Practical Investigation for Water Solar Thermal Storage System Enhancement Using Sensible and Latent Heats in Baghdad-Iraq Weathers

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Abstract: *Solar power is a clean and sustainable energy,but the intensity of solar irradiation is unstable due to the change of season, weather, day and night. The period of the sunshine does not coincide with the time of the hot water consumption generally. The hot water consumption in family houses is generally bigger in the evening and in the morning, so it is necessary to store the utilized energy. The collectors transform but not store the solar energy. The storage is accomplished in a storage tank. The heat storage system can be used as a buffer to mitigate the fluctuation of solar incidence.*

The present study summarizes the investigation of improving thermal energy storage extracted from solar heater and use for domestic purpose. Two *materials were used to improve heat storage inside the tank. Pebbles were used as a sensible store medium. The second material was paraffin wax which stores heat as latent heat. The two materials were stuffed in ten copper pipes (1 in dia). The storage energy of each material was compared to an ordinary conventional solar heater. The tests were conducted in Baghdad-Iraq wintertime (December-2012, January and February-2013).*

The two materials improved the storage efficiency of system and increased the hours of storage, butthe phase change materials (PCMs), as latent heat storage is more efficient than sensible heat storage. Paraffin wax provides many advantages, as it has high storage density and the isothermal nature of the storage process. It increases the time of storage and preserve water temperatures in case of no water drawl.

Key words:Thermal storage system, Phase change material, solar heating system, discharge process, mass flow rate, Latent heat storage system

1. Introduction

The development of alternative energies becomes now adays more important issue, due to the continuous increase in greenhouse gas emissions levels and the fossil fuels climbing prices [1].The main characteristics of new alternative energy that it must be clean, cheap, and sustainable. Solar energy can be considered as the most appropriate energy possesses these requirements [2]. Solar energy has a great prospect for buildings heating and cooling, heating water for domestic and industrial purposes, cooking, warming greenhouses for agricultural crops, etc [3 & 4]. However, solar energy is sporadic, fluctuant, and available only during the day. Hence, its applications require active thermal energy storage so that the overabundant heat collected during sunshine hours may be stored for later use during the night [5 & 6].

Solar energy needs a heat storage system to be used as a buffer to pacify the alteration of solar incidence. Hence some form of thermal energy storage is necessary for the most effective utilization of this energy source [7]. Most of the thermal energy storage systems in use rely on the specific heat or sensible heat of the storage material, such as water, oil and rock beds and they are known as sensible heat storage systems [8. The other concept is latent heat storage, which involves storing and recovering heat through the solid-liquid phase change process [9].

In case of sensible heat storage thermal energy is stored by raising the temperature of a solid or liquid. In this type of storage, the storage unit is charged and discharged by varying the temperature of a pebble bed in air-based systems or a water tank in waterbased systems. The amount of stored thermal energy depends on the specific heat of the medium, the temperature change and the amount of storage material [10]. Rocks or pebbles beds are used since decades for air heating, but due to poor heat exchange by conduction between each others, the stratification is maintained over reasonably long time intervals[11]. One limitation of stratified rock bed system is that it cannot be charged and discharged simultaneously[12]. Therefore a large load draw in the day time causes a drop in temperature of air outlet from solar collector[13].However, the stratified rock bed system is as effective as similar water storage for night time delivery to the load [14].

Latent Heat Storage system is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice-versa. Also through certain chemical reactions some energy can be saved [15]. The latent heat method of storage and their materials that have been studied during the last forty years have been reviewed recently by [16], these are usually hydrated salts, paraffin, non-paraffin,fatty acids and eutectics of organic and non-organic compounds [17].

Latent heat thermal energy storage systems using phase change materials (PCM) to store heating or cooling have many applications such as water heating, air conditioning and waste heat recovery system[18]. Regin et al. (2008)[19] present study of heat transfer characteristics of thermal energy storage system using PCM capsule. Such systems have the advantage of large surface to volume ratio of the packed beds and higher storage density for phase change materials compared to conventional bulk storage in tank heat exchangers and sensible heat storage systems.

Paraffin wax is the most commonly used commercial organic heat storage PCM [19 &20]. The normal paraffin of type C_nH_{2n+2} are a family of saturated hydrocarbons with very similar properties [21 & 22]. Increasing the number of C-atoms increases the melting point too. Paraffin between C5 and C15 are liquids, and the rest are waxy solids. Paraffin waxes are cheap and have moderate thermal energy storage density but low thermal conductivity and, hence, require large surface area [23]. These materials can store energy by the melting at a constant temperature. No material has all the optimal characteristics for a PCM, and the selection of a PCM for a given application requires careful consideration of the properties of various substances. Over 20,000 compounds and/or mixtures have been considered in PCM, including singlecomponent systems, congruent mixtures, eutectics and peritectics[24 & 25].

Paraffin waxes show no tendency to segregate. They are chemically stable; they did not show regular degradation in thermal properties after repeated melting / freezing cycles [26 &27]. Paraffin waxes show high heats of fusion. They also have no tendencies to super cool, so nucleating agents are not necessary. Paraffin waxes are safe and non-reactive[28 & 29]. They are compatible with all metal containers and easily incorporated into heat storage systems. Care should be taken when using plastic containers as paraffin have a tendency to infiltrate and soften some plastics [30 & 31].

