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Hosepipe Pool Heater Aided by Solar Powered DC Water Pump

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Abstract

We have carried pool (water) heating using black hosepipe in which water was pumped and cycled in the hosepipe by a dc water pump powered by photovoltaic (PV) panels thereby making the heating device almost purely solar. This has previously been achieved using ac water pump which relies on ac power sources. The major materials used include a 45.7m (50 yards) long black hosepipe formed into a circular coil of surface area 0.986m^2; a 100-watt dc water pump; 200-watt photovoltaic solar panel; a 120-liter reservoir contained in a wooden box filled with sawdust to provide thermal insulation to the water inside the reservoir, etc. The water pump runs water (at some initial temperature) stored in the reservoir through the solar exposed coiled hose and back into the reservoir. This cycle is continued at a controlled speed for a period of time until the bulk water heats up to higher temperatures. The device was tested in the month of January. The test location was Owerri, South East Nigeria. On each day, the water pump was operated from 10:00 am to 6:00 pm local time. For a water volume of 100 liters (0.1m^3), a peak temperature of 48.0^{o}C from initial water temperature of 28.0^{o}C was recorded (at about 3:30pm) for a particular day. It was however observed that even when the initial water temperature was as high as 41.0^{o}C, there was no significant change in the peak temperature. We show that the thermal insulation provided to the water reservoir ensured that the heated water retained its warmth, long enough to provide for a warm bath the next day. This prototype system described here can provide regular warm bath water for an average household. Larger systems are capable of heating larger volumes of water such as swimming pools at lower cost than the convectional electric water heaters.

Keywords: Hosepipe, Pool heater, DC water pump, Solar collectors, Greenhouse.

1.0 Introduction

The demand for hot or warm water in homes, health centers, production and hospitality industries and other sectors is huge. One of the commonest conventional means of getting hot water is the use of electric heaters which demand huge electric power (1000 watts and above per unit). Ordinarily this makes heating water very expensive. In addition to this, the erratic electric power supply by power companies in most developing countries, particularly, Nigeria has compelled individuals and bodies to generate their own electric power in order to meet hot water and other power related demands. Because of the heavy power consumption by electric heaters, average household generators cannot be used to heat water in the absence of public power supply. Furthermore, the use of electric water heaters carries high risk of fire outbreak due to wrong use of the appliances and the ever increasing substandard electric wiring materials and accessories. All these problems underscore the need for alternative and efficient means of heating water. The use of direct solar energy for water heating is relatively safe and cost effective and has been discussed in several studies (Danshehu & Rikoto, 2010; Peni & Rikoto, 2010).

Solar water heating involves the conversion of sunlight into thermal energy. The most important component of any solar heating system is the collector. The solar collector serves the purpose of a heat exchanger. There are three basic categories of collectors; flat (plate) collectors, focusing (concentrating) collectors and photovoltaic (panel) collectors (Paul, 1979). While many different flat plate collectors have been built and used successfully in water and space heating applications, only few studies have been done on focusing collectors. The flat plate collector is the most widely used (Paul,

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1979).

The most common flat plate collector consist of a metal plate which is painted black on the side facing the sun and thermally insulated on the edges and on the reverse side. The metal surface may have imbedded or bonded tubes for heat exchange to water. The metal tubes may come in various designs such as U-coils, Spiral-coils, combination of U- and Spiral-coils, *etc.* (Agbo *et al*, 2005; Enibe, 2007; Ojosu & Komolafe, 1989; Sambo & Bello, 1990). Above the absorbing plate are one or more transparent glass or plastic surfaces to reduce upward heat losses by convention. The glass surface also acts like the glass in a *greenhouse*. It increases the infrared radiation inside the greenhouse (Giambattista *et al*, 2007); in this case the collector enclosure. The collected energy is removed by circulating water or some other working fluid in the embedded tubes.

Solar water heating systems can be passive or active. Passive systems rely on heat-driven conventions to circulate water or heating fluid in the system. Passive systems cost less and have very low maintenance, but their efficiency is significantly lower than that of an active system. Active systems use pumps to circulate water or heating fluid in the system. Though slightly more expensive, active systems offer several advantages: The storage tank can be situated lower than the collectors, allowing increased freedom in system design and allowing pre-existing storage tanks to be used. They are also more efficient. The system described in this work is an active system with three major component systems, namely: the collector, the water pump and the water storage systems. The three components are shown schematically in Figure 1.

