Design and Construction an Efficient Solar Water Heating System for Building Heating Purposes

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Abstract

Solar water heating systems (SWHS's) is the technology of the most important applications used for energy-saving in renewable energy. A solar water heater system (SWHS) constructed for building heating consists of solar panel (vacuum tube type) absorber with different heat radiators are used as a closed-cycle system to heat a room with dimensions: (7x7x3) m. The maximum heat transfer depends on the temperature difference between the external ambient and the room temperature, liquid flow rates, and the radiator material type. The results show that the radiator made of aluminum material is more efficient than that radiator made of iron material, so that, it can be utilized for building heating.

Key words: solar water heater, closed loop, radiator, building heating.

تصميم وبناء منظومة سخان ماء شمسي كفوء لأغراض تدفئة المباني

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الخلاصة

نظام سخان الماء الشمسي هي التكنولوجيا الأكثر أهمية لتوفير الطاقة من الشمس كنوع من أنواع الطاقات المتجددة. يتكون نظام سخان الماء الشمسي المستخدم في تدفئة المباني من لوح الأمتصاص الشمسي من نوع الأنابيب المفرغة مرتبط مع مشع حراري متعدد الأنواع كنظام مغلق

لتدفئة غرفة بالأبعاد m (7x7x3). إن أعظم انتقال حراري يعتمد على الفرق بدرجة حرارة الغرفة والمحيط الخارجي ومعدل سرعة جريان السائل (الماء) وكذلك نوع المعدن المصنع منه المشع الحراري. تم دراسة تأثير نوع المعدن (سبيكة الحديد او الألمنيوم)، وأظهرت النتائج ان المشع الحراري المصنوع من معدن الألمنيوم هو الأكثر كفاءة من المشع الحراري الصنوع من سبيكة الحديد، لذلك ينصح باستخدامه كمشع حراري في نظام سخان الماء الشمسي لتدفئة المباني.
الكلمات المفتاحية: سخان الماء الشمسي، الدورة المغلقة، مشع حراري، تدفئة المباني،

1. Introduction

Iraq is a country located near the solar belt, lies between latitudes 2950-37220 N, and longitudes 38450-4450 E, which makes it characterized by high solar radiation intensity and high brightness period throughout the year. This makes Iraq receives a quantity of solar radiation with an average of (6.5-7) kW/m^2, so that, Iraq is well known for long hours of sunshine, besides, Iraq suffer from a high-temperature ranges for most days of the year. The temperature ranges from (4.4-16) ^{o}C, with solar intensity 416 W/m^2 in January, and (25-44.5) ^{o}C, with solar intensity 833 W/m^2 in July.[1]

A SWH is any system that utilizes the infrared spectrum of the solar radiation usually aimed to heat water to a temperature hot enough for many uses and applications. SWHS's mainly consists of three major items: solar thermal absorber (STA), storage tank and hot water pump with controller figure (1). The other components and accessories are differs according to the system type and applications.