In the same time paraffin have drawbacks. Paraffin has low thermal conductivity in their solid state; this presents a problem when high heat transfer rates are required during the freezing cycle [32]. Paraffin has a high volume change between the solid and liquid stages. This causes many problems in container design also paraffin greatly decrease heat storage capacity. Paraffin is flammable, but this can be easily alleviated by a proper container [33].

This work represents a small contribution to the ongoing research in Machines and Equipment Engineering Department, UOT, aiming to develop effective ways of utilizing thermal energy, solar heat in particular, thereby replacing the consumption of high quality resources for low quality purposes [34, 35 & 36]. The objective of the present study was to investigate the feasibility of introducing thesensible and latent heat storage system directly to a thermal storage tank developed by General Company of Electrical Manufactures, with no forced flows or other additional means. Of particular interest was to determine and compare energy storage capacity and also if charge/discharge rates were compatible with solar collection- and energy utilization rates.

2. Experimental Setup

The study focused on the use of solar heat as an inherently low quality source for covering low quality demands associated with hot water. The different stages of solar energy production, storage, and distribution of heat are discussed. A photo of the experimental set-up is shown in Fig. 1. Present tests were conducted on asollar collector and storage tank which were produced by the General Company of Electrical Manufactures. A 20 copper pipe (2 in dia.) were used as an absorber insidethe solar collector. The company storage tank was used; this tank is an isolated tank has a capacity of 120 liters (450 mm diameter and 1500 mm length) to supply hot water for a family of 5 to 6 persons. It was connected to the collector from below, and the hotwater was withdrawn from upper outlet cock. The copper pipes between the collector and water drum were insulated by foam to avoid heat losses to atmosphere. A very common figure in solar collector system is to lose between 5% and 10% to the ambient through walls of the storage unit, even for very well insulated storage tank. Losses were reduced to a minimum. Glass wool insulation was used for this purpose. It was important to minimize the heat loss by avoiding thermal bridges in the upper (hot) part of the tank. It is important to secure a high degree of thermal stratification, that is, with the top of the tank hotter than the bottom. A high degree of thermal stratification increases the thermal performance of the solar hot water system. Density of water depends on the temperature and it is possible to create density driven stratification with water as heat storage medium.

Copper pipes were used to store pebbles and PCM material. The diameter of copper pipes is 2.54 cm with a wall thickness of 0.8 mm. The total number of pipes in the thermal energy storage tank is 10. The pipes are uniformly packed in three layers, the lower one has 5 pipes, the medium one has 3 pipes and the higher one has 2 pipes. Fig. 2 illustrates the pipes distribution and locations, while Fig. 3 shows the paraffin wax pipes before it were blocked.

Due to the need high temperature difference between the inner and stored water, two aluminumsheets were used as reflectors to focus the dispersedsolar rays on the collector face. It was fixed on collector both sides with 70o from the collector face. These sheets were manufactured from wood panels and covered by aluminum foils from one side and glass wool of 50 mm thick from the other. It was used as a cover to the collector to reduce the night heat losses from the exposed surface at night.

Fig. 1, a photo of experimental setup

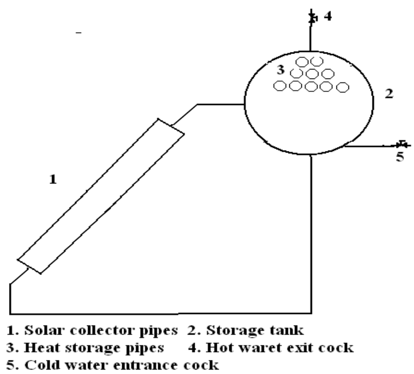

Fig. 2, Schematic diagram of pipes distribution and locations inside the collector

Fig. 3, photo of the paraffin wax pipes

Method of selectionpebbles

The samples of pebbles were first dried by exposing it to sun for several days. Its thermal properties were measured to remove any moisture in the samples. The dried pebbles of diameters less than 0.6 cm were then stuffed inthe copper tubes of 1.0 in diameter and 1.5 m length. The apparent density of the dried sample can be determined by calculating the difference between the weight of the full and empty container then dividing this difference by the container volume.

Method of selection of PCM

In order to select the best qualified PCM as a storage media some criteria were considered according to thermal properties:

- The melting point of the PCM must be lying in a practical range of operation. Temperature intervalgoing from 25 °C to 70 °C.
- The latent heat should be as high as possible to minimize the physical size of the heat storage.
- A high thermal conductivity would assist the charging and discharging of the energy storage.

According to chemical properties, a suitable Iraqi paraffin wax was used. Due to its physical properties, it has limited changes in density to avoid problems with the storage tank, low vapor pressure, and favorable phase equilibrium. Moreover paraffin wax is available in large quantities and cheap in order to make the system economically feasible.The paraffin is used as PCM that has a melting temperature of 45 ± 1^{o}C and latent heat of fusion of 217kJ/kg.

Experiment trial

During the morning hours the water is circulated through the thermal energy storage tank and the solar collector unit continuously by natural convection. The water absorbs solar energy sensibly, and exchanges this heat with thepebble and paraffin in the copper pipes inside storage tank, which is initially at feed water temperature.

The discharging process used was by withdrawn a certain quantity of hot water (20 liters) from the thermal energy storage tank, divided in intervals of 2 liter/ 10 min. The tank was refilled with new cold water to maintain a constant amount of water in tank. This is then repeated for intervals of 1hour, in which time transfer of energy from the pebbles and PCM would have occurred. This procedure is continued till PCM reaches a temperature of entering water.

