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Abstract: In this paper experimentally has been tested the effect of rotating the hot water between the storage tank of solar heater and thermal radiators and the effect of the energy gained from solar radiation on the stratification phenomenon in the thermal storage tank of solar water heater with (32) evacuated tubes and tank capacity (263 liters) that have used in the design of a solar energy system operate on solar power only for the official working hours in government department for heating a meeting hall of specified area in Iraq under the ministry of science and technology. This test was in environmental conditions in Baghdad, where in this testing have used data logger with the use of thermo couples (type k) to measure the temperatures of hot water in the middle and bottom to the storage tank of solar water heater, hall temperature and ambient temperature.

Keywords: Evacuated Tube Collector, Solar Energy, Stratification Phenomenon, Thermal Storage Tank.

I. INTRODUCTION

Thermal stratified storage tanks are an effective management technique to improve the efficiency of solar thermal systems. Thermal stratification improves the overall performance of the systems by increasing the efficiency of solar collectors (reducing the average collector absorber plate temperature) and by enhancing the temperature level of the water supplied to load. Significant improvements in yearly performance of solar energy systems may be realized if stratification can be maintained in the storage tank [1-3]. Many scientists have recognized that the thermal stratification is required to obtain better performance in heat storage in solar applications. Stratification in a thermal storage tank is determined mainly by the volume of the tank, the size, location and design of fluid inlet and outlet. Because of global warming, pollution and oil peak, renewable energies seem to be the best solution to these issues. Solar energy is a suitable solution for building needs. Solar thermal systems can be used in buildings to provide energy for Domestic Hot Water (DHW) and/or space heating. Heat storage for heating systems is required in order to accommodate the intermittent nature of solar radiation and energy resources. Besides, the performance of solar heating systems is strongly influenced by thermal stratification in the storage tank. Stratification allows an optimal use of the store with minimized heat losses and can also be used to ensure that the collector inlet is as low as possible. Furthermore, hotter water is at the top of the tank, which in some cases enables not to use energy supply. Annual performances can be increased by 37% with the use of a stratified solar tank [4].

Thermal stratification in storage tanks has been the subject of various experimental and numerical studies [5-7]. It has been shown that thermal stratification is affected by a number of factors such as mixing due to the inlet and outlet streams, heat losses to the environment and tank configuration [8-15]. The height to diameter ratio is a factor that influences stratification [16] which may be enhanced through the proper design of tank parameters such as aspect ratio [17]. The overall performance of a solar energy system for water heating can be increased with an optimal thermal stratification in the hot water storage tank [18]. The degradation of thermal stratification in solar storage tanks can be caused by different factors: (i) the water inlet jet mixing that occurs during charging and discharging processes; (ii) the natural convection inside the tank driven by the difference of temperature between the inlet water and the stored water with which it comes into contact; (iii) the thermal conduction and diffusion within the water due to the vertical temperature gradient; (iv) and the vertical thermal conduction along the tank walls.
II. EVACUATED TUBES SOLAR COLLECTOR CONFIGURATION

The Evacuated tube solar collector in the present study consists of (32) evacuated tube made of borosilicate glass 3.3,1800mm-long evacuated tube providing the hot water to a (263 liter) horizontal storage tank as shown in figure 1. Hot water in the tube moves by natural convection upward to be replaced by colder water. The hot water produced will be accumulated in the storage tank. The steel mounting structure permits the solar heater to be tilted flexibly to the ground to suit geographical locations. The storage tank is equipped with an electrical heating element to provide hot water in solar unfavorable times.

Figure 1: Evacuated –tube thermal solar collector array.

A. Solar Heating Elements

Each element (Evacuated tube) is composed of two coaxial borosilicate Glass tubes figure 2 joined at the top and sealed at the bottom which contain a vacuum, the outer of 58mm diameter and (1800mm) length (cover tube) and the inner 47mm diameter and (1720mm) length (absorber tube) that contain 2.6 liters of water. The thickness of inner tube and outer tube is 1.6mm. The inner tube contains the water to be solar heated and its exterior is coated with a suitably dark absorbing material (Nitrite Aluminum) for collecting the incident solar radiation and transmitting it to water. The closed volume between the outer and the inner tube being evacuated works as a thermal insulator preventing heat loss primarily due to convection and conduction. Thus the trapped solar energy absorbed and transmitted to water is prevented from escaping backward to the environment (green house phenomena). At night or at cold weather the heated water thermally insulated by this vacuum is also then protected from being cooled or frozen. The whole borosilicate-glass tube structure is supported at the bottom on the edge of the outer tube on a horizontal PVC livelihood. According to the manufacturing company (China), transmittance of cover tube is 91% Solar absorptance 93%. Emittance <8% at (80 ºC). Pressure of vacuum space: <5×10−3 Pa. Stagnation temperature (typical) is 200ºC degree. Impact resistance withstand 25mm diameter hailstone without breaking. Glass strength (pressure tested) is 1 Mpa.

