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Experimental Study of a Solar Water Heater for the Effect of Solar Radiation and Mass Flow Rates

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ABSTRACT

Thermal applications and power generation from solar radiation are emerging rapidly as the world continues to thrive for future energy sources, other than conventional sources. The solar thermal collector is one of the basic needs to convert the sun's energy to usable forms. Broadly, these collectors are divided into two groups, non-concentrating solar thermal collectors and concentrating solar thermal collectors. This report aims to review the 'Solar Flat Plate Thermal Collector' which falls under the non-concentrating thermal collectors.

The Experimental measurements indicate that the solarimeter heated the water in the tank to be absorbed by the solar collector. Moreover, the water temperature measurements at different points. Results indicate that the design of the thermosiphon solar water heating system was a success. Furthermore, the experimental apparatus described in this paper is a valuable addition to the laboratory**.**

Keywords: Efficiency. - Mass Flow Rates. -Outlet Temperature. - Solar Radiation. - Solar Water Heater.

دراسة عملية لسخان الماء الشمسي لتأثير الإشعاع الشمسي ومعدلات التدفق الكتلي

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الملخص

تتباين التطبيقات الحرارية وتوليد الطاقة من الإشعاع الشمسي بسرعة مع استمرار العالم في الازدهار لمصادر الطاقة المستقبلية، بخلاف المصادر التقليدية. يعد المجمع الحراري الشمسي أحد الاحتياجات الأساسية لتحويل طاقة الشمس إلى أشكال قابلة للاستخدام بشكل عام، تنقسم هذه المجمعات إلى مجموعتين، المجمعات الحرارية الشمسية غير المركزة والمجمعات الحرارية الشمسية المركزة، يهدف هذا التقرير إلى مراجعة "المجمع الحراري ذو الألواح المسطحة" والذي يقع ضمن المجمعات الحرارية غير المركزة.

تشير القياسات التجريبية إلى أنه تم تسخين الماء الموجود في الخزان بواسطة جهاز قياس الطاقة الشمسية ليتم امتصاصه بواسطة المجمع الشمسي، وعلاوة على ذلك قياسات درجة حرارة الماء في نقاط مختلفة، تشير النتائج إلى أن تصميم

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نظام تسخين المياه بالطاقة الشمسية الثيرموسيفون كان ناجحاً وعلاوة على ذلك فإن الجهاز التجريبي الموضح في هذه الورقة يعد إضافة قيمة للمختبر.

الكلمات المفتاحية: اشعاع شمسي، درجة حرارة المخرج، سخان ماء شمسي، الكفاءة، معدلات التدفق الشامل.

Introduction

The sun is a constant source of energy. Every day, the sun enriches the earth with uncountable amounts of solar energy, most of which comes in the form of yellow light. All around planet Earth, sunlight is by far the most important source of energy for all living things [1]. Without it, the earth is lifeless. Solar energy has been used since prehistoric times but in a most primitive manner. Before 1970, a few nations conducted some research and development to better use solar energy, but the majority of this effort remained primarily academic. After the dramatic rise in oil prices in the 1970s, several countries began to formulate extensive research and development programs to exploit solar energy. Solar energy is the most readily available source of energy. It is also the most important of the non-conventional sources of energy because it is non-polluting and, therefore, helps in lessening the greenhouse effect. The solar light can be a free source of renewable energy for everyday jobs such as cooking, heating water, or warming up homes. Solar energy can also be used to meet our electricity requirements. Through Solar Photovoltaic (SPV) cells, solar radiation gets converted into DC electricity directly. This electricity can either be used as it is or can be stored in the battery. This stored electrical energy then can be used at night. There are several uses for SPV, including:

- domestic lighting,
- village electrification,
- water pumping,
- desalination of salty water, and
- Railway signals.

If the means to make efficient use of solar energy could be found, it would reduce our dependence on non-renewable sources of energy and make our environment cleaner[2].

Energy received from the sun can be categorized:

1. in the form of heat (or thermal energy), and
2. in the form of light energy.

Solar thermal technologies use solar heat energy to heat substances (such as water or air) for applications such as space heating, pool heating, and water heating for homes and businesses. There are a variety of products on the market that use solar thermal energy. Often the products used for this application are called solar thermal collectors and can be mounted on the roof of a building or in some other sunny locations. Solar

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heat can also be used to produce electricity on a large utility scale by converting solar energy into mechanical energy.