The tests were conducted in Baghdad-Iraqi wintertime weathers, In December-2012, January and February-2013. Every case was tested one a week in a shiny day to insure the measurement repeatability, and the average temperature was used in the study.

Efficiency Calculation

The efficiency of the collector with an alternative working fluid was calculated using the heat gained by water with respect to the actual solar energy received by the collector (Eqn. 1).

Overall efficiency of the system,

$\eta = Q_w/Q_I$ (heat gained by water /input solar energy) (1)

Heat gained by the water

$$Q_w = m\,cp\Delta T \quad (2)$$

Input solar energy (solar energy falling on the collector)

$$Q_I = qAT \quad (3)$$

Where

m = weight of water (gram)

cp= specific heat of water (joule/gram ^oC)

ΔT = temperature difference (outlet temperature-inlet temperature, ^oC)

q = solar intensity (joule/ hour. m^2), it was taken from Iraqi meteorology organization

A = area of the collector (m^2)

T = time (hour)

Experimental errors and uncertainties

The difference between measured and true values of quantity is known as an error. By assigning a value of that error, an uncertainty is defined. The uncertainties in each individual measurement lead to uncertainties in experiment [37]. In general, the uncertainty in the results is:

$$e_R = \left[\left(\frac{\partial R}{\partial V_1} e_1\right)^2 + \left(\frac{\partial R}{\partial V_2} e_2\right)^2 + \cdots + \left(\frac{\partial R}{\partial V_n} e_n\right)^2\right]^{0.5} \quad (4)$$

Where:

e_R : Uncertainty in the results

R : a given function of the independent variables $V_1, V_2, \ldots, V_n$ or $R=R(V_1, V_2, \ldots, V_n)$.

ei : uncertainty interval in the nth variable.

The partial derivative $\frac{\partial R}{\partial V_1}$ is a measure of the sensitvity of the result to a single variable.

The summarized analysis of the experimental accuracy of the measuring properties for some selected measuring devices is shown in table (3). From these values the experiments uncertainties can be calculated:

$$e_R = [(0.5)^2 + (1)^2 + (0.05)^2]^{0.5} = \mp 0.502$$

3. Results and Discussions

Solar domestic hot water systems are currently widely used due to its simplicity, easily maintained, and relatively inexpensive. This type of thermal energy storage eliminates the temperature drop between transport fluid and storage medium. These systems performance is dependent on local climatic conditions, such as solar radiation and ambient temperature.

The temperature histories for the three systems for Baghdad winter weather 2012-2013 are represented in **Figures 4, 5&6**. Water is heated in solar collector and its temperature is increased till it reached its maximum value around 1 PM then it start to decline especially after 4PM. During this time, the phase change material undergoes an isothermal phase transformation at 45±1°C. At this time the water temperature increased by up to 7°C, reaching a maximum of about 60°C.

If heated water is assumed to mean water with temperature higher than feeding water with about 20^oC, then the activity of water system stopped about 5PM for the three tested months. While for water and pebble system it stopped at 6PM for the tested period. In other hand water and PCM system activity stopped about 7PM, 8PM and 9PM for Dec., Jan. and Feb. respectively. These results decline that the stored energy in PCM materials is better than for other systems. Pebbles system introduces an insignificant improvement may be because it need more mass to achieve significant amelioration.

The paraffin slowly gets heated, sensibly at first, until it reaches its melting point temperature. During the melting process there are three stages namely; solid heating, phase change and liquid heating as mentioned by [38]. The paraffin wax used in this experiment is characterized by its melting starts at a temperature of 45^oC and is completed at 45.3^oC. As the charging proceeds, energy storage as latent heat is achieved as the paraffin wax melts at constant temperature (45±1°C). After complete melting is achieved, further heat addition from the water causes the PCM to superheat, thereby again storing heat sensibly. The charging process continues till the PCM and the water attain thermal equilibrium at about 2 PM. The PCM is charged through the day, whenever hot water is not demanded by the user.

Figures 7, 8&9 show the stored energy distribution around day hours. The stored energy increased as the day time proceeds till noon hours (1 PM). Due to continuous withdrawing from the system, the stored energy declined rapidly after 2 PM. The pebble and PCM systems preserved their energies for longer time. For pebbles system the stored energy persisted until 7 PM. PCM system preserved energy until 10 PM.

Energy storage is usually in the form of sensible energy of a fluid or solid medium, or in the energy associated with the phase change of a material. In general, sensible energy storage is characterized by low cost and the availability of the storage medium. Water is not a latent heat medium for the operating temperature range; it is common to use it for solar heat storage application. For this reason, water was used as the baseline and compares the results with pebbles and PCM. The water exchanges its energy to pebbles and paraffin wax in tubes and at the beginning of the charging process.Pebbles stored this temperature as sensibleheat and this why it kept about 2 to 3^{o}C less than water to preserved heat transfer from water to it. The temperature of the paraffinwas raised until it reached 45^{o}C (its melting point). Initially the energy is stored inside the wax as sensible heat until it reached its melting temperature. As the charging process proceeds, energy storage is achieved by melting the PCM at a constant temperature. Finally, the PCM becomes superheated. The energy is then stored as sensible heat in liquid PCM.