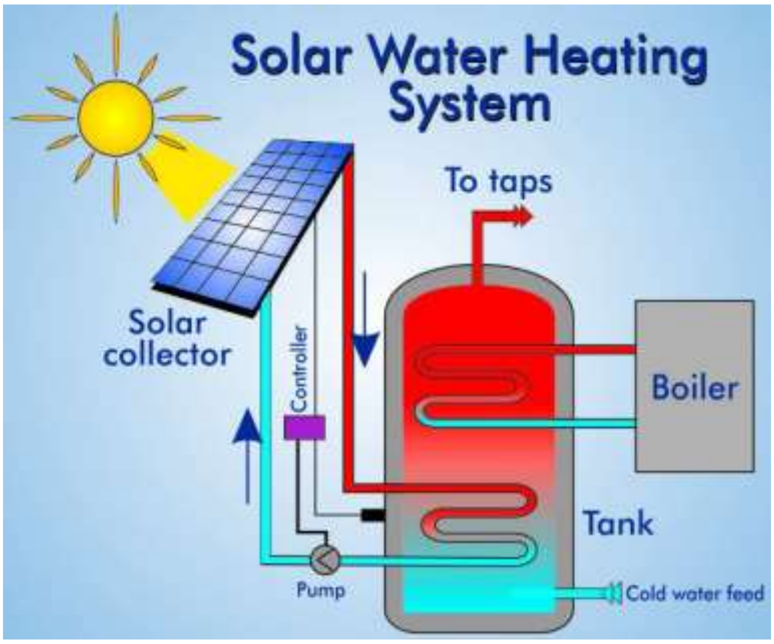

Figure (1): Block diagram of Solar Water Heating System [2]

However, as long as it is clean, the hot water can also be used for heating buildings to save power costs in addition to some environmental and economic benefits. There are some benefits of utilizing solar heating systems: Endless amounts of energy, free of charge, no CO_2 emissions during operation, cost savings: up to 60% less energy to heat water, up to 35% less energy for space heating, Reduced consumption of fossil fuels, solar thermal systems can be integrated into existing systems, modern systems work efficiently even in winter.

Building heating at winter season has a significant impact on energy use and the environment. Commercial and residential buildings use almost 40% of the primary energy and approximately 70% of the electricity.[3]

Based on the collector type, solar water heaters can be classified into two categories: flat plate collectors (FPC) based solar water heaters and evacuated tube collector (ETC) based solar water heaters. In other hand; solar water heaters can be characterized as either direct (also called open loop) or indirect (also called closed loop) depending on whether the incoming water is heated via exchanger. Both types of system can be either active or passive. An active system uses an electric pump to circulate water or a heat transfer fluid from storage tank through the collector. Whereas a passive system relies on gravity and the tendency for water to naturally circulate as it is heated, allowing water or heat transfer fluid to move through the system without the use of circulating pump. Figure (2) summarize in a hierarchy configuration the classification of SWHS's types.

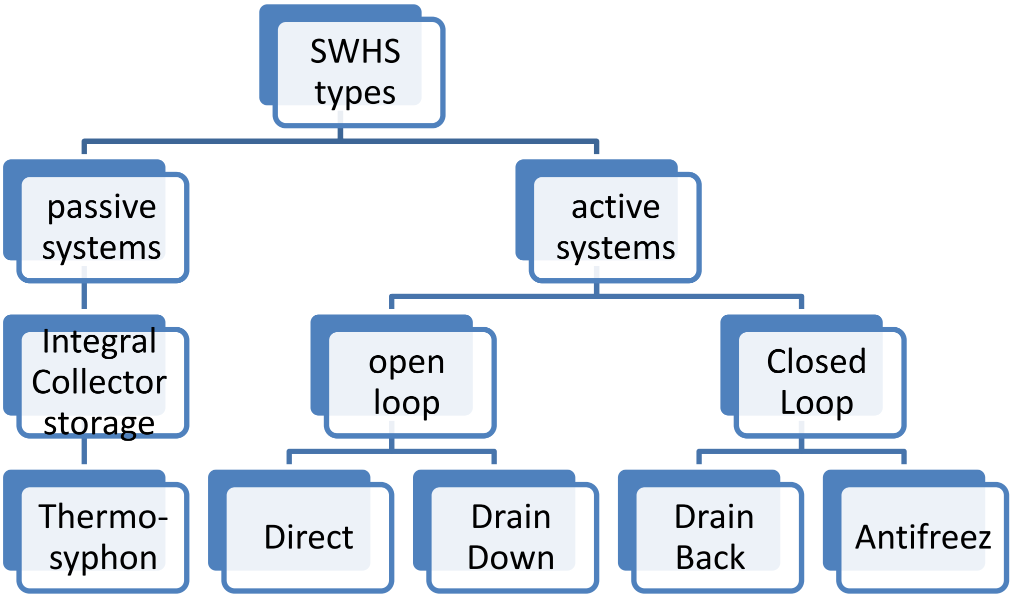

Figure (2): The classification of SWHS's types.

