10 a.m.	30
11 a.m.	45
12 p.m.	65
1 p.m.	75
2 p.m.	80
3 p.m.	80
4 p.m.	80
5 p.m.	78
6 p.m.	78

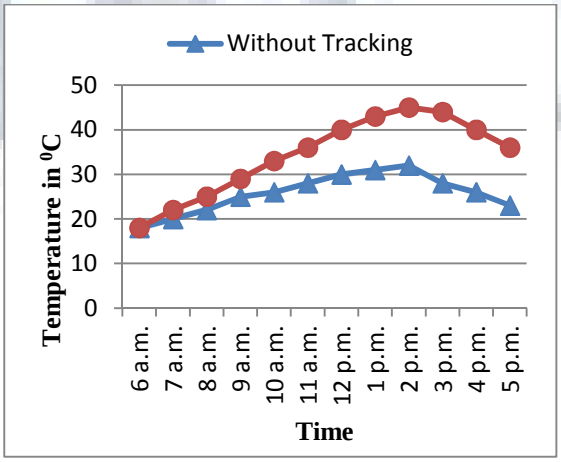
TABLE 3: TEMPERATURE OF VAPORIZATION FOR DIFFERENT REFRIGERANT MIXTURES

Refrigerant Mixtures	Boiling Point in °F
Carbon tetrachloride-(R-10)	170.2
Hexachloroethane-(R-110)	365
Methanol	149
Trichloroethane-(R-140a)	165

PERFORMANCE ANALYSIS

The performance of the system depends on the amount of heat produced by the parabolic trough. As it is fitted with a tracking kit, the heat production rate will be more than normal heat produced. The analysis of the process is carried out and table 1 illustrates the temperature on the focal point, using the tracking kit and without the tracking kit. This analysis is carried out as read from [2] and [7].

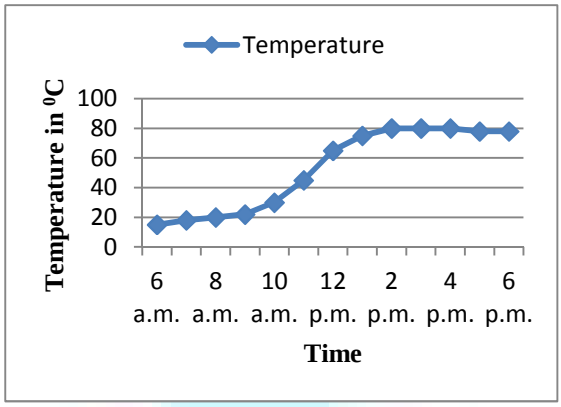
FIG. 3: ANALYSIS CHART OF THE TEMPERATURE AT FOCAL POINT WITH AND WITHOUT TRACKING



The chart (Fig.3) depicts that when the tracking system is fitted to the parabolic trough, the trough movement is adjusted in relevance to the movement of the sun. So as a result there is more focusing of the sun onto the focal point which results in increasing the temperature when a tracking device is fitted.

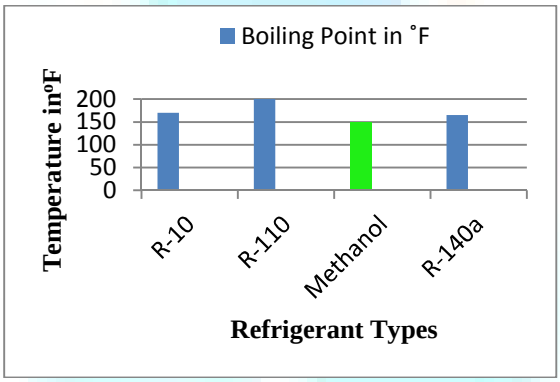
Calculating the temperature of the water in the storage container is an important phenomenon. It helps in pumping the water back into the water tank if the sufficient temperature is not reached. After carrying out the experiment for a certain number of times, the temperature of the water stored in the container at various time intervals is tabulated in table 2 and represented in the second chart.

FIG. 4: REPRESENTATION CHART OF THE TEMPERATURE OF THE WATER AT CONSTANT TIME INTERVALS



As studied from [1], the chart (Fig.4) indicates that as the day progresses the temperature of the water stored inside the container increases. Till the desired temperature is attained, the water is recycled back into the tank and sent through the trough. Once the water reaches the desired temperature, its temperature does not come down as it is kept inside a black coated container to prevent loss of heat.

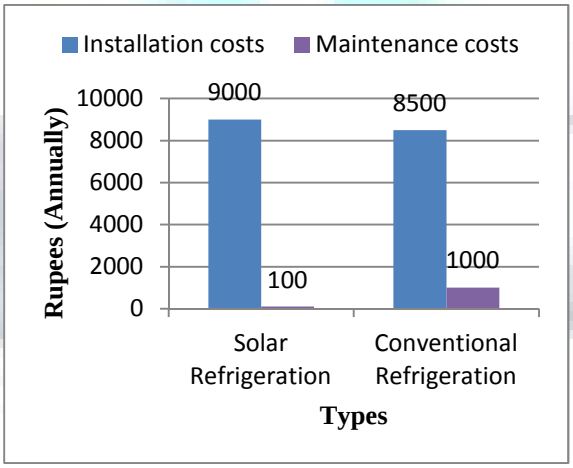
FIG. 5: REPRESENTATION CHART OF THE BOILING POINT OF DIFFERENT REFRIGERANTS



From the analysis carried out on various refrigerant components that can be used as refrigerants for this process as in [9], it is understood that the refrigerant methanol is of very low boiling point and also it forms a cohesive link with the adsorption component – Activated carbon. The different refrigerants and their boiling points are shown in table 3 and the corresponding chart is shown in fig. 5 above.

As it is studied from [10], the cost-wise analysis is also done and it is very less when compared to conventional refrigeration system, as it includes only installation costs and no maintenance costs.

FIG. 5: ANALYSIS CHART OF THE COSTS INVOLVED IN THIS PROCESS



The Reference [6] indicates a low cost approach and the chart (Fig.5) shows that though the installation cost of solar refrigeration is little more than conventional refrigeration system, when considering the maintenance costs, it is very minimal. Therefore, this system proves there is an alternate non-conventional way of creating refrigeration at an environment friendly way.

FUTURE WORKS AND CONCLUSION

The future works that can be done in this process is that by using Activated Carbon Fiber instead of Activated carbon as an adsorbent; Activated Carbon Fiber is a little costlier; the rate at which the adsorption process takes place can be fastened and also the formation of ice can be made quicker.

Thus the efficiency of the solar adsorption refrigeration system can be improved by continuous tracking of the parabolic trough and monitoring of the process. This process helps in bringing down the money spent on energy. The process is completely analyzed and by implementing in a larger scale will help many rural

people and diary industries. Storage of food items and vaccines in this refrigeration system will also benefit people living all over the world. Moreover implementing this process will help in reducing the environmental impact of the current refrigeration system.

ACKNOWLEDGEMENT

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