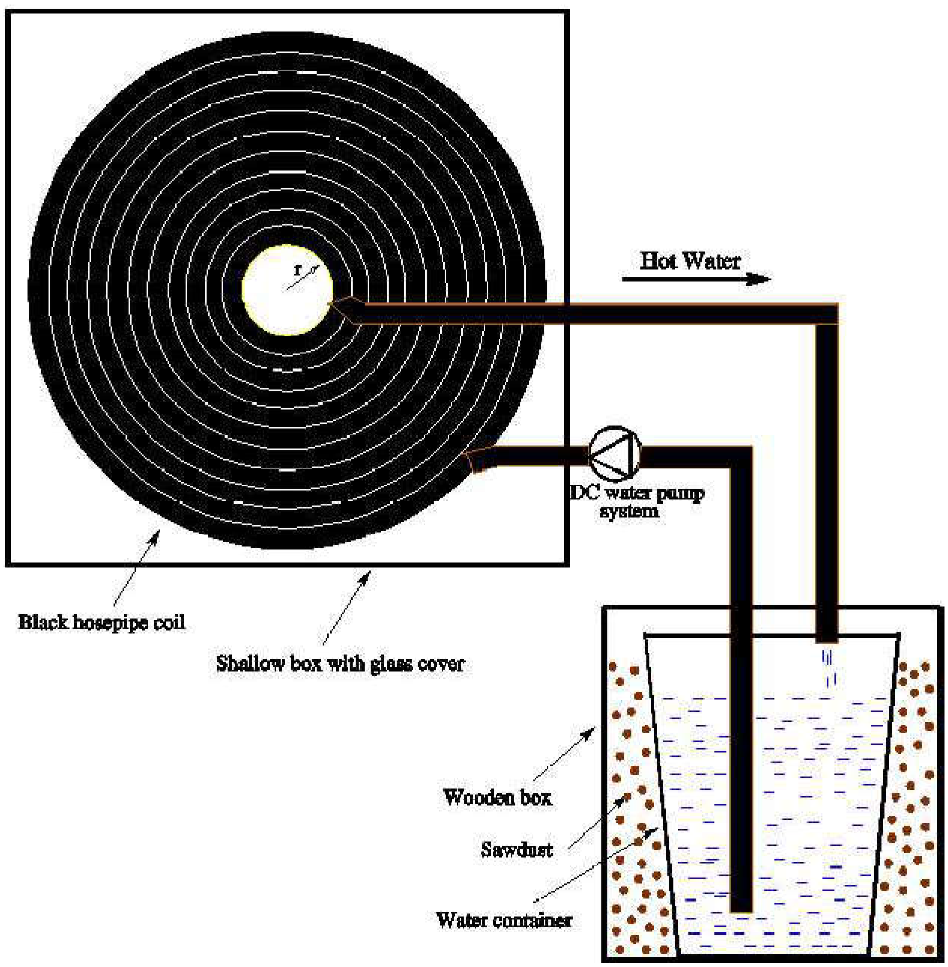

Figure 1: The schematic diagram of the solar pool heater showing the collector, the water pump and the water storage components.

1.1 The Collector System

A 50-yard (45.7m) long black hose was coiled to about 20 turns inside a shallow wooden rectangular box mounted on a metal stand. The box has openings for passing water-in and water-out ends of the hose. The 20-turns hose formed a circular 'flat' surface of diameter 1.12m. The box (with the coiled hose inside) is then covered with the 2mm thick transparent plastic glass. The coil in the glass covered box as shown in Figure 2 constitute the solar collector for our device.

