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RENEWABLE CONVECTIVE HEATING BY THE METALLIC STRIPS HEATED VIA A SOLAR VACUUM TUBE

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ABSTRACT

The majority of power consumption nowadays goes to heating. Global warming, air and water pollution caused by burning fossil fuel for heating encourage researchers and engineers to focus more on renewable energy. The solar system is one of Earth's primary sources of clean power. Apart from photovoltaic panels and their effectiveness of power generation contribution, solar heaters are primarily used in different applications to recover heating needs in residential and commercial buildings. This paper focuses on an experimental study to generate heat from Solar System using metallic strips immersed in cement inside a solar vacuum tube. Heat can be transferred from inside the tube to the outside using metallic strips with high conductivity. Then, the metallic strips can be used as a heater to heat water or air in an isolated tank by direct contact between the hot strips and the fluid. In order to keep the system providing heat after the absence of sun's rays, cement is used in this experiment as a heat repository.

Keywords: Solar energy; alternative energy sources; convective heat transfer; heat energy storage.

1. INTRODUCTION

Energy is one of the basic needs on Earth. Energy is sustainable, it has many forms, and it can be converted from one type to another. In recent decades many efforts have been made to save the environment from global warming and the green gas effect. Floods, heat waves, and health problems due to air pollution caused by the emission of burning fossil fuels encouraged researchers and scientists to increase their efforts in using techniques that can take advantage of the solar system. Solar system is considered the largest source of power on Earth. The radiant light that incident to the Earth from the sun is approximately ten thousand times compared with the energy requirement worldwide today [1]. About 80-85% of this radiation is directly incident to the surface of the Earth. Between 15% to 20% is diffused radiation due to clouds and the atmosphere [1]. However, it is impossible to collect all the energy from the sun, but different technologies have been used to capture it. While photovoltaic cells convert sun rays to electrical power for residential buildings, automobiles, and other applications, solar heaters are used to convert solar radiation into a helpful form of heating. Solar heaters can be classified as solar air heaters and solar water heaters. Solar air heaters have been dramatically used recently due to low fuel consumption and low cost of operation and installation [2]. Compared with solar liquid heaters, solar air heaters have many benefits, such as preventing problems of stagnation, leakages, and freezing. However, solar air heaters have limited specific heat capacity compared with water [2], which makes the heat transfer rate low. Solar air heaters are widely used in applications with temperatures below 60º C with low flow rates [3]. Also, some solar heaters are distinguished by their ability to operate without a pump or fan by natural convection [4]. That can add an additional contribution to power saving.

After a brief introduction to solar heaters, this paper focuses on a new design of solar heaters illustrated by the insertion of highly conductive metallic strips accompanied by a cement mixture inside a solar vacuum tube to generate the absorbed heat from inside the vacuum tube to the outside. Metallic strips can then be used as a water or air heater by direct contact between the hot strips and the fluid. In addition, the paper will address a detailed procedure to simulate this experiment inside a laboratory. Moreover, the results and discussion section will provide an application where this design can be functional.

2. MATERIALS AND METHODS

In this experiment, a solar vacuum tube will capture the light. The solar vacuum tube has been proven effective in many applications [4,5] due to its ability to absorb a significant amount of solar radiation and transfer it into proper heat, which can be used for air heating, water heating, or cooking. In experimental results [5], a solar vacuum tube was used for cooking. The tube succeeded in heating 5 kg of water to about 97º C, in ambient temperature about 32º C, after 13 hours of solar time on March 25.

A 483 mm solar vacuum tube length with 43.8 mm inner diameter has a double glass outside surface with a black absorber layer inside and support clips in the bottom coated with 50 mm Getter coating applied to the bottom of the tube to increase the heating during use. In this experiment, the tube will absorb the

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light. Therefore, this light will heat metallic strips convectively. Four copper strips, 609.6 mm in length and 31.75 mm in width, will be immersed in a cement mixture. Then, the strips, accompanied by the solid cement, will be placed inside the solar vacuum tube. While 75% of the strips will be inserted inside a cement block and fully covered by the tube, 25% will stay outside the tube. Cement is a mixture of 98% Gypsum (Calcium Sulfate) and 2% Portland Cement. Cement is used inside the solar vacuum tube as a heat storage medium to store the heat after the absence of the light source and to help to save the temperature from dropping when there is a variety of light intensities. Cement has been used in many experiments as a source of heat storage in solar desalination [6].

The objective of the experiment is to monitor the temperature changes of uncovered strips in the presence and absence of the light source. The experiment was run inside a laboratory with an unchanged room temperature of 21.5^{o} C. The light source is an artificial Halogen lamp with an intensity of 8460 lux as a substitute for the sun's rays. A solar vacuum tube was placed 30 cm distance away from the source of light. Thermocouple was used to measure the temperature of the uncovered parts of copper strips every 15 minutes when the light was on for 4 hours. After the light was turned off, temperature measurement continued every 15 minutes until the temperature dropped to test the cement's effectiveness as heat storage after the absence of the light source.