System efficiency is defined as the amount of energy stored in the storage tank and the heat energy available from the solar radiation. Systems efficiencies behaved as temperature and stored energy as **Figures 10, 11&12** illustrate. Water system efficiency preceded other system at first day hours until 1 PM, then it declined and retarded from the other for the evening hours. PCM material delayed from water and pebbles systems in the first hours, due to its need for the stored energy to changeits phase. At afternoon the

PCM efficiency exceeded the other system, due to phase change benefits.

As the time preceded the system efficiency decreased during sensible heating of pebbles and solid PCM and it remains nearly constant during phase change period for PCM. The decreasing efficiency can be accredited to decreasing temperature differences between PCM and water during charging, which lowers the amount of heat transferred to the wax. This decreases the amount of heat transferred to the storage tank and thus the energy stored decreased with the time moving forword. Also the increase in water temperature at the inlet of solar collector decreases the heat absorption rate from the collector.

4. Conclusions

The main conclusions are:

1. Hot water (temperature 15–20 °C > feed water temperature) can remain throughout the day and night, and the fluctuations in water temperature decrease.
2. Commercial phase change materials are available around the temperatures of interest, as paraffin wax used in this study. Their cost is achievable, but their long term performance not sufficiently tested.
3. Although interesting possibilities of innovation exists by using this kind of storage, further research is needed for the design of the storage system and heat exchanger, which are tasks probably out of the scope of this study.
4. It is important to select the PCM on the basis of its melting temperature, rather than its latent heat, because the melting temperature has a significant effect on system performance.
5. There are many factors which affect system performance such as:
    i. the average temperature of the storage unit,

ii. the fraction of time that the storage unit is charged (collector to storemode),
iii. the fraction of time that the storage unit is discharged (store to load mode),
iv. the fraction of time that the storage unit is isolated (collector to load mode),

These factors depend primarily on the amount of incident solar energy relative to the heating load.

6. The advantages of using PCMs as storage medium over the conventional methods (i.e. sensible storage) are:

a. significantly reduced storage mass,
b. high storage efficiency,
c. Reducedwater temperature fluctuations because the energy exchanged in phase-change materials takes place at approximately constant temperature.

References

[1] Chen Z, Gu M, Peng D, ***"Heat transfer performance analysis of a solar flat-plate collector with an integrated metal foam porous structure filled with paraffin"***, Applied Thermal Engineering, vol. 30, pp: 1967-1973, 2010.

[2] Tseng C J, Kao T Y, Chen C F, ***"Study on the flow and thermal characteristics of a heat storage system"***, The Asian Symposium on Computational Heat Transfer and Fluid Flow, Kyoto, Japan, 2011.

[3] Dhifaoui B, Jabrallah S B, Belghith A and Corriou J P, ***"Experimental study of the dynamic behavior of a porous medium submitted to a wall heat flux in view of thermal energy storage by sensible heat"***, International Journal of Thermal Sciences, vol. 46, pp: 1056-1063, 2007.

[4] Kenisarin M and Mahkamov K, ***"Solar energy storage using phase change material"***, Renewable and Sustainable Energy Reviews, vol. 11, pp: 1913-1965, 2007.

[5] Sözen A, Menlik T, Ünvar S, ***"Determination of efficiency of flat-plate solar collectors using neural network approach"***, Expert Systems with Applications, vol. 35, No. 4, pp: 1533-1539, 2007.

[6] Varol Y and Oztop H F, ***"A comparative numerical study on natural convection in inclined wavy and flat-plate solar collectors"***, Building and Environment, vol. 43, No. 9, pp: 1535-1544, 2008.

[7] Chen Z, Gu M, Peng D, Peng C and Wu Z, ***"A numerical study on heat transfer of high efficient solar flat plate collectors with energy storage"***, International Journal of Green Energy, vol. 7, pp: 326–336, 2010.

[8] Shukla A, ***"Heat transfer studies on phase change materials and their utilization in solar water heaters"***, PhD thesis, School of Energy and Environmental Studies, Devi Ahilya University, Indore, India, 2006.

[9] Jegadheeswaran S &Pohekar S D, ***"Energy and exergy analysis of particle dispersed latent heat storage system"***, International Journal of Energy and Environment (IJEE), vol. 1, pp: 445-458, 2010.

[10] Zhang D &et. al., ***"Development of thermal energy storage, Concrete Cement and Concrete Research"***, vol. 34, pp: 927-934, 2004.

[11] Khalkhali1 A, Sadafi M H, Rezapour J, Safikhani1 H, ***"Pareto based multi-objective optimization of solar thermal energy storage using Genetic algorithms"***, Transactions of the Canadian Society for Mechanical Engineering, vol. 34, No. 3–4, 2010.

[12] Safikhani H, Akhavan-Behabadi M A, Nariman-Zadeh N and Mahmoodabadi M J, ***"Modeling and multi-objective optimization of square cyclones using CFD and neural

networks”, Chemical Engineering Research and Design, vol. 89, No. 3, 2011.

[13] Kalogirou S A, ***“Solar thermal collectors and applications”***, Progress in Energy and Combustion Science, vol. 30, No. 3, pp: 231-295, 2004.

[14] Velraj R, Nallusamy N, ***“Experimental investigation on combined sensible and latent heat storage un it integrated with solar water heating system”***, Renewable Energy Journal, vol. 34, No. 7, pp: 1206-1227, 2007.