Generally speaking, solar technologies may be classified as either passive or active based on how they collect, process, and disperse sunlight. Choosing building materials with advantageous thermal characteristics, planning spaces with natural air circulation, and aligning a building's location with the Sun are examples of passive solar design strategies. Demand-side technologies, such as passive solar technology, lessen the requirement for alternative resources.
Active solar techniques are photovoltaic panels and solar cells to convert sunlight into useful outputs. [2]

1.1 Solar Energy:

Because, it is ultra clean, natural, and a sustainable source of energy that one can utilize for generating electricity, solar heating appliances, solar cooling appliances, and also solar lighting appliances. On the global front, making use of solar energy seems to be one of the best options available. The worldwide climate change is a serious threat to our planet that is causing much of the problems. The emission levels of carbon dioxides that we generate by the constant use of fossil fuels are literally killing our planet. The usage of solar energy will only provide us with a clean environment, a life where we will not have to constantly worry about the ever so reducing natural resources. With net meeting, the ever so reasonably priced solar technology, and the ultimate willingness
To change this situation around, you can augment the energy competence of your home, and in due course accomplish net zero fossil fuel expenditure and utilization. You will also save the planet from dying out by using solar energy.

Another key aspect of using solar energy is that it has massive financial benefits. On the whole, the planet is being drained of its oil resources, and energy prices are only bound to go up. To only mend your own personal cost of energy needs is probably one of the smartest things to do and not to forget a very valuable future investment when measured up to the unavoidable rise in the cost of energy in recent times as well as the not so far future. [3]

The energy that finally reaches the earth is very low to the amount of energy filtered, yet this amount of energy is sufficient to provide enough electricity to the earth for an entire year. Some portion of the energy is reflected into space, some amount of energy is utilized by land, oceans, and plants, still, rest of the energy is up for us to utilize effectively. [2], [3]

1.2 Advantages of Solar Energy:

There are plenty of excellent reasons that equate advantages of using solar energy. Here are some advantages of using solar energy.

(i) Solar energy is non-polluting.

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Solar energy is an excellent alternative to fossil fuels like coal petroleum because solar energy is practically emission-free while generating electricity. With solar energy, the danger of further damage to the environment is minimized. The generation of electricity through solar power produces no noise. So noise pollution is also reduced.

(ii) Accessibility of solar power in remote locations. Solar power can generate electricity of matter how remote the area is as long as the shines there. Even in areas that are inaccessible to power cables, solar power can produce electricity.

(iii) Available Free of Cost.

Sunlight is free. There is of course the initial investment for the equipment. After the initial capital outlay, you won't be receiving a bill every month for the rest of your life from the electrical utility.

(iv) Solar energy is getting more cost effective.

The technology for solar energy is evolving at an increasing rate. At present photovoltaic technology is still relatively expensive but the technology is present photovoltaic technology is improving and production is increasing. The result of this is to drive costs down. Payback times for the equipment's are getting short as five years.

(v) The abundance of solar energy.

Even in the middle winter each square mater of land still receives a fair amount of solar radiation. Sunlight is everywhere and the resource is practically inexhaustible. Even during cloudy days, we still receive some sunlight and it is this that can be used as a renewable resource.

(vi) Solar energy systems are virtually maintenance-free.

Once a photovoltaic array is setup it can last for decades. Once they are installed and set up there are practically zero recurring costs. If needs increase solar panels can be added with ease and with no major revamp. [2],[3]

1.3 Disadvantage of Solar Energy:

(i) High initial capital investment.

The initial cost of installing a solar energy system can be prohibitively high for some budgets. The cost of buying and installing solar panel arrays is a bit steep. Payback times may reach from ten to fifteen years before you can even break even with your initial investment.

(ii) Doubtful reliability.

It is obvious to power your home with a solar array at night if you don't have a system in which to store power. This means batteries at our present level of technology. So, one probably needs to draw electricity from the local utility grid.

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iii) Position of the surface on which sunlight falls.

The position of your solar array is obviously of major importance in the generation of electricity. This means that some houses will not be ideally suited for conversion or for installing a solar energy system.

(iv) Polluting materials used in solar panels.

