Comparison of Properties of Various Heat Storage Fluids used with Evacuated Tube of Solar Water Heater

Salah S. Abd Aed I. Owid* Emad J. Mahdi* Amer A. Salamn**

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Abstract:
The aim of this work was to capture solar radiation and convert it into solar thermal energy by using a storage material and the heat transfer fluid like oil and water and comparison between them, we used the evacuated tube as a receiver for solar radiation, The results showed that the oil better than water as storage material and the heat transfer fluid and the effective thermal conductivity material and good for power level, rates and durations of charge and discharge cycles.

Key words: capture solar radiation, heat transfer fluid, thermal conductivity, heat storage material

Introduction:
In the last two decades, Concentrating Solar Power (CSP) technology has successfully demonstrated its capability of converting solar radiation into high-temperature heat. The produced power is the cleanest and most efficient form of renewable, solar energy has the greatest potential of all the sources of renewable energy especially when other sources in the country have depleted. There are so many methods introduced to increase the efficiency of the solar water heater .The storage system can be classified directed storage of the primary working fluid single phase fluid (thermal oil, pressurized water), indirect storage thermal energy transferred to separate storage medium sensible heat storage medium (solid or liquid) phase change material[1,2]

However, due to the high intermittency of solar radiation reaching the surface of the Earth, the CSP technology has a limited capability of replacing fossil fuels for power production. Natural phenomena, such as unstable weather conditions, variations of the elevation and azimuth angle of the sun through the cycle of the day, and also the year, and the necessity to pause the solar plant operation in nighttime have a strong negative impact on the availability of solar energy for utility-scale power generation. Thus, an average daily operating time of a CSP system throughout a year is approximately 6 hours only, while load demand from the utility grid normally continues 24 hours a day. [2,3,4]

For this purpose, the size of a CSP system must be increased by a factor called as solar multiple to allow operating of the power block simultaneously with charging the thermal storage on daylight hours when the insulation level is sufficiently high, this makes possible continuous heat water production at full load during the day by direct input of solar energy to the power block combined with utilizing the storage when the solar radiation is low or not available, including some hours after sunset. [2,3,4]

*Ministry Of Sciences & Technology

In general, solar thermal energy storage (STES), as the factor increasing solar capacity of a power plant while improving its operating performance, has the potential to bring down the levelized cost of solar energy, which is still higher than most of fossil fuels. It is clear that a long-term (tens of hours and more) storage can be very expensive due to large capital investments in both the storage and the CSP system, taking into account a large solar multiple.

A feature characteristic of CSP storage systems is that they are widely diverse with respect to thermal storage technology, based on either sensible, latent or thermo-chemical heat. Different storage materials and heat transfer fluids are available for charging and discharging the storage the variety of operation parameters includes temperature, power level, rates and durations of charge and discharge cycles [2,3,4]

One of the important characteristics of a storage system is the length of time during which energy can be kept stored with acceptable losses. If solar energy is converted into a fuel such as hydrogen, there will be no such a time limit. Storage in the form of thermal energy may last for very short times because of losses by radiation, convection and conduction. Another important characteristic of a storage system is its volumetric energy capacity, or the amount of energy stored per unit volume. The storage system inversely proportional with the volume, i.e., the smaller volume leads to better storage system. Therefore, a good system should have a long storage time and a small volume per unit of storage energy.

A variety of new techniques of thermal energy storage has become possible in the past. A major application for thermal storage today is in family dwellings. Heat storage at power plants typically is in the form of steam or hot water and is usually for a short time. Recently other materials such as oil having very high boiling point have been suggested as heat storage substances. Other materials that have a high heat of fusion at high temperatures have also been suggested for this application. Another application of thermal energy storage on the electric utilities is to provide hot water. [1,3,4,5]

Perhaps the most promising application of thermal energy storage is for solar heated structures, and almost any material can be used for thermal energy storage.