For data collection, each strip was divided into 3 points: 0 cm, 5 cm, and 10 cm distance away from the top surface of the solar vacuum tube. Therefore, the temperature was measured for each strip at the three mentioned levels. The first set of data will show the temperature of strips when the light source is on to monitor the temperature growing. The second data set will indicate how long cement can store heat and release it to the uncovered strips in the absence of the light source.

Figure 1 will show four copper strips immersed in a cement mixture inside a vacuum tube. Also, it will show the points in each copper plate that they used to measure the temperature. Figure 2 will show the whole system during the heat. The solar vacuum tube is covered by silver light reflector film to mirror the light’s rays.

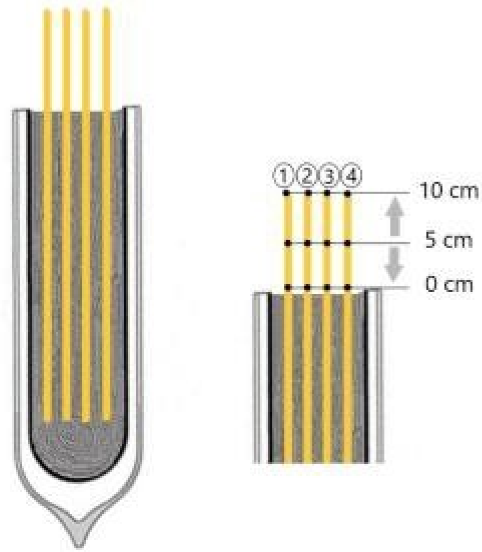

FIGURE 1: FOUR COPPER STRIPS IMMERSED IN CEMENT INSIDE A SOLAR VACUUM TUBE, AND THE POINTS USED TO MEASURE THE TEMPERATURE

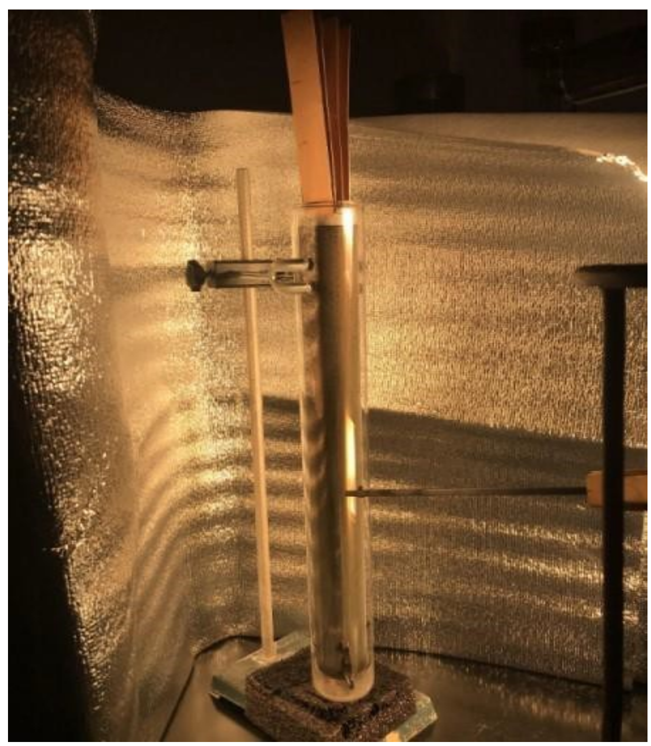

FIGURE 2: EXPERIMENTAL PHOTOGRAPH TO SHOW THE WHOLE DESIGN DURING HEATING IN FRONT OF A HALOGEN LAMP INSIDE A LABORATORY.

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3. RESULTS AND DISCUSSION

As discussed in the data collection procedure, temperature was measured at three different levels of the four copper strips. For beneficial analysis, the average temperature of four copper strips was calculated and will be examined based on the three different levels (0 cm, 5 cm, and 10 cm) for data analysis.

The following chart will demonstrate a relation between average copper strips temperature at 0 cm, 5 cm, and 10 cm level, above the surface of the solar vacuum tube, and the recorded time from 0 minutes to 240 minutes at a fixed ambient temperature of 21.5ºC.

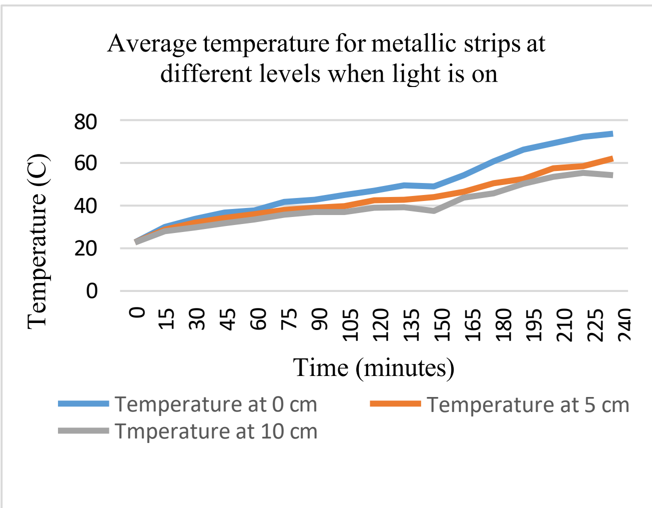

FIGURE 3: AVERAGE TEMPERATURE FOR METALLIC STRIPS AT DIFFERENT TESTING LEVELS WHEN THE LIGHT'S SOURCE IS PRESENT.