The majority of photovoltaic panels are made from silicon and other metals that are potentially toxic like mercury, lead, and cadmium. This is the dirty secret of this "clean" technology.

(v) low efficiency.

The current efficiency rate of most solar panels is just 40%. This means that 60% of the sun's energy is wasted. The solar panels can reach a maximum efficiency of 80%. [2],[3]

4. Types of Solar Collectors:

Solar energy collectors are a special kind of heat exchanger that transforms solar radiation energy into internal energy of the transport medium.

The major component of any solar system is the solar collector. This is a device that absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector.

The solar energy is thus collected and is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank which can be drawn for use at night and/or cloudy days.

There are basically two types of collector based on intercepting area:

- Non-concentrating or stationary**.**
- Concentrating**.**

4.1 Collectors are further as classified as:

4.1.1 Tracking concentrator:

i. One axis tracking concentrator (MODERATECONCENTRATION):
- Cylinder parabolic concentration (FMSC)
- Linear Fresnel lens/reflector

ii. Two-axis concentrators (HIGH concentration)
- Parabolic disk concentrator
- Central tower receiver
- Circular Fresnel lens
- Hemispherical bowl mirror

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4.1.2 Non tracking concentrator:

i. Flat receiver with booster mirror
ii. Tabor Zimmer circular cylinder
iii. Compound parabolic concentrator
iv. V trough

4.1.3 Reflecting/Refracting Concentrator

i. One piece/composite
ii. Single stage/Two-stage
iii. Symmetric/asymmetric

4.1.4 Imaging/Non imaging

4.1.5 Line focussing/point focusing

4.2.8 Flat Plate Collector:

A typical flat-plate collector is a metal box with a glass or plastic cover (called glazing) on top and a dark-coloured absorber plate on the bottom. The sides and bottom of the collector are usually insulated to minimize heat loss. Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal- typically Copper or Aluminium- because the metal is a good heat conductor. The main use of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. This generally means a situation with a large family or a situation in which the hot water demand is excessive due to frequent laundry washing. Fig. 1 represents a flat plate collector.

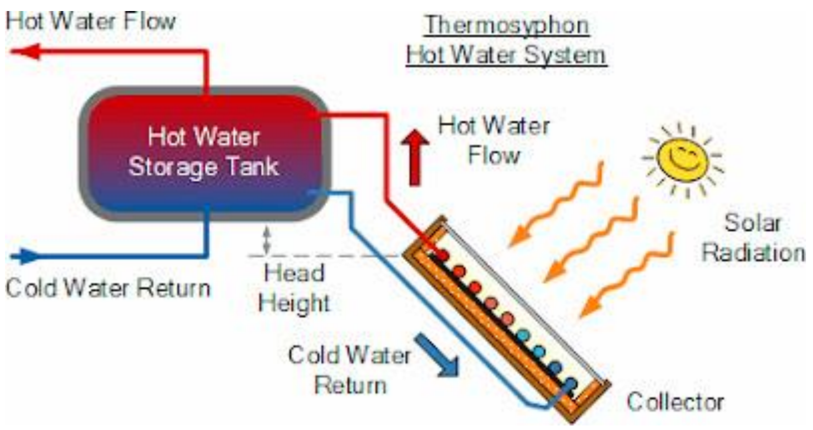

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Fig. 1 Flat plate collector and Tank, (Thermosiphon systems)

The typical components of a flat plate collector are: -

a) **Absorber Plate:**

The absorber plate is a rectangular sheet made of high heat-conducting material, especially copper or aluminium because of their high heat conductivity. It is usually painted in black and coated with absorptive material to get the maximum absorption of solar radiation[6]. This thin layer is highly absorbent to shortwave solar radiation but comparatively translucent to long-wave radiation. Another thin layer is provided below the coating with high reflectance to long wave radiation. The absorber plate absorbs the sun's heat energy and transfer that to the working fluid with minimum heat loss[8],[16],[17],[18],[19].

b) **Headers:**

Tubes of large diameter are placed at the top and bottom of the absorber plate for the entrance and discharge of fluid. The header pipes are made of copper for maximum heat conduction from the absorber plate[6]. These header pipes are connected to the copper tubes by welding[8],[16],[17],[20].

c) **Tubes:**

Several tubes made of copper are placed on the absorber plate. The working fluid flows through the tubes where they are heated. The copper tubes are positioned parallelly on the absorber plate. (John Twidell, 2015)The liquid tubes are connected at both ends by large diameter header tubes. These are soldered and brazed to the absorber plate so that

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smooth heat transfer takes place between them by getting maximum surface contact [6],[8],[16],[17],[18].

