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ON INTEGRATED SOLAR WATER HEATING SYSTEM

Mousa S. Mohsen and Bilal A. Akash
Department of Mechanical Engineering, Hashemite University
Zarqa, 13115, Jordan
Email: msasmohsen@yahoo.com

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ABSTRACT

Experimental results on the performance of an integrated solar water heater (ISWH) are presented. ISWHs are considered to be an ideal solution for providing remote areas with hot water. Especially, for those where population density is low and with low-income households. Such scenario exists in what is known as the Badia region of Jordan. Two identical ISWHs were used, except that one with fins and the other without. Experimental results show that this type of ISWH can achieve a temperature rise of about 30°C, during the month of November under local climate conditions. The cumulative thermal efficiency of about 60% was reached by the system when extended fins were used.

Introduction

Jordan is a developing non-oil producing country in the Middle East. The use of fossil fuels completely depends on importing crude oil from neighboring countries. Energy consumption is rapidly increasing due to the vast increase in population and urbanization. Efforts to overcome the unsustained energy demand in Jordan include optimization of energy use in all sectors, demand management, and also use of renewable energy sources such as solar and wind energies. The use of solar and wind energies in different activities such as water desalination, water pumping, and electric power production in Jordan were addressed in recent studies [1-10]. It is a fact that Jordan is blessed with great solar energy resources. In the desert, which covers 87% of the land, the average daily solar radiation is equal to 5.5 kW h/m^2, and there are 3000 sunshine hours per year, roughly.

Solar water heating systems are quite popular in Jordan, about 24% of the dwellings are equipped with such system [9,10]. In a recent study a multi-criteria methodology was used to evaluate the domestic solar water heating (SWH) system in Jordan [11]. It was found that SWH system was the most beneficial system when compared to other systems used.

ISWHs are in use in different countries around the world such as Japan, South Africa, India, and Ghana [12,13]. The simplicity, and low cost of manufacturing and installation of such water heater make it very attractive alternative to thermosyphone system especially in the Badia regions. This experiment was inspired by the national research and development efforts directed towards the Badia region of Jordan. A distinction has been made between Desert and the Badia region. The Badia region is characterized by a low rainfall of about 100-200 mm per year and a very low population density, 20 to 60 persons per km^2 [14]. This region is unique in its wide bio-diversity and ecosystem, which made it vital to settle indigenous inhabitants and to ensure sustainable development. The objective of this paper is to study the performance of the integrated solar water heater experimentally at local conditions.

Experimental

A schematic diagram of the integrated solar water heater used in this study is presented in Fig. 1. It is constructed from locally available material. Briefly, it consists of a galvanized steel box, with the dimensions of 112 cm X 80 cm X 10 cm, and a nominal volume of 90 L. The top of the box, having an area of 0.896 m^2, is made of flat black plate. The glazing is single ordinary window glass sheet. The heater is insulated with 5.0 cm of local rock-wool material that is fixed in place by an outer galvanized box. Two heaters were constructed, one without fins, and the second with fins extended from the absorbing plate. The fins were used as a way of increasing the absorbed solar radiation and eventually increase the efficiency of the heater. The heaters were placed facing south with an inclination angle of 45°.

The instrumentation of each heater included three thermocouples to measure the temperature of storage water at three locations: lower-, middle-, and upper-parts of the tank. These thermocouples are inserted inside the tank by drilling holes in the tank at these locations. One Kipp and Zone pyranometer was fixed at the same plane of inclination of the heaters to measure direct solar irradiation on the absorber plate. Ambient temperature was also recorded. Temperatures of absorber plate, and glass cover were recorded, too. All observations of temperatures and solar intensity were recorded using a data acquisition system every half-hour.

The heaters were filled with fresh water daily at 7:00 a.m. after draining all water from the previous day.