The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, annual solar radiation, etc.[4]

Building heating system is a practical application of a SWHS, in such a system, containing heat radiator as a load to extract heat by circulating fluid between solar absorber and the main reservoir. The common fluid for heat transfer in this application is water; also, the main parts are storage unit (tank) and electrical water-pump. In combination with conventional solar heating equipment, it provides the same level of heating and temperature stability as in conventional systems.

Recently, many studies toward SWHS's were carried out to design, construction, and development to enhance its performance. Igor Shesho will design and constructed a SWHS for building heating and cooling [5]. The performance analysis of different types of SWHS's with simultaneous climate conditions, cities and methods such as numerically or using programs like Matlab, TRNSYS16, etc. [6, 7, 8, 9].

2. **Experimental Part**

In this work, the suggested (SWHS) consists of 300-liter solar water absorber panel and low consumption electric power (100 Watt, 220 volt) heat pump. The solar water collector evacuated tube collector (ETC) type figure (2), it has lower thermal losses as compared with flat plate collector (FPC) and hence less affected by ambient conditions, this will enhance the SWH performance by increasing transmission of energy through the collector to working fluid also reduce thermal losses [10]. The ETC installed toward the south as it is the optimum conditions in order to ensure the largest amount of solar energy absorption [11]. The building roof is of 3m height from the load in order to warm the room space, in addition, thermally insulated plastic pipes which has low thermal conductivity are used to reduce the leakage losses due to the heat transfer during the flow of the fluid in such a system. The load room is of (7*7*3) m dimension. Figure (3) show the schematic diagram of the constructed SWHS for room heating.

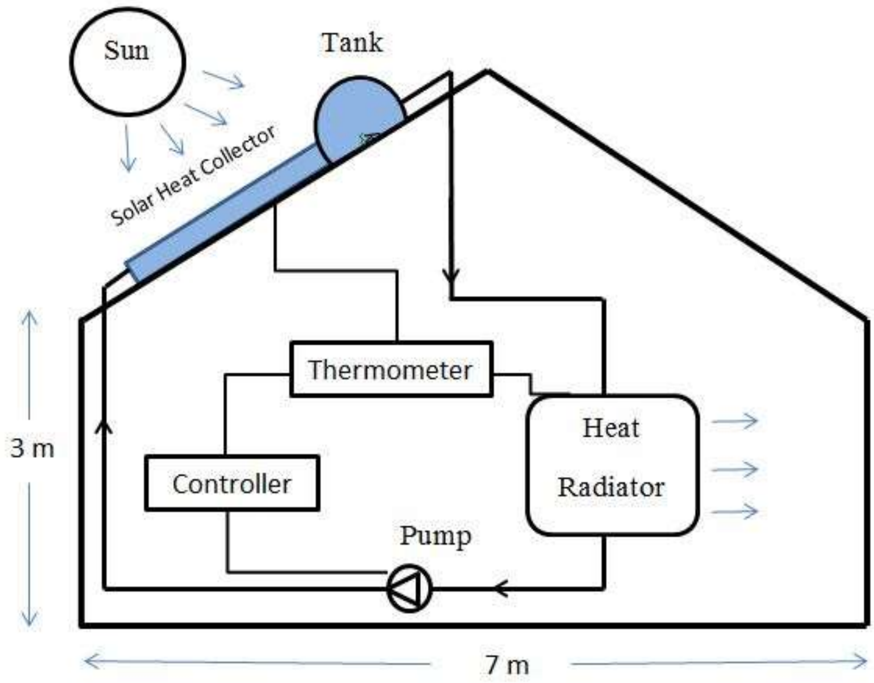

Figure (3): schematic diagram of the constructed SWHS for room heating.

Figure (4): The evacuated tube type solar water heater absorber (ETA) with Tank.