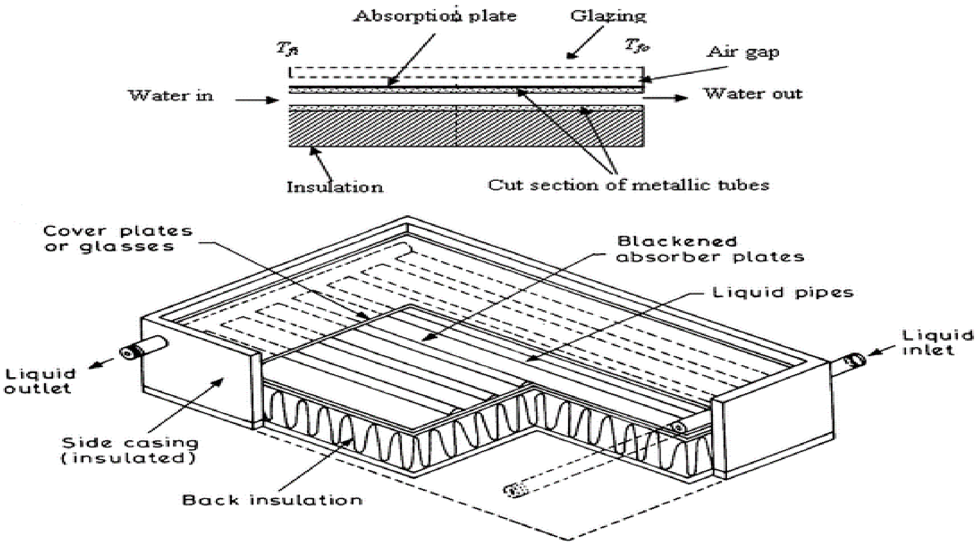

Fig. 2 Parts of a Flat Plate Collector

d) **Glazing:**

Glazing refers to covering with glass or plastic having radiative properties. A flat plate collector has single, double, or multiple layers of glazing above the blackened absorber plate. Low iron glass is mainly used for glazing having high transmissivity of short-wave radiation and low or zero transmissivity of long-wave radiation[6]. The main purpose of glazing is to allow as as solar radiation possible and create insulation of the absorber plate with the environment by entrapping radiation to reduce convective losses as well as radiative losses. Transmission of short-wave radiation can also be increased by antireflective coating and surface texture. The glazing materials don’t absorb heat like absorber plates [8],[17],[18].

e) **Insulation:**

Insulation is provided to the sides and bottom of the flat plate collector to reduce heat loss. Different insulating materials like rubber, cotton, and wool is used for this purpose. Insulating substances decrease heat loss from the absorber plate and help in heating the tubes as well as the plate[8],[17].

f) **Casing:**

A steel or wooden casing is used to hold the parts together. In the casing, a layer of insulation is provided at the bottom. The absorber plate is placed after that with copper tubes incorporated in it. The sides are also insulated for the reduction of heat loss through convection[6]. Finally, the glazing is done with glass to provide an air gap between absorber and the atmosphere. All the parts are soldered, brazed or welded properly to

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get maximum surface contact and high heat transfer. Casing protects the parts from environmental influences like dust particles, rainfall, moisture etc[17],[18].

Working:

A solar collector works as a water heater and is based on the transformation of the absorbed solar radiation to thermal energy. In general, solar collector works by absorbing solar radiation which incidents on the collector plate passing through the glazed glass. The absorbed heat is then transferred to the working fluid flowing through the connected copper tubes with minimum heat loss. The heated fluid is then moved to the place of its use or to a storage tank for later use[6].

A solar collector heating system is two types- active or direct and passive or indirect.

Active or direct solar collector is basically an open-loop system. In this system, a differential temperature sensor is used to compare the temperature of the water to be heated. The heat collected by the collector is transferred to the working fluid which goes directly to the storage tank and then supplied to the household needs. A heat pump is used which draws cold water from the bottom of the storage tank and circulates it through the solar collector. As a result, the heated water is circulated through the tanks directly from the collector [8],[18],[21].