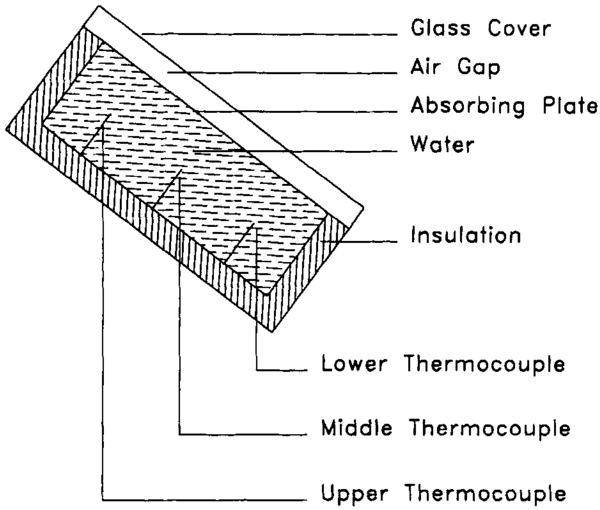

FIG. 1

Schematic diagram of the integrated solar water heater used in the study.

Results and Discussion

Figure 2 shows the experimental performance of both finned and unfinned heaters for a typical sunny day during the month of November in Amman, Jordan. It presents variations of water temperatures, ambient temperature, and solar irradiation recorded versus hour of the day. It is clear from the figure that water temperatures begin to increase as the day progress. Initially at slow rate and then later in the day at higher rate. The maximum temperatures were reached at about 3:00 p.m. It is shown that the system could heat the water up to an average temperature of 52 °C when fins were used, and up to 50 °C when fins were not used. Both temperatures considered as average are located at the middle of the storage tank. Similarly, temperatures at the top of the tank reached 61 °C and 60 °C for the heater without fins and with fins, respectively. A maximum solar intensity of about 950 W/m^2 was recorded at 11:30 a.m. It is clear from the figure that the presence of fins tends to increase water temperature most of the day at the top, middle, and lower parts of the heater. In order to compare the results the instantaneous and cumulative efficiencies were calculated for both with and without fins water heaters. Instantaneous and cumulative efficiencies for the finned heater are shown in Fig. 3. Whereas efficiencies of the unfinned heater are shown in Fig. 4. The maximum instantaneous efficiency was about 68% when fins were used, and 77% when fins were not used. The cumulative efficiency was higher for the finned water heater. It rises up to about 59%. On the other hand it was little lower for the unfinned heater at about 50%.