The thermal pump is necessary to close cycle system in 5 liter /min flow rate and is usually controlled by a variable thermostat connected as a differential controller senses temperature differences between water leaving the solar absorber panel and the water in the heat radiator. The controller starts the pump when the water in the absorber is sufficiently about 8–10 °C warmer than the water in the tank and stops it when the temperature difference reaches 3–5 °C. This ensures that stored water always gains heat when the pump operates and prevents the pump from excessive cycling, (In direct systems the pump can be triggered with a difference around 4 °C because they have no heat exchanger). The radiator that provides heat to the load (room) is of two types; first is made of iron, and the second is made of aluminum material with a fan in order to increase the heat dissipation rate.

The experiment was done in three steps to operate SWHS with different materials and water tank capacity in order to distinguish the optimum heat exchange (efficiency) between the SWH and the radiator (load).

Step (1): using a radiator made of Iron shown in figure 5a, 20 liters, large weight and thickness in the form 10 cells separated by grooves to increase surface area and then heat dissipation.

Step (2): using a 5 liters radiator made of Aluminum shown in figure 5b was used in the form of (1cm) diameter pipes in closed cycle surrounded by Aluminum plates to increase the emission area of the radiator and then increase heat exchange amount with the environment.

Step (3): A fan was used inside the Aluminum radiator in order to increase the rate of temperature exchange between the radiator and the room ambient.

Figure (5): the iron material (a), and the Aluminum material (b) radiator types

3. Results and Discussion

The measurements were made on a sunny day with some pieces of clouds Three consecutive days (25, 26, 27/3/2019) as shown in Figure (6)

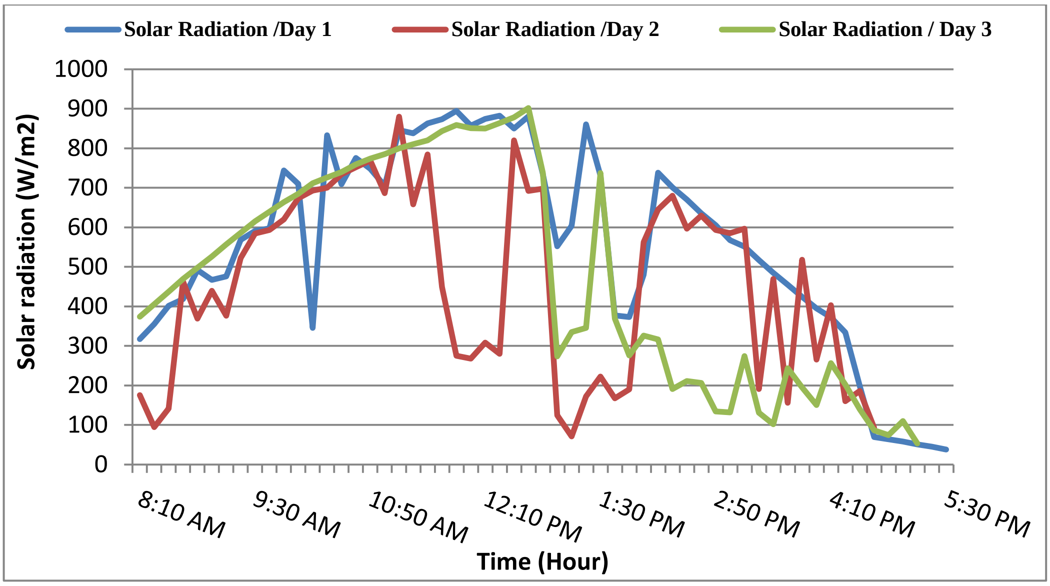

Figure (6): the solar radiation for three days.

The average ambient temperature was low during the three days as shown in figure (7).