Open-loop system is of two types- drain-down system and the recirculating system.

In the drain-down system a valve is used to allow the solar collector to fill with water when the collector reaches a certain temperature.

In the recirculating system water is pumped through the collector when the temperature in the storage tank reaches a certain critical value.

Passive or indirect system is a closed-loop system. In this system, a heat transfer fluid called glycol is used to circulate through the solar collector. Glycol after absorbing radiant heat from the collector is passed to a heat exchanger where it heats the working fluid through heat transfer. Glycol works as anti-freezing substance and can operate efficiently at freezing temperature. The working fluid after being heated from the heat exchanger is transferred to a storage tank for after use[22],[23].

Thermo-siphon system is a kind of passive system which consists of an insulated storage tank set above the collectors. The heated fluid moves to the storage tank by convective process and stored there. In response, the cold fluid circulates to the collector and gets heated up. In this system, flow of fluid is slow. This system is simple and uses no energy and requires comparatively low maintenance [9],[24].

Air flat plate collectors works on the same principle but is used for conditioning of household or commercial premises. It works by natural or forced convection of

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depending on absorbed heat. In air heating systems, boiler is used to heat the air before using for space heating. Blower or fan may also be used for forced flow of air in other applications [25].

Applications:

Solar collectors are primarily used for heating water for household purposes to reduce the usage and of energy and fossil fuel. Typical application of flat plate solar collector includes the following:[6],[8],[19]

- Water heating for household and residential use like washing clothes, bathing, washing other equipment as well as drinking warm water is done by solar collectors
- Industrial application of solar water heating includes the use of warm water in leather industry, textile industry, food and beverage industry etc.
- Laundry shops use warm water for washing clothes by using either active or passive collector
- Water of swimming pool is heated using solar collector
- Solar collectors are used in desalination plants for evaporation of water by heating it to high temperature
- Solar concentrators are used for solar distillation by heating copper boilers filled with water
- Solar powered electricity is generated from the radiant energy of the sun using solar collectors
- Air heater is used for space heating in household and commercial zones
- Crop drying for agriculture industry is done by forced flow of air using air heaters

Advantages of a Flat Plate Collector

Some advantages of a flat plate collector include

1. A Flat plate collector facilitates the collection of direct energy from all directions and diffuses thermal radiation.
2. It is a clean, pollution-free system of energy generation.
3. The power utilized by FPCs is natural & renewable.
4. Flat plate collector devices have relatively low maintenance costs and longer working life.
5. It is easy to fabricate and economical.
6. It can be installed effortlessly. FPCs are fixed to a mounting structure in tilt and orientation in which they receive maximum sunlight.

With FPCs, more energy can be generated even at low temperatures

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- **Overall loss coefficient and heat transfer correlations**

It is convenient from the point of view of analysis to express the heat loss from the collector in terms of an overall loss coefficient, defined by the equation-

$$q_u = U_c A_a (T_c - T_a) \quad \text{……………..(1)}$$

The heat lost from the collector is the sum of the heat lost from the top, the bottom and the sides. Thus,

$$q_{total} = q_t + q_b + q_s \quad \text{……………..(2)}$$

Each of these losses is also expressed in terms of coefficient called the **Top Loss Coefficient, Bottom Loss Coefficient** and **Side Loss Coefficient** and can be defined by the equations:

$$q_t = U_t (T_{pm} - T_a) \quad \text{……………..(3)}$$

$$q_b = U_b (T_m - T_a) \quad \text{……………..(4)}$$

$$q_s = U_s (T_{pm} - T_a) \quad \text{……………..(5)}$$

The definitions of each of the coefficient is based on the area A_p and the temperature difference(T_m-T_a). This is done for convenience and helps in giving the simple additive equations

$$U_r = U_t + U_b + U_s \quad \text{……………..(6)}$$

- **Top Loss Coefficient**

  The T_{op} loss coefficient U_t is evaluated by considering convection and re-radiation losses from the absorber plate in the upward direction.

  In a steady state, the heat transferred by convection and radiation between: The absorber plate and first cover.