The first-law efficiency of thermal energy storage systems can be defined as the ratio of the energy extracted from the storage to the energy stored into it

$$\eta=\frac{m_C(T-T_0)}{m_C\,(T_\infty-T_0)}$$

Where m_C is the total heat capacity of the storage medium and T , T_0 are the maximum and minimum temperatures of the storage during discharging respectively, and T_∞ , is the maximum temperature at the end of the charging period. Heat losses to environment between the end of discharging and the beginning of the charging periods, as well as during these processes are neglected. The first law efficiency can have only values less than one.[1,2,6,7]

Materials and Methods:

An experimental setup was used at three evacuated tubes fixed at 45 $^{\circ}$ tilt angle as receivers, to capture the solar radiation. These evacuated tubes filled with three different types of materials (oil , Distilled water, Drinking water) as heat transfer fluids, and there properties shown in tables (1) and (2). During the test of each receiver (three of evacuated tubes), which are shown in Figure (1) , several temperatures of them were measured using K-type thermocouples placed at the top points of the their locations. The temperature of all the receivers recorded with time by thermometer with data logger (Temperature Recorder), solar radiation (in w/m^2) also measured with time by solar power meter.

Table (1) show properties of oil

Properties	Quantity
Type of oil	150 H.V.I
Density at 15.6 c^o	0.904 g/ ml
Acid No.	0.3800 mg/gm
Viscosity at 100 c^o	29.97
P.pt	-3 c^o

Table (1) show properties of water

Symbol water	EC conductivity	PH	TEC
Distilled water	61μS	7.45	17.5PPμ
Drinking water	1081 μS	5.3	537 PPμ

Fig (1) The set up of experiment.

Results and Discussion:

The obtained result from all three receivers showed the variation of temperatures with time. From the experimental performance of these receivers which have been compared as shown in Fig (2), and the temperatures which measured upon the receivers and inside them with same solar radiation which shown in Fig (3), it has been found that the increase of temperature of oil is the highest, and low energy needed to increase the oil temperature because of the specific heat capacity of the oil is lowest than the specific heat capacity of water, and the temperatures of water measured upon the receivers and inside them are very close to each other, when compared between the three receivers for three materials which are different in its thermal conductivity. From Fig (2) , we observe that the decreasing of the temperature of the oil is faster than for the water , and because of the oil gains heat faster than the water and does not need much energy like water , also it losses heat quicker than water . The maximum value of the oil temperature reached at 4:40 pm, than begin to decrease because of the decreasing of solar radiation intensity . Form Fig (3) , which shows the relationship between solar radiation and time , we notice that , there is sudden decreasing in the curve at 11:40 am ,1:20 pm ,2:00 pm ,and 2:20 pm because of same pieces of clouds which caused decreasing of solar radiation intensity .