As stated earlier, the plastic cover acts like the glass in the greenhouse. When sunlight falls upon the glass, most of the visible radiation and short wavelength infrared (near-infrared) travel right through the glass because the glass is transparent to those wavelengths. The radiation transparent to the glass is absorbed by the black hose to heat up the circulating water. This form of heating also occurs in the absence of the glass covering. Since the inside of the glass (greenhouse) is much cooler than the sun, it emits primarily infrared radiation (IR). The glass is not transparent to the longer wavelength IR; much of it is absorbed by the glass. The glass itself also emits IR, but in both directions: half of it is emitted back inside the 'greenhouse'. This absorption and emission of IR keep our *collector greenhouse* warmer than it would otherwise be (Boeker & Van-Grondelle, 1999; Giambattista *et al*, 2007). The choice of the hose being black is to optimize absorption of IR as black bodies are known to be better absorbers of heat (Mgbenu *et al*, 1995). It would be interesting in subsequent studies to use transparent instead of black hose to see how important the colour of the hose is.

1.2 Water Pump System

In previous studies (Mbamala et al, 2017; Mbamala & Wokoma, 2017), ac water pump was used. For an ac water pump, one needs ac power sources such as the public power supply or private power generator. The major challenge for the ac system is the difficulty (in most parts of the world) in having uninterrupted power for up to eight sunny hours of the day. In this work, a dc system is employed for the water pumping. As shown in Figure 3, the dc water pump system is comprised of a dc water pump (100 watts), a rechargeable battery, a solar charge controller and a photovoltaic (PV) panel. The dc pump is powered by the battery while the PV charges the battery. Here the system continues to run uninterrupted as long as the battery can drive the pump and as long as there is enough sun for the PV panel. This makes the entire water heating system almost completely solar.

Figure 2: The solar collector system: The coiled hose of about 20 turn in a shallow box covered with a transparent glass.

1.3 The Water Storage System

The water storage system consist of a 120 liter plastic reservoir and a rectangular wooden box. The reservoir is placed inside the wooden box and the space between the container and box filled with sawdust. The sawdust provides heat insulation to the water container to reduce heat loss. Plumbing pipes were used to connect water in and out of the container as shown in Figure 1.

2.0 Materials and Methods

All the materials for this project were sourced and assembled locally.

2.1 Materials

In the design and construction of our solar pool heating system, the major materials used are as follows:

(i) Black polymeric hose of length 45.7m (50 yards) and diameter 12.5mm
(ii) A 120-liter plastic water reservoir
(iii) 100- watts dc electric water pump
(iv) A 12V, 100 Ampere-hour rechargeable battery
(v) A 200W, 12V PV panel
(vi) Rectangular 2mm thick transparent plastic glass cover
(vii) Some plumbing materials

2.2 Method

The water-in and the water-out of the coiled hose collector are connected to the water pump as shown in Fig 1. The powering of the water pump is illustrated in Fig. 2. A tap is fixed to the pipe connecting the water container to the pump. This tap controls the speed of water circulation. The collector system was placed outside with maximum possible exposure to the sunlight. With the water pump turned on the water temperature in the container and ambient