Hence,

$$\frac{qt}{Ap} = h_{p-c1}(T_{pm} - T_{c1}) + \frac{\sigma(T_{pm}{}^4 - T_{c1}{}^4)}{\frac{1}{\epsilon_p} + \frac{1}{\epsilon_c} + 1} \quad \text{……………..(7)}$$

$$= h_{c1-c1}(T_{pm} - T_{c2}) + \frac{\sigma(T_{c1}{}^4 - T_{c2}{}^4)}{\frac{1}{\epsilon_c} + \frac{1}{\epsilon_c} + 1} \quad \text{……………..(8)}$$

$$= (T_{c2} - T_a) + \sigma(T_{c1}{}^4 - T_{sky}{}^4) \quad \text{……………..(9)}$$

- **Bottom Loss Coefficient**

The bottom loss coefficient U_b is evaluated by considering conduction and convection losses from the absorber plate in the downward direction through the bottom of the

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collector. It will be assumed that the flow of heat is one-dimensional and steady. Thus neglecting the convective resistance

$$U_b = \frac{ki}{\delta b} \quad \text{……………..(10)}$$

Where, $\mathbf{k_i}$ = Thermal conductivity of the insulation, **b**= Thickness of the insulation.

- **Side Loss Coefficient**

In case of side loss coefficient, it will be assumed that the conduction resistance dominates and that the flow of heat is one dimensional and steady. The one dimensional approximation can be justified on the ground that the side loss coefficient is always much smaller than the top loss coefficient. Thus

$$U_s = (L_1 + L_2)L_3 k_i / L_i L_2 \quad \text{……………..(11)}$$

- **Effects of Various Parameters on Performance of solar collector**

A large numbers of parameters influence the performance of a liquid flat-plate collector. The parameters are the selectivity of the absorber surface, the number of glass cover, the spacing between the covers, the tilt of the collector, the fluid inlet temperature, thetransmissivity of the glass and dust settlement on the top glass cover.

1. Selective Surfaces:

Absorber plate surfaces which exhibit the characteristics of a high value of absorptivity for incoming solar radiation and a low value of emissivity for outgoing re-radiation are called selective surfaces. Are desirable because then maximize the absorption of solar energy and minimizes the emission of the radiative loss. If a surface has a high absorptivity for wavelengths less than 4µm and a low emissivity for wavelength greater than 4µm can be prepared, it would have the characteristics desirable for an absorber plate surface to act in a selective manner, the characteristics desired for an ideal selective surface. The selectivity of the surfaces is achieved by having a polished and cleaned metal base and depositing on it a thin layer which is transparent to have large wave lengths, but highly absorbing for small wavelengths solar radiations. The layer is less than 1nm in thickness, and is deposited by a variety of methods like electroplating, chemical conversions, anodic oxidation, rf-magnetron sputtering

2. Number of Covers:

As the number of covers increases, the value of both (τα) b and (τα) d decreases. Thus the flux S absorbed in the absorber plate decreases. The addition of more covers also causes the value of Ut, and hence the heat loss, to decrease. Thus, the useful heat gained

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(consequently the efficiency) goes through a maximum value with a certain number of covers

3. **Spacing:**

The proper spacing to be kept between the absorber plate and the first cover or between two covers has been the subjects of considerable discussion. From the point of view of the heat loss from the top, it is evident that the spacing must be such that the values of the convective heat transfer coefficients are minimized.

4. **Effects of Shading:**

The main problem associated with the use of large spacing is that shaping of the absorber plate by the side walls of the collector casing increases. Some shaping always occurs in every collector and need to be corrected for. It is estimated that for most designs, using spacing of 2-3 cm between the covers, shading reduces the radiation absorbed by about 3%. It is recommended that absorber flux S can be calculated in the usual manner but with a multiplying factor of 0.97.

5. **Collector Tilt**

Flat plate collector are in one position and do not track the sun[13].

6. **Mass Flow Rate**

The flow rate affects system efficiency and operating temperature. Slower flow rates keep the solar fluid in the collectors longer, so it comes out hotter, but overall efficiency decreases when heat is transferred more slowly. Higher flow rates do the opposite: more fluid is pumped around the system to improve efficiency, but the overall temperature is lower. It's important to understand what your paper requires, so you can choose the right pump. Do you need a lot of low temperature water for domestic supply or do you need less at a higher temperature for solar cooling.

7. **Solar Rediation**

Solar radiation provides a positive relationship with temperature changes in the solar collector. The temperature inside the solar collector is strongly influenced by solar energy.