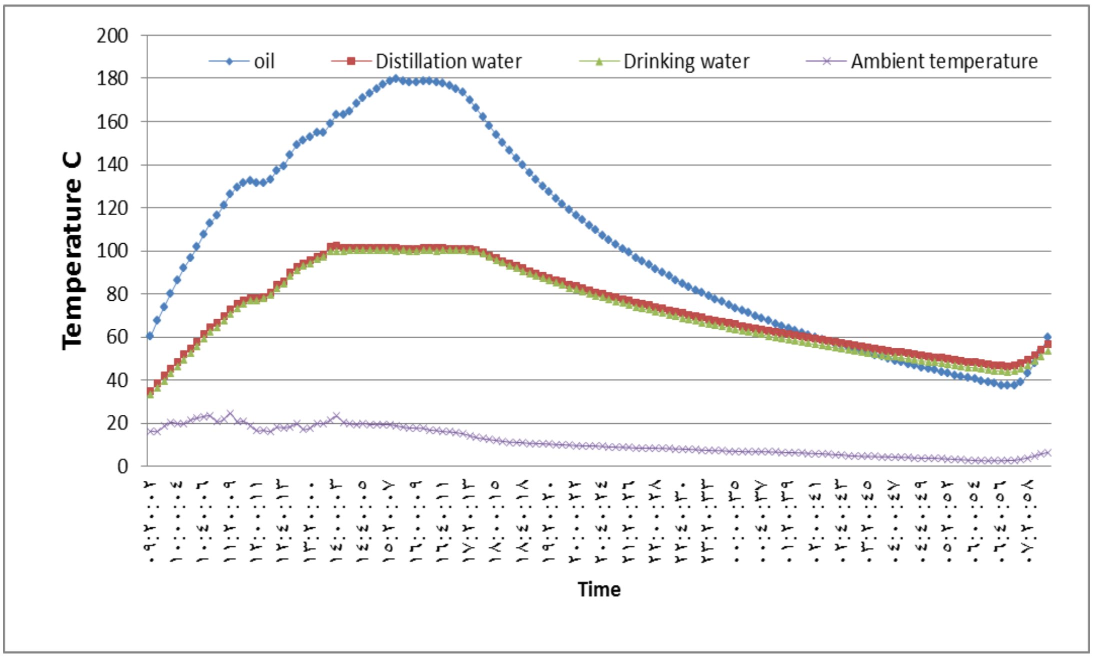

Fig (2)The comparison between temperatures of three receivers tubes and ambient temperature with time.

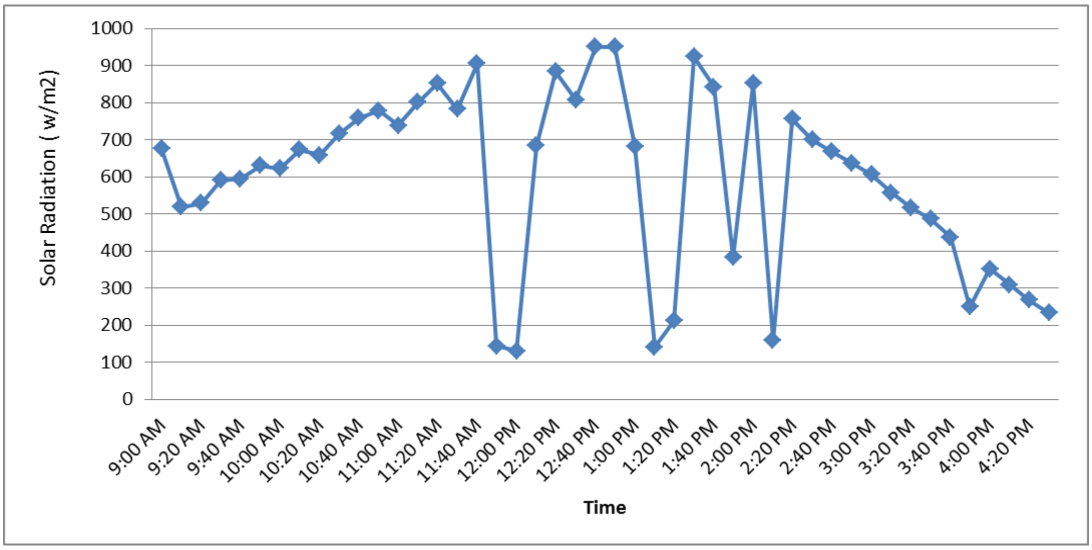

Fig (3) The Solar Radiation with time.

Conclusions:

The results indicate receiver temperatures, the oil receiver is a better as use oil as a heat transfer fluid than water receivers inserted into the two receivers are nearly equal.

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مقارنة خواص موائع الخزن الحراري المختلفة المستخدمة مع الأنبوب المفرغ للسخانات الشمسية

صلاح صبحي عبد* عايد ابراهيم عويد* عماد جليل مهدي*
عامر عبد الله سلمان*

*وزارة العلوم والتكنولوجيا

الخلاصة:
الهدف من هذا العمل هو اقتناص الاشعاع الشمسي وتحويله الى قدرة حرارية بواسطة استخدام مواد خازنة وموائع ناقلة للحرارة مثل الزيت او الماء ,والمقارنة بينهما ، واستخدمنا الانبوب المفرغ كمستقبل للاشعاع الشمسي .وتم الوصول الى نتائج بان الزيت افضل من الماء كمادة خازنة وكمائع ناقل للحرارة و مادة ذات توصيلية حرارية فعالة وجيدة لمعدلات مستوى القدرة والفترة الزمنية لدورات الشحن و التفريغ.