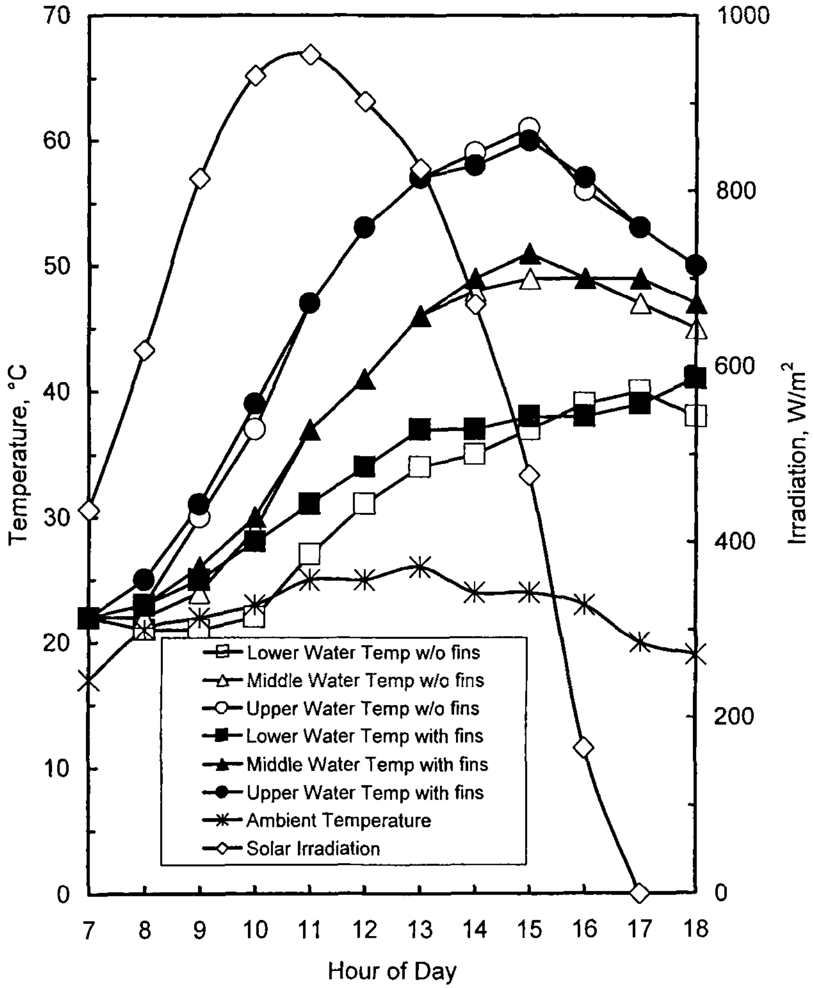

FIG. 2

Variation of irradiation and temperatures at various locations for both water heaters.

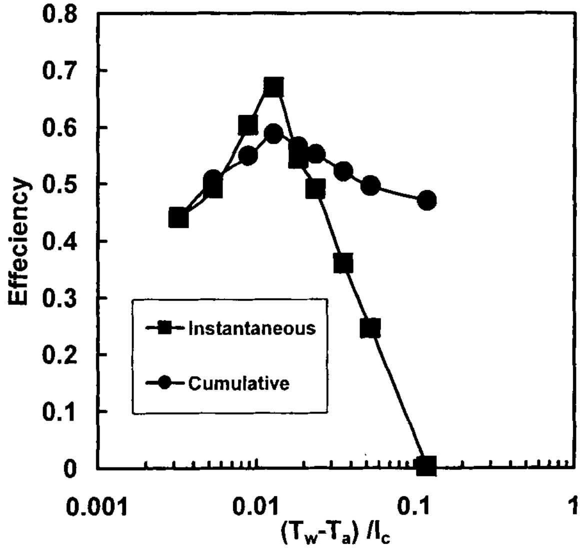

FIG. 3

Instantaneous and cumulative thermal efficiencies of the finned integrated water heater.

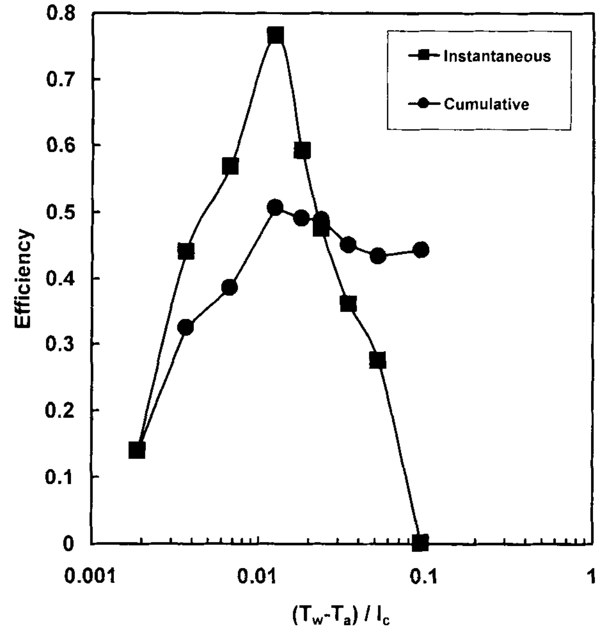

FIG. 4

Instantaneous and cumulative thermal efficiencies of the finned integrated water heater.

Conclusion

We can conclude that a temperature rise of about 30 °C can be achieved by the system for a particular sunny day during the month of November at local conditions. The use of extended fins can improve the cumulative efficiency of the system from 50% to 59%. The system is constructed from inexpensive locally available materials. It is simple in construction and operation and can be used in the Badia region of Jordan where the demand for domestic hot water is somewhat lower than urban areas. An extensive work will be carried out on this system which is a part of a comprehensive research program for the Badia region development.

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