Tube Centre distances: distance between centers of tubes is 7.8cm

Water volume in evacuated glass-tubes: 32 evacuated glass-tubes are containing 32×2.6 liters = 83.2 liter.

Figure 2: A schematic diagram of the Evacuated tube-heating element.

B. Hot Water Storage Tank

Thermally isolated horizontal tank, Outer container made of stainless steel circular cylinder of 270 cm length and 47 cm outer diameter and inner container made of stainless steel circular cylinder of 259 cm length and 36cm diameter, (total volume 263liter) with 55 mm-thick thermal insulation (polyurethane foam) figure 3.

Figure 3: A cross-section schematic diagram of the water storage tank.
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Water in/outlet: The cylinder storage tank is equipped with two circular openings at its bottom where two (19mm) diameter steel pipes are fixed to the tank. The two pipes are used for cold water inlet and hot water outlet. Two one-way valves direct the water for either allowing cold water to enter or hot water to leave the tank as required. The total water volume heated by the solar radiation in the system consists of the water contained in the tank and the total amount of water in the heating glass tubes = 263 + (32×2.6) = 346.2 liter.

C. Solar Absorbing
The total heating aperture area of the collector comprising the (32) Glass vacuum tubes is (0.0544m×1.72m) × 32= 2.994176 ≈ 3 m². The absorber Area is (1.72 m x 0.0470m x 32 tubes) = 2.58688 m².

D. Supporting Steel Structure
The steel frame housing the (32) evacuated glass tubes are tilted to the ground by an angle suitable for the geographic location site. The solar collector is situated at a tilt angle (45 degree) and oriented towards south (for northern Hemisphere).

III. COMPONENTS OF SOLAR SPACE HEATING SYSTEM
The system components are cleared as shown in figure 4. Where the system consist of two solar heaters from the type –Evacuated tube –with (32) tubes and storage capacity of (263) liter for each heater, two solar panels with power (80 watt), solar charger (solar charger rating 12 v d.c /14 amp), battery type (Deep cycle 200 amp. h), electrical reflector, compensation water tank with capacity (1000) liter, conducting water tubes type (1/2” C.P.V.C SCH 80), (Chlorinated Polyvinyl Chloride), circulating pump with (100 watt) power. Two thermal radiators, control unit consists of two parts, the first is fixed within the space which is responsible for measuring and control the space temperature, and the second to be fixed on the solar heater to measure the internal temperature for hot water of the storage tank solar heater [19].

IV. THE OPERATING PROCEDURE OF THE SYSTEM
The operating of the system thereby the control unit which run the circulating pump in case of existence of two

Figure 4: Meetings hall with components of the heating system [19].  
Figure 5: Image hall meetings after the construction of the system [19].  
Figure 6: Picture of solar water heaters installed on the roof of the building [19].
less than (22°C) and the other is the inlet temperature of the hot water in the middle of solar collectors storage tanks must be more than (40°C), where the system working continuous till the space temperature becomes (22°C), it will stop then it will work when the temperature decrease and become less than (22°C) and so on depending on the control unit as shown in figs.5 and 6.

V. MEASURING AND RECORDING DEVICES

A. Thermocouples
Thermocouples are used to measure temperatures at several locations in the system as shown in figure 3 and figure 8, according to their purpose:
- Three thermocouples type K (1, 2, 3) to measure the inlet and outlet temperatures of water in the tank and ambient with measuring range (−50 to 150°C).
- Three thermocouples type K (4, 5, 6) to measure the temperature of entry and exit of water to and from the space and inner space temperature.

The thermocouples are connected to electrical digital reader. The thermocouples were calibrated according to the company that manufactured these thermocouples and the errors are found to be 0.4°C for K-type.