[15] Kanimozhi B, Ramesh B R and Sivashanmugam M, **“Enhancement of solar thermal storage system using PCM”**, National Journal on Advances in Building Sciences and Mechanics, vol. 1, No.2, 2010.

[16] Farid M, Khudhair A M, Razack S A and Al-Hakkaj S, ***“A review on phase change energy storage: materials”***, Energy Conversion and Management, vol. 45, pp: 1597- 1612, 2004.

[17] Mahmud A, Sopian K, Alghoul M A and Sohif M, **“Using paraffin wax-aluminum compound as a thermal storage material in solar air heaters”**, ARPN Journal of Engineering and Applied Sciences, vol. 4, No. 10, 2009.

[18] Abdel-Rehim Z S and Lashine A, ***“Packed bed-PCM material latent heat thermal energy storage system”***, ESRJ-Faculty of Engineering at Shoubra, 2011.

[19] Regin F A, Solanki S C and Saini J S, ***“Heat transfer characteristics of thermal energy storage system using PCM capsule: a review”***, Renewable and Sustainable Energy Reviews, vol. 12, pp: 2438–2458, 2008.

[20] Dharuman C, Arakeri J H and Srinivasan K, ***“Performance evaluation of an integrated solar water heater as an option for building energy conservation”***, Energy and Buildings, vol. 38, pp: 214–219, 2006.

[21] Lovász A; Bajnóczy G; Gagyi-Pálffy E and Prépostffy E, ***“Domestic hot water pre-heater utilizing solar***

energy",PeriodicaPolytechnica Chem. Eng., vol. 50, No.1, pp: 45-53. 2006.

[22] Sharma S D &Sagara K, ***"Latent heat storage materials and systems: a review"***,International Journal of Green Energy, vol. 2, pp: 1–56, 2005.

[23] Demirbas M F, ***"Thermal energy storage and phase change materials: An overview"***, Energy Sources, Part B: Economics, Planning and Policy, vol. 1, No. 1, pp: 85-95, 2006.

[24] Szabó I P, ***"Design of an experimental PCM solar tank"***, ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering, vol. 8, No. 1, pp: 134-146, 2010.

[25] Mazman M, Cabeza L F, Mehling H, Nogues M, Evliya H and Paksoy H Q: ***"Utilization of phase change materials in solar domestic hot water systems"***, Renewable Energy, vol. 34, pp: 1639–1643, 2009.

[26] Sweet M L, ***"Numerical simulation of underground seasonal solar thermal energy storage"***, MSc thesis, Virginia Commonwealth University Richmond, Virginia, USA, 2010.

[27] Vega E E, ***"Seasonal Heat Storage Phase Change Materials"***, M Sc thesis, DTU DanmarksTekniske University, 2011.

[28] Regin A F, Solanki S C and Saini J S, ***"Solidification of phase change materials inside a cylindrical capsule"***, In: Proceedings of ASME–ISHMT heat and mass transfer conference, IIT Guwahati, India; 2006.

[29] Sharma A, Tyagi V V, Chen C R and Buddhi D, ***"Review on thermal energy storage with phase change materials and applications"***, Renewable and sustainable Energy Reviews, vol.13, pp: 318- 45, 2009.

[30] Seeniraj R V, Velraj R and Lakshmi N N, ***"Heat transfer enhancement study of a LHTS unit containing high***

conductivity particles", J. Sol. Energy Eng., vol. 124, pp: 243-249, 2008.

[31] Benli H &Durmus A, ***"Performance analysis of a latent heat storage system with phase change material for new designed solar collectors in greenhouse heating"***, Sol Energy, vol. 83, pp: 2109–2119, 2009.

[32] Alkilani M M,Sopian K, Alghoul M A, Sohif M, Ruslan M H, ***"Review of solar air collectors with thermal storage units"***, Renewable and Sustainable Energy Reviews, vol. 15, pp: 1476–1490, 2011.

[33] Zhong Y, Li S, Wei X, Liu Z, Guo Q, Shi J and Liu L, ***"Heat transfer enhancement of paraffin wax using compressed expanded natural graphite for thermal energy storage"***, CARBON, vol. 48, pp: 300–304, 2010.

[34] Chaichan M T, ***"Practical study of basement kind effect on solar chimney air temperature in Baghdad-Iraq weather"***,Al Khwarizmi Eng. Journal, vol. 7, No. 1, pp: 30-38, 2011.

[35] Chaichan M T &AbaasKh I, ***"Practical investigation for improving concentrating solar power stations efficiency in Iraqi weathers"***, Anbar J for Engineering Science, vol.5, No. 1, pp: 76-87, 2012.

[37] Ahmed S T & Chaichan M T, ***"A study of free convection in a solar chimney sample"***, Engineering and Technology J, vol. 29, No. 14, pp: 2986-2997, 2011.

[37] ASHREA GIUDE LINE,***"Guide engineering analysis of experimental data"***, Guideline 2-1986.

[38] Godarzi A A, Samimi J, Jalilian M and Vesaghi M A,***"Numerical analysis of the thermal behavior of a rectangular storage system using phase change material"***, American Solar Energy Society, SOLAR 2010 Conference Proceedings, 2010.