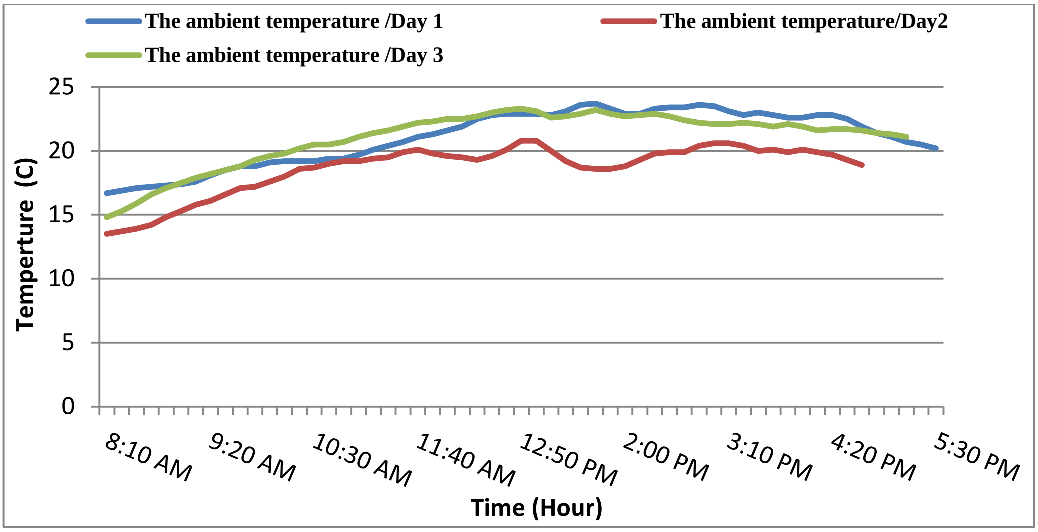

Figure (7): The room ambient temperature for three days.

After the operation of the system, the income hot water temperature where measured. The circulation of hot water in closed cycle by connecting the pump between the solar water heater and the radiator and monitoring the temperature rise in of the radiator gained from hot water for two hour period, figure (8) shows the amount of radiator and room temperature variation with time.

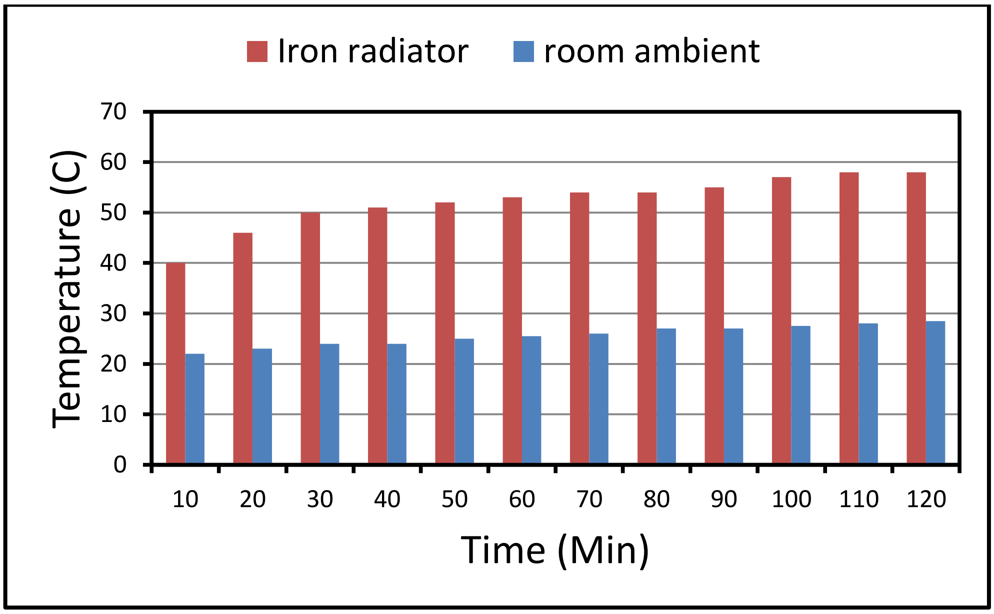

Fig (8) the iron heat radiator and room temperature in the first day

The procedure were repeated on the second day with aluminum-type radiator, and the results reveals a rapid dissipation of heat from the radiator to the room ambient and raise temperature within a shorter time than that at the first day as shown in figure (9).