The previous figure showed that the average temperature for the strips at 0 cm increased from about 22º C (ambient temperature) to about 73º C. Strips average temperature at 5 cm and 10 cm levels increased from 22º C to 62º C and 54º C, respectively. However, strips temperatures at 5 cm and 10 cm levels have lower values than 0 cm levels' values because they were more exposed to the ambient temperature.

The next part of the experiment is to prove cement's ability to store heat. After 240 minutes of heating, the light source was turned off to start a new temperature recording at the same procedure and conditions where the heating had happened.

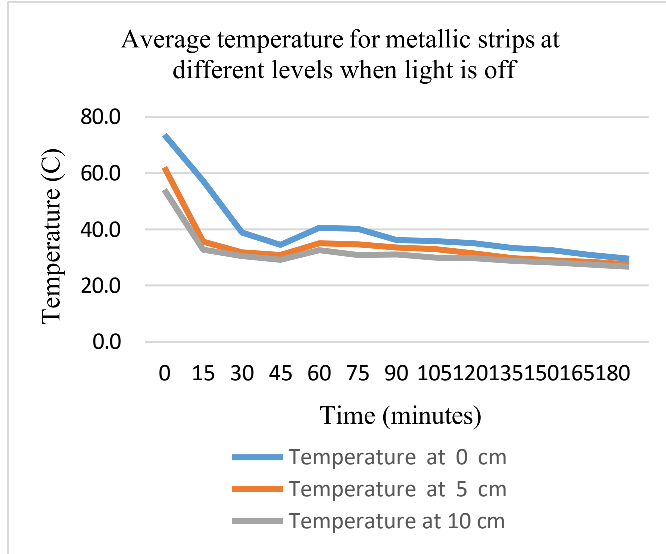

FIGURE 4: AVERAGE TEMPERATURE FOR METALLIC STRIPS AT DIFFERENT TESTING LEVELS WHEN THE LIGHT'S SOURCE IS ABSENT.

Data showed that cement could save heat and release it after the absence of the light source. After 180 minutes, the temperature returned to approximately its original value (ambient temperature). This is a piece of evidence that cement can provide the system with heat in the absence of the light source. The sharpness decreases in temperature after 30 minutes of turning the light off is because the system is non isolated and suddenly exposed to ambient temperature.

Copper strips can be employed as a water or air heater. The following figure will illustrate a practical approach where convective heating by metallic strips heated via a solar vacuum tube can be used practically.

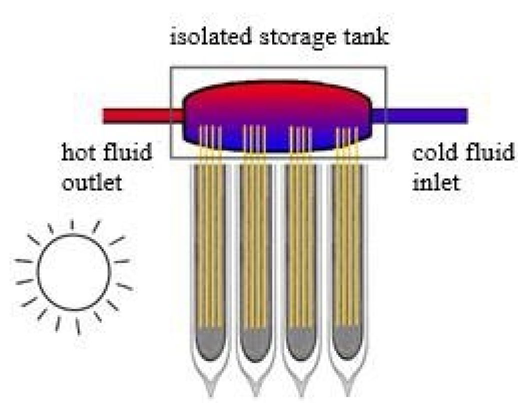

FIGURE 3: ILLUSTRATION TO SHOW HOW METALLIC STRIPS HEATED VIA A SOLAR VACUUM TUBE CAN BE USED AS A HEATER IN AN ISOLATED SYSTEM

The previous figure showed a simple illustration of a renewable heating system where fluid can enter an isolated tank, connected with metallic strips, at a low temperature and exit at a

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higher temperature. Metallic strips transfer the heat from the solar vacuum tube to the fluid. Cement helps to provide heat for metallic strips after the absence of the sun's rays. The system is isolated in order to minimize the heat losses. Numerous tubes can be used as desired depending on the heater's capacity.
One prominent example is where this design can be used as a water heater in domestic applications in cold or hot climates. In hot climates, up to 80% of domestic hot water can be provided by solar energy, While 55-60% in cold climates [7].

4. CONCLUSION

This experiment focuses on a solar heater design that is simple to install and affordable. It has a long lifetime and can play a vital role in reducing global warming and air pollution caused by burning fossil fuels for heating. The simulation system in this experiment simulates approximately natural conditions where a solar vacuum tube can be placed in the environment. Collected data showed the ability of this design to reach higher temperatures after a short time of exposure to light. Moreover, it shows how the technique can store heat and release it slowly for metallic strips, which can still behave as a heater in the absence of light. In addition, cement makes this design applicable to install in any climate, especially in a cold environment, and where the direction of the sun's rays is oscillated due to clouds.

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