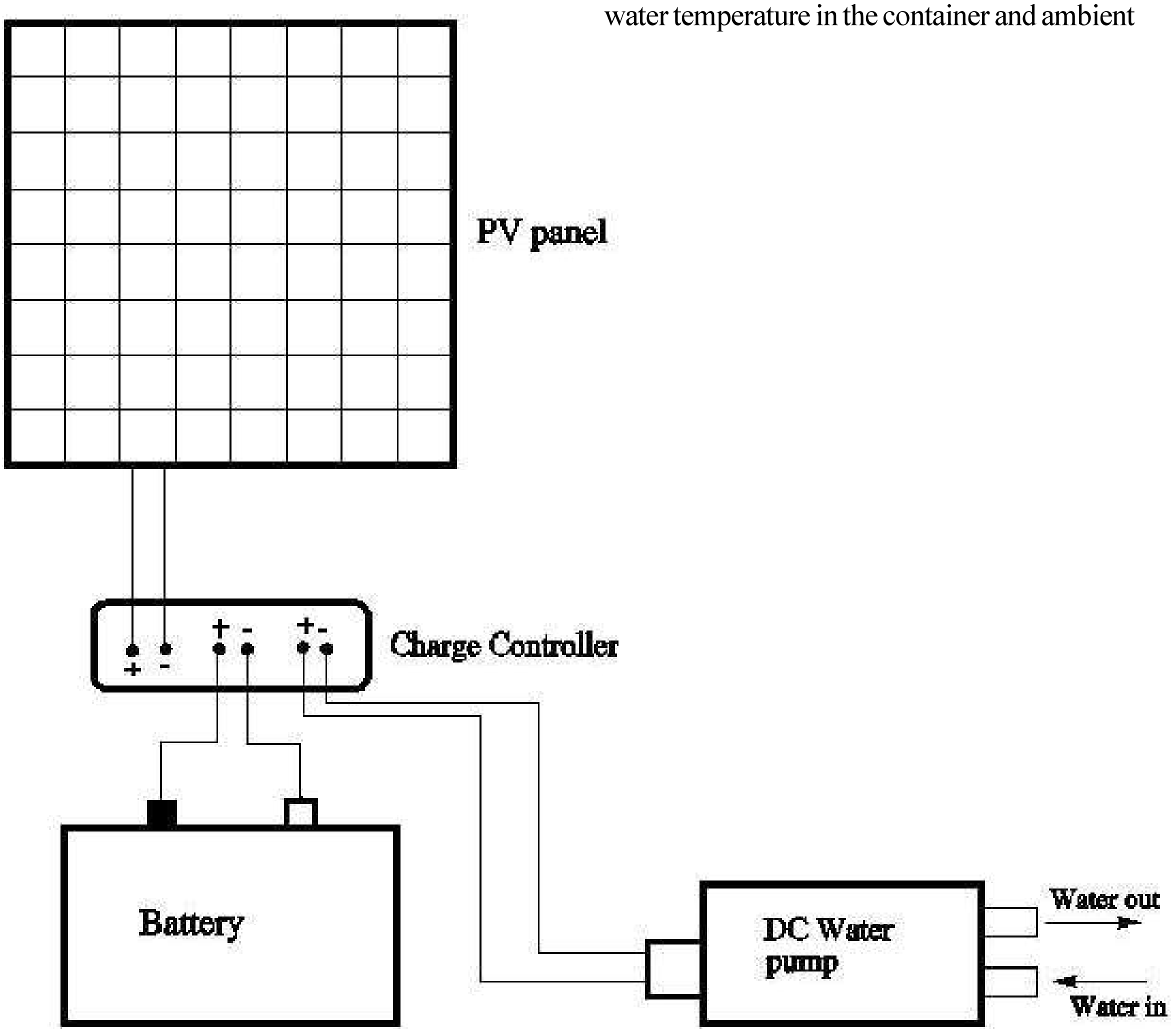

Figure 3: The schematic diagram of the dc water pump system.

temperature were taken every 30 minutes from 10am on each day of test.

3.0 Results and Discussion

In this work, we have set out to heat water with active system of black polymeric hose and a dc water pump. This system has been previously designed with an ac water pump (Mbamala et al., 2017). Here we have also incorporated a simple mechanism for retaining the warmth of the heated water. The main aim is not necessarily to boil water but rather to heat large volumes of water (such as swimming pools) to reasonably high temperatures at lower cost than using the convectional electric heaters.

Measurements and evaluation of the system were carried out in the month of January. Quantities measured include: the temperature of water at any time, T_t and the ambient temperature during measurement, T_a. In all the investigation here, the initial volume of water was kept at 100 liters.

Figure 4 shows how the water temperature T_t and the ambient temperature T_a vary with the time of the day. Here the water pump was turned on at 10:00am and turned off at 6:00pm, but the measurement of the temperatures (T_t and T_a) continued till about 5:00am the following day. This plot shows that the temperature of the 100 liter water peaked at 47°C from 28°C (dashed line) between 3:30pm and 4:00pm. The plot further reveals that the rate of heat loss by the water container was low since at 5:00am the following day, the temperature has only gone down to 40°C from the peak, 47°C (i.e. 7°C in 14 hours). We observe from the plot that at this time (5:00am) T_a (the ambient temperature) has dropped to as low as 19°C. The temperature difference between the water in the container and the surrounding was 21°C. Clearly, without the heat insulation (lagging) system T_t would be very close to T_a after such long period of time. This shows that our solar water heater in the scope implemented here can provide enough warm bath water for an average household in both morning and evening — ideal warm bath water or swimming pool temperature is between 37°C and 38°C.