5. Experimental and Constructional Details of the Setup:

The Computer Controlled Thermal Solar Energy Unit, "EESTC", is a system that transforms solar energy into usable the energy. It uses the thermosiphon solar system to heat water or the traditional pumping system. In both cases, the absorbed thermal energy is given by the simulated solar radiation; in our case, it is done using a panel with powerful luminous sources. As showed in the Figure 5.1

The EESTC unit mainly consists of the following elements:

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- Thermal solar collector.
- Accumulator tank.
- Solar simulator.
- Pumping system.

The solar collector is mounted on an aluminum frame and the fluid (water) flows through cooper tubes. It has been developed in such a way that the geometrical shape of the surface allows the most efficient absorption.

The accumulator tank is protected with an anti-corrosive material. It has a computer controlled heating element with a safety device to prevent over-temperatures.

Lamps of the solar simulator emit radiation similar to the sun radiation, which is measured by a radiation sensor. The light is converted into heat in the solar collector and transferred to the heat transfer fluid. Three different configurations can be simulated with the solar simulator: all the lamps are turned on, half of the lamps are turned on in zigzag, or only one lamp is turned on.

Besides, the unit includes a computer controlled pump to perform a forced convection of the heat transfer fluid through the accumulator tank.

The unit is fitted with sensors and meters to record the relevant parameters (temperature, flow and radiation) and are included safety valves for overpressure protection.

This Computer Controlled Unit is supplied with the EDIBON Computer Control System (SCADA), and includes: The unit itself and a Control Interface Box a Data Acquisition Board and Computer Control, Data Acquisition and Data Management Software Packages, for controlling the process and all parameters involved in the process**.**

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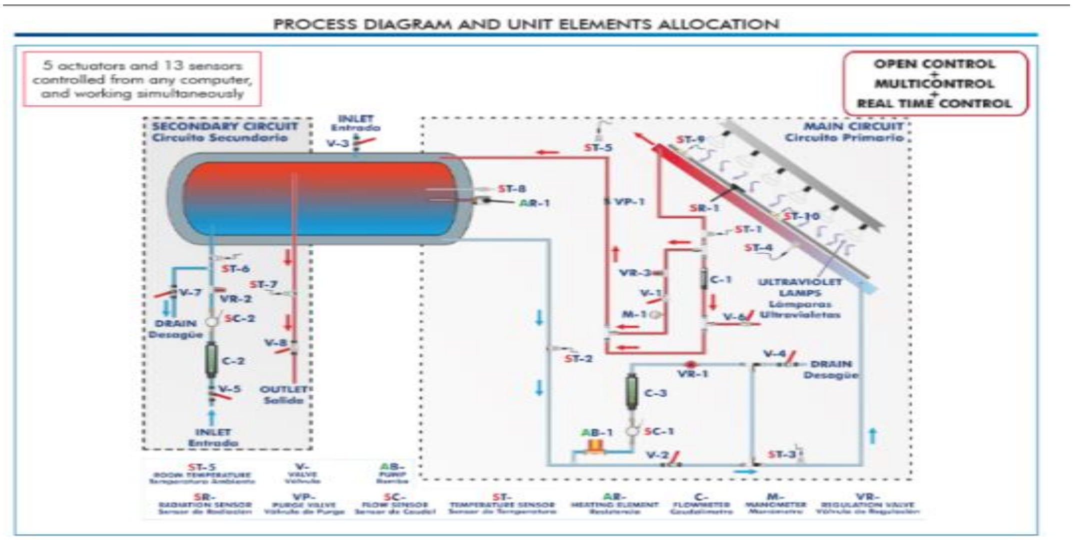

Figure 3 EESTC.

The EESTC is a system built to transform solar energy into thermal energy.

Practical possibilities:

1.Study of the thermosiphon operation
2- Study of the lamp luminosity profile
3- Study of the output of the solar panels
4- Free circulation: influence of the tilt angle on the efficiency of the unit
5- Relationship between flow and temperature
6- Energy balance of the solar panel
7- Energy balance in the accumulation tank
8- Experimental study of the output
9- Influence of the angle of incidence on the temperature.

Solar simulator. (Lamps)

Aluminium frame with adjustable height.
Sixteen ultraviolet lamps of 300W each.
Control interface or console, depending on the mode

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