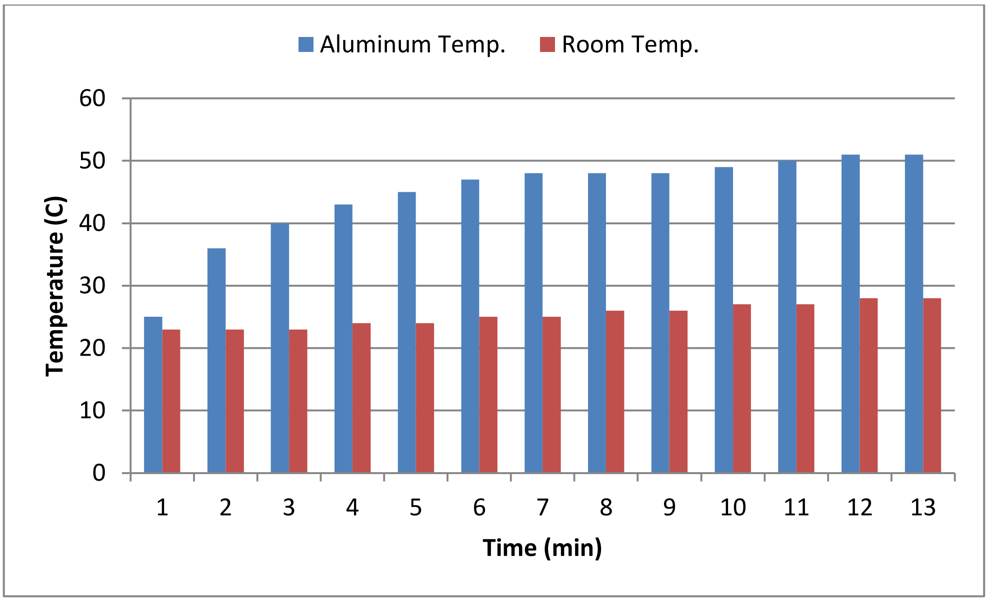

Figure (9) the aluminum heat radiator and room temperature in the second day.

It was obviously noted that the heat dissipation to the room ambient faster and in a shorter time than the two previous steps when a fan was operated with aluminum radiator at third day as shown in figure (10).