B. Recording Device and Store temperature Data
- Accurately measures 12 channels of temperature independently.
- Records data onto an SD card in Excel format for easy transfer to a PC for analysis.
- Data logging capability up to 20,000 records using a 2G SD card.
- Manual store and recall of up to 99 records

The system operated on 15.01.2014, and through operating the system we derived the data from the measuring and data recorder device that fixed as shown in figures 3 and 8, we observed the control unit operated the system at that day continuously from the time 09:10 am until the time 10:30 am and at this time the system operating stopped because of the hall temperature has reached to the calibrating temperature in the control unit (22°C) and after that the control unit continued in operating and stopping the system with kept the hall temperature (22°C) till the time 01:30 pm in the end of official working hours as shown in figure 10, that represent the relation between the

VI. RESULTS AND DISCUSSIONS
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entry temperature $T_i$ for the hot water that come from the storage tank of solar collector and enters to the hall, the exit temperature $T_o$ for the hot water that return to the storage tank of solar collector after the exit from the hall, the hall temperature $T_h$ and the ambient temperature $T_a$ versus the local time.

During the period of operating the system continuously from the time 09:10 am until the time 10:30 am, where the energy supplying to the load without stopping through rotating the hot water between the storage tank of solar collector and the thermal radiators in the hall, we observed the temperatures difference between the temperatures of the hot water in the middle and bottom the storage tank at time 09:10am it was (21.1°C) and with continuation rotating the hot water the difference decreased gradually to (4.8°C) at the time 10:30 am as show in figure 11, that represent the

In the period of operating and stopping the system by the control unit depending on hall temperature, after the period of the continuous operating till reaching the hall temperature (22°C), we observed from the figure 12, the difference between the hot water temperatures in the middle and bottom of the storage tank equal during the period from the time 10:30 am where the difference was (4.8°C) until the time 01:30 pm where it was (4.9°C), This equal difference because of the energy supplying to the load in this period less than supplied energy in the continuous operating period for the system in the previous period and this energy almost equal to energy gained from solar radiation.

After stopping the system operating in the end of official working hours at time 01:30 pm until the sunset at time 04:40 pm, we observed as shown in figure 13, the difference in temperatures of the hot water in the middle and bottom to the storage tank of solar water heater at time 01:30 pm it was (4.9°C) until the time 04:40 pm where it was (9.1°C), this increasing in the temperatures difference during this period because of the energy gained from solar radiation without energy supplying to the system.

Relation between the hot water temperature in the middle of the storage tank $T_m$, the temperature of hot water in the bottom of the storage tank $T_b$, the hall temperature $T_h$, the ambient temperature $T_a$ versus the local time, where we observed the effect of continuation supplying energy to the load on the stratification phenomenon through the convergence between the hot water temperatures in the middle and bottom of the storage tank with lack of solar radiation in the morning and this means the effect was because of the energy supplying more than the energy gained.
While in the period from the time 04:40 pm until the time 07:50 am on the next day, we observed the temperature difference of the hot water between the middle and bottom of the storage tank of the solar water heater as shown in figure 14, where at time 04:40 pm it was (9.1°C) and after some time the hot water temperatures Stabilized in the storage tank and the difference became approximately equal until the time 07:50 am where was (5.9°C) and this due to there is no energy supplying to the load and there is no energy gained from solar radiation.

VII. CONCLUSIONS
The effect of energy supplying to the load on stratification phenomenon in the thermal storage tank of evacuated tubes solar collector during operating the system continuously with little energy gained from solar radiation in the morning, it was more than the effect of energy supplying to the load during operating the system sporadically by the control unit after reaching the hall temperature to the calibrating temperature with raise the solar radiation because of the supplied energy to the load higher than the energy gained in the continuously operating period and the supplied energy to the load approximately equal to the energy gained in the sporadically operating period while there is effect after stopping the energy supply to the load and Continuation the energy gained from the solar radiation till sunset because of there is energy gained in the collector without energy supply to the load and after that in the period from sunset to the morning of the because there is no energy supply to the load and there is no energy gain from solar radiation.

VIII. REFERENCES
[8] Kusyi O, Dalibard A. 2007” Different methods to model thermal stratification in storage tanks- Examples on uses of
Effect of Supplying Energy and Energy Gained Experimentally on the Stratification Phenomenon in the Thermal Storage Tank of The Evacuated Tubes Solar Collector

the methods” SolNET PhD Course, 10-17 October, Technical University of Denmark (DTU).