Experimental Accuracies

Measurements	Accuracies in this study
Temperatures measurement	0.5
Water flow measurement	1
Time measurement	0.05

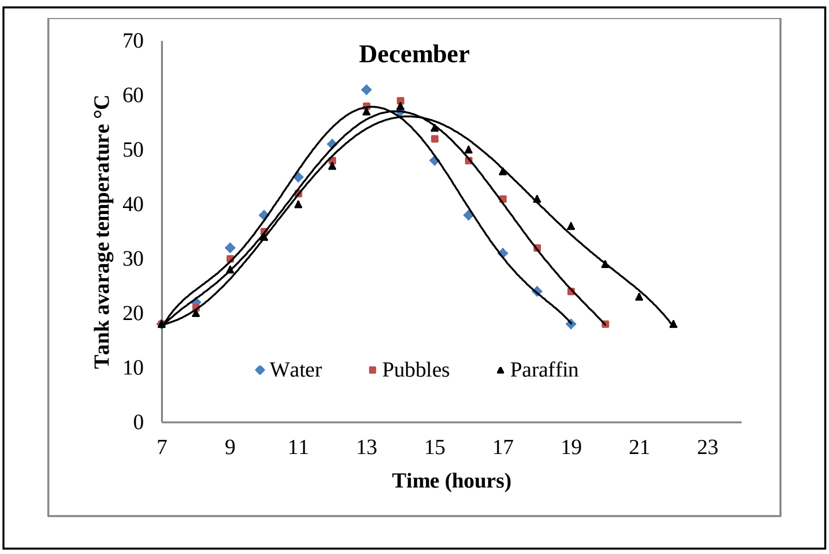

Fig. 4, time average temperatures distribution for the day hours in December

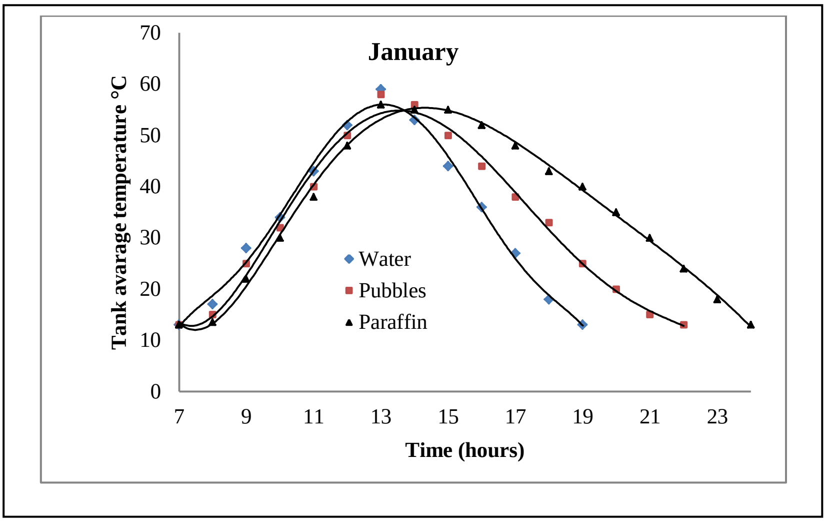

Fig. 5, time average temperatures distribution for the day hours in January

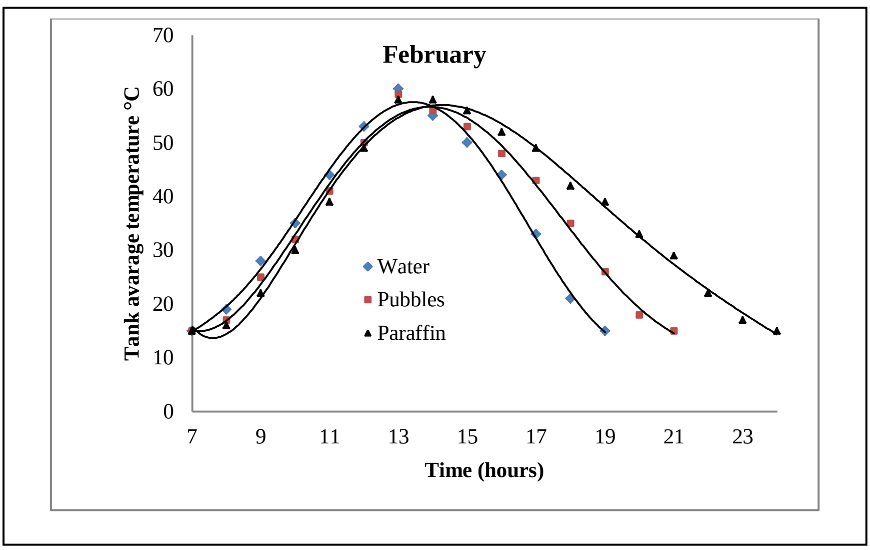

Fig. 6, time average temperature distribution for the day hours in February

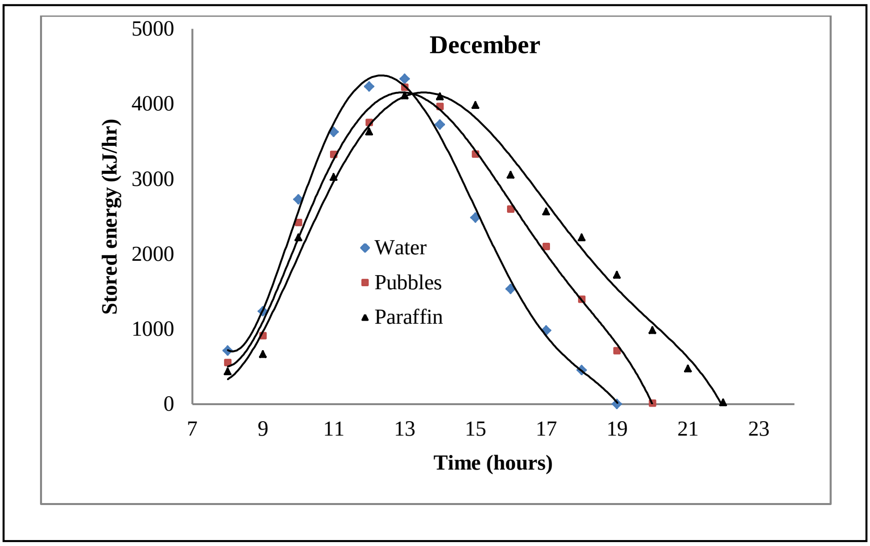

Fig. 7, stored energy distribution for the day hours in December

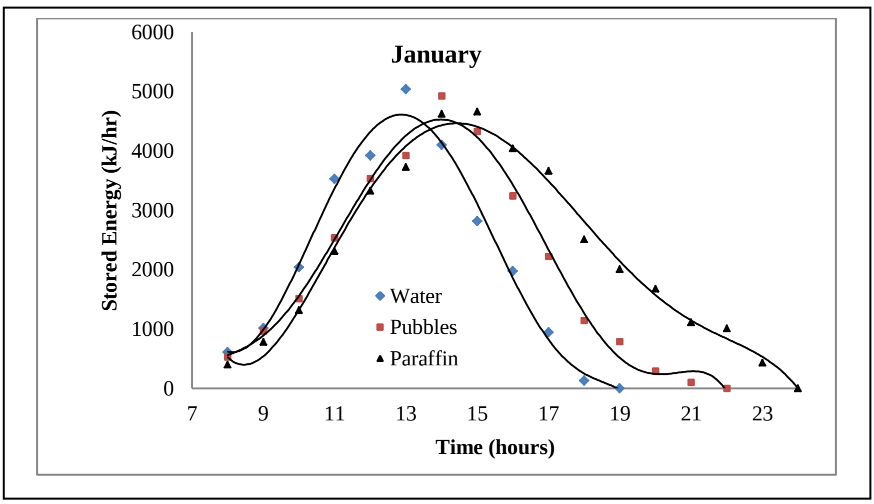

Fig. 8, stored energy distribution for the day hours in January

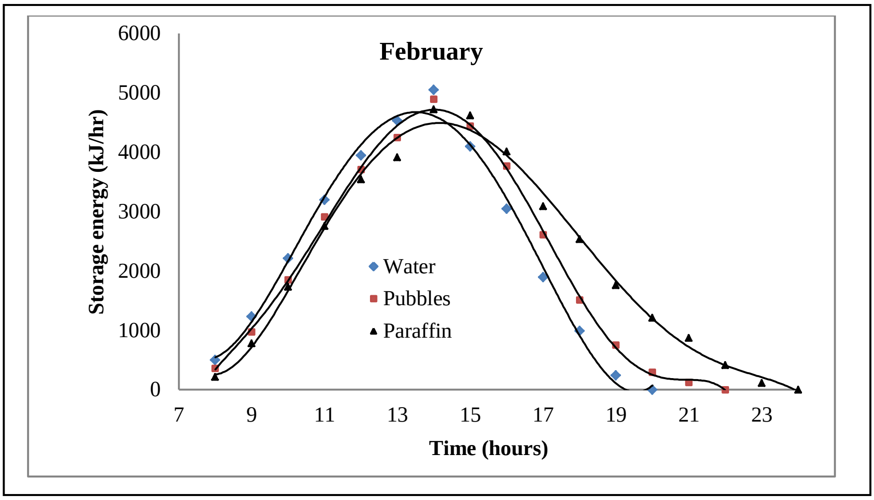

Fig. 9, stored energy distribution for the day hours in February

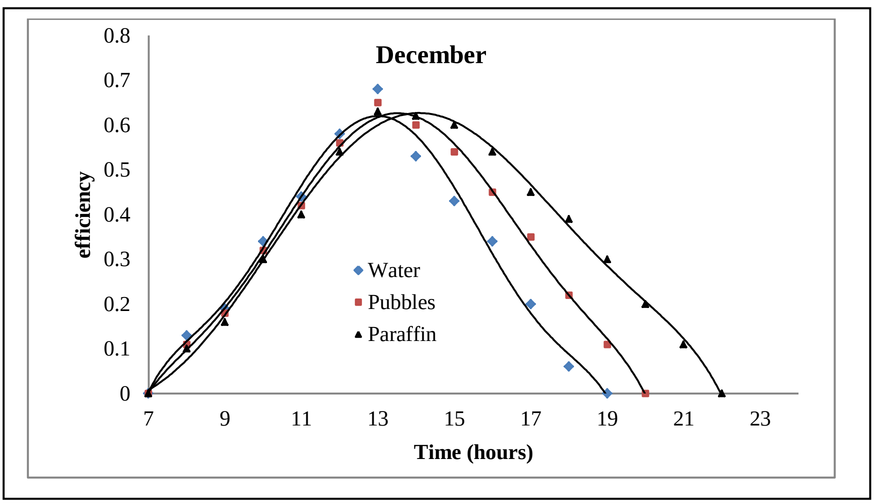