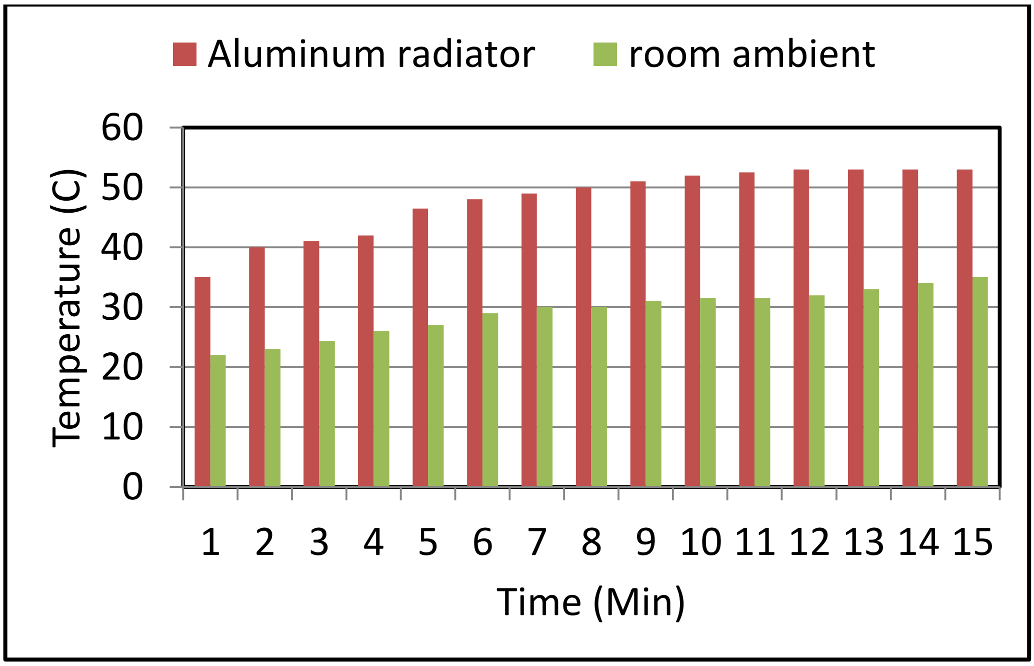

Figure (10): The aluminum heat radiator with fan and room ambient temperature.

From the three previous steps, it is clear that the radiator made from Iron alloy material has a lower heat dissipation rate than Aluminum material due to its low heat conductivity in spite of large radiator surface area, so that it has a higher heat capacity (heat storage) for a long time period, and it can be enhanced by adding a fan, but its shape and design prevent the construction of fan with this system. So that this radiator manufactured by Iron will be limit the efficiency of heat exchange.

In the second step, when the radiator was replaced with aluminum type and the temperature difference (ΔT) is greater than the first type (Iron), it is noted that this radiator is typical for heating application because the aluminum has a greater thermal conductivity than the iron alloy, and the amount of heat exchange between the radiator and the load is large which accommodating to such applications as that the aluminum plates surrounding the pipes will increase the surface area that has a large role in the amount of heat exchange of the radiator with load.

In order to increase the amount of heat exchange (ΔT) and diffuse heat into the room ambient by inserting a fan into the radiator. This stage included with a temperature controller (thermostat) in order to control the room ambient temperature by controlling the pump switching according to the radiator outlet water temperature using a special program. This step represents an optimal constructed system.

From the three previous practical steps, it is shown that there are advantages and disadvantages for each case. In the first stage, when there is a low heat exchange between the radiator and the load, this give an advantage that it is possible to reach the suitable room temperature but in a long time interval, that means possibilities to maintain the amount of heat generated in the solar heater for a long period of heating. Whereas, in the second and third cases, when the amount of heat exchange suitable for room heating, this is at the expense of the value of the heat stored in the solar heater where the heat diffusion is faster but it may be treated by using solar heater with a higher heat capacity, i.e. inserting of a storage tanks connected seriously, and controlling the room temperature automatically, when reaching to a suitable degree of room temperature, switch OFF the pump in order to maintain the amount of stored heat.

It is worth noting that both thermal pump and fan has low power consumption (about 250 Watts) compared with large power consumption in the case of water heated via electric power of (1000-1500 Watts), in addition to the financial resources of the electricity wages, and the price of shorter operating time perishable heaters.

The success of this technique requires simple maintenance, which is to clean the pipes from the accumulated dust, because it will in some way reduce the radiation absorption, as well as the installation direction of these heaters to ensure that they will receive the largest amount of solar radiation, as well as the removal of barriers and obstacles close to the solar heater to avoid the shadow. Although the susceptibility of these tubes absorption of atmospheric scattered radiations for a wavelength range in mid infrared region.

As well as the isolation of all parts of the system including hot water pipes, pump, radiator and shortening transport distance to reduce energy loses along the path of the conveyor. The efficiency of the system can be enhanced by connecting solar heater seriously, as well as in the case of absence of the sun in dark, dust and/or cloud existence by use the thermal energy storage method, in order to achieve longer period of heating. Such a system can be employed to reduce the electricity consumption by the spread of such systems for water heating used in building heating or other various industrial purposes.

4. Conclusions

1- The SWHS technology is a low cost (500-700 $), depending on the size of the tank and the equipment attached to the solar heater, which has a long operating life.

2- Some development of this technology can be introduced to be non-consumption to the national electric power by operating the pump and the radiator fan with DC voltages through the employing PV panels with batteries to be the whole system depends on solar energy, but this will add another cost to the total of the system costs.

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