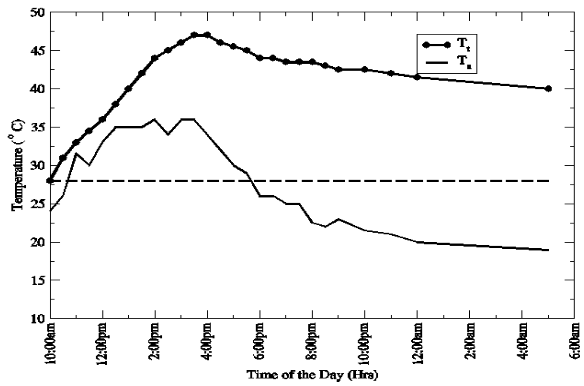

Figure 4: The water temperature T_t and the ambient temperature T_a versus time of the day. The dashed line shows the initial water temperature.

Figure 5 is a plot of the water temperature T_t versus the time of the day for the cases of insulated container (with lagging) and not insulated container (without lagging). The data for no insulation were obtained from previous study (Mbamala *et al.*, 2017). Figure 5 shows clearly that when the water container is not insulated, the water temperature dropped faster.

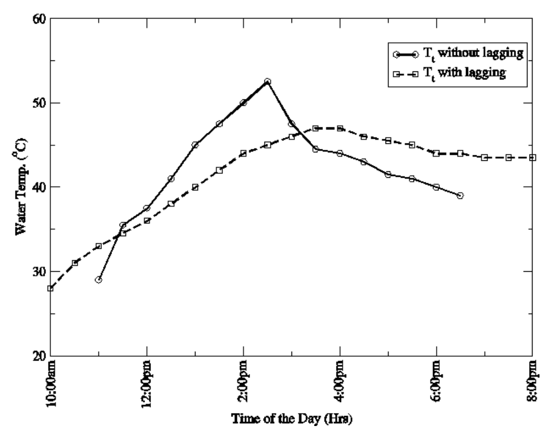

Figure 5: Water temperatures T_t when the container was not insulated (without lagging) and when insulated (with lagging) versus time of the day.

What happens if we run the solar heater system for two consecutive days without replacing the water in the insulated container? Can we get a much higher peak temperature on the second day? Fig. 6 shows that on the first day, the water temperature rose to a peak of about 48°C from 27°C. By 10:00am the following day (2^{nd} Day), when the water pump was switched on, the initial temperature was 41°C. Day 2 recorded a peak temperature of only 49°C, almost same for Day 1. While Day 1 showed a peak rise in temperature of 21°C (i.e. peak water temperature minus initial water temperature), Day 2 showed a peak rise of only 8°C. This shows that the rise in temperature does not depend strictly on the initial water temperature, but to a great extent on the ambient temperature or solar radiation power. Figures 4, 5 and 6 all show that after some time (the peak period), the water temperature begins to drop, even with water still circulating. This is also true of the ambient temperature. It appears that in this region, the drop in ambient temperature hastens the drop in water temperature if water circulation continues. It is therefore suggested that the water pump be turned off when the water temperature starts dropping. This will slow down the rate of heat loss and also save the battery power for the next operation.

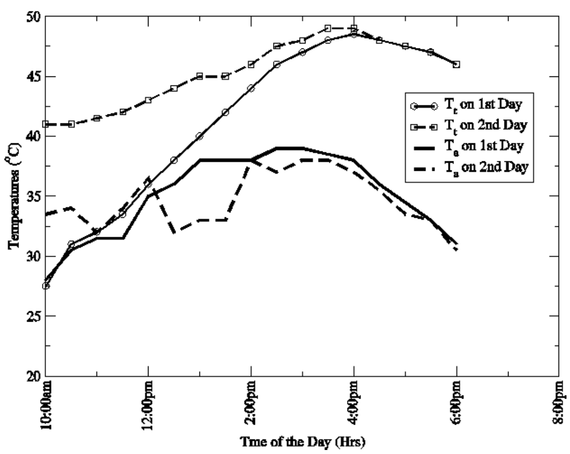

Figure 6: Plot of water temperature T_t and ambient temperature T_a versus time of the day for two consecutive days.