Fig. 10, system efficiency distribution for the day hours in December

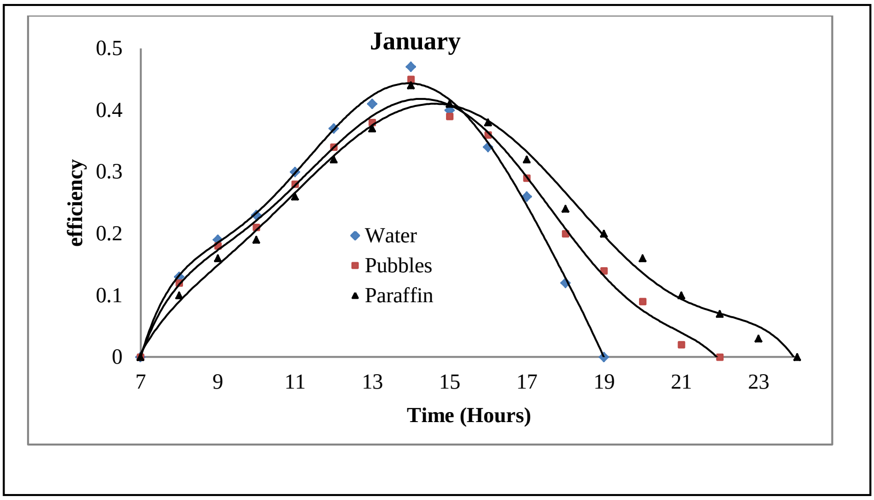

Fig. 11, system efficiency distribution for the day hours in January

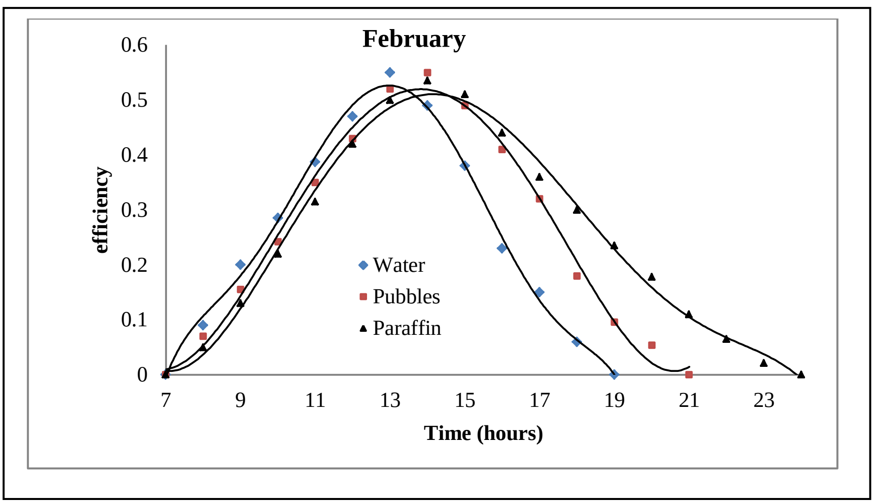

Fig. 12, system efficiency distribution for the day hours in February

دراسة عملية لتحسين نظام خزن تسخين ماء شمسي باستخدام الحرارة المحسوسة والكامنه في أجواء بغداد-العراق

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المستخلص:

تعتبر الطاقة الشمسية طاقة نظيفة ومتجددة، ولكن شدة الأشعاع الضوئي غير مستقرة بسبب تغير الفصول والطقس و النهار والليل. ولا تتوائم فترة ضياء الشمس مع زمن استهلاك الماء عادة، فاستهلاك الماء الساخن في المنازل العائلية يكون أكبر في المساء وفي الصباح بشكل عام، لذا من المهم خزن الطاقة المستخدمة. تقوم المجمعات الشمسية بنقل الطاقة الشمسية ولكن لا تخزنها، ويتم الخزن في الخزان، ونظام خزن الحرارة يمكن استخدامه كمخمد يسكن التذبذب في الأشعاع الشمسي الساقط.

تلخص الدراسة الحالية البحث عن تطوير الطاقة الحرارية المختزنة المستخلصة من سخان شمسي وتستخدم لاغراض منزلية. إذ تم استخدام مادتين لتطوير الخزن الحراري داخل الخزان، وتم استخدام الحصى كوسط خازن للحرارة المحسوسة، والمادة الثانية هي شمع بارافيني وتقوم بخزن الحرارة كحرارة كامنة. وتم حشو المادتين في عشرة أنابيب نحاسية بقطر 1 إنج. والطاقة المخزونة لكل نظام تم مقارنتها مع سخان شمسي تجاري اعتيادي. وأجريت التجارب في شتاء عام 2012-2013 في مدينة بغداد-العراق.

حسنت المادتين من كفاءة الخزن وزادت ساعات الخزن، ولكن مادة تغيير الطور كخازن كامن للحرارة هي أكثر كفاءة من خزن الحرارة المحسوس. وأعطي

الشمع البارافيني عدة فوائد، إذ يمتلك كثافة خزن عالية اضافة الى عملية خزن الحرارة بثبات درجة الحرارة، وهي تزيد زمن الخزن وتحافظ على درجات حرارة الماء في حالة عدم سحب الماء.