4.0 Summary and Conclusion

For efficient utilization of solar energy, we have used black coiled hosepipe as the major component of solar collector in the design and construction of a solar powered pool heater. The black hosepipe, being polymeric and flexible is easy to form into a flat coil of defined surface area. This is unlike metal pipes such as copper that are stiff. The major contribution of this work is the use of a dc water pump powered by battery and PV panel system. This made the system completely dependent on renewable energy sources.

The water-pump, runs water of volume 100liters stored in a 120-liter container through the coiled black hose collector and back into the container. This cycle is repeated at a controlled speed for a period of time until the water heats up. The project aims at heating large volumes of water such as swimming pools at more convenient and lower cost than using the convectional electric heaters. We also implemented a simple heat insulation for the water container by placing it in a wooden box. The space between the water container and the wooden box was filled with sawdust.

The device was operated on some selected days in the month of January between 10:00hrs and 18:00hrs. The location was Owerri, South East Nigeria. For a 100 liter volume of water we recorded peak temperatures of 47.0°C to 49.0°C from initial water temperatures of about 28°C for different days. When the device was operated from an initial temperature of 41°C the peak temperature did not change significantly. We therefore concluded that the extent of water heating is limited by the ambient temperature irrespective of the initial water temperature.

Due to the insulation provided, the water in the container retained its warmth losing only a few degrees in Celsius when left overnight. This prototype system was used to provide regular warm bath water for an average household. Larger systems will be capable of heating larger volumes of water such as swimming pools and overhead warm bath water for hotels at lower cost than using the convectional electric water heaters.

We suggest that the water pump be switched off as soon as the peak temperature is reached and the ambient temperature observed to be going down. This would save battery power and reduce the rate of heat loss — continued circulation the heated water under lowering ambient temperature leads to cooling rather than heating. It is also be suggested that this experiment be carried all year round for a comprehensive set of data.

References

Agbo, S. N., Unachukwu, G. O., Okeke, C. E., & Enibe, S. O. (2005). Solar water heater for residents. *Nigeria Journal of Solar Energy*, ***15***, 85–92.

Boeker, E., & Van-Grondelle, R. (1999). *Environmental Physics* (Second). New York: JOHN WILEY & SONS.

Danshehu, B. G., & Rikoto, I. I. (2010). Development of a booster assisted solar water heater. In *2nd FUTO International conference on renewable and alternative energy* (pp. 4–8). Owerri.

Enibe, S. O. (2007). *Solar water heater operating principle and construction method. 1st International workshopon renewable energy for sustainable development in Africa*. University Press Ltd.

Giambattista, A., McCarthy-Richardson, B., & Richardson, R. C. (2007). *College Physics* (Second). New York: McGraw Hill.

Mbamala, E. C., Eguzoro, I. D., Alozie, G. A., & Akujor, C. E. (2017). Solar powered pool heater using black hosepipe as collector. *African Journal of Renewable and Alternative Energy*, **2(1),** 41–49.

Mbamala, E. C., & Wokoma, V. O. (2017). Solar powered pool heater: Effect of tracking the sun. In *7th Annual and International Conference of the Renewable and Alternative Energy society of Nigeria.* (pp. 70–76). Akure, Nigeria.

Mgbenu, E. N., Inyang, A. E., Agu, M. N., Osuwa, J. C., & Ebong, I. D. U. (1995). *Modern Physics*. Lagos: Spectrum Books.

Ojosu, J. O., & Komolafe, L. K. (1989). An integrated water heater for low cost housing and rural areas. *Nigeria Journal of Solar Energy*, ***8*,** 97–104.

Paul, J. K. (1979). *Solar Heating and Cooling: Recent Advances*. New Jersey: Noyes Data Corporation.

Peni, I. T., & Rikoto, I. I. (2010). Importance of solar water heater in homes and industries. In *2nd FUTO International conference on renewable and alternative energy* (pp. 24–32). Owerri.

Sambo, A. S., & Bello, M. B. (1990). An experimental evaluation of collector for thermo-syphonic solar water heater. *Nigeria Journal of Solar Energy*, ***9*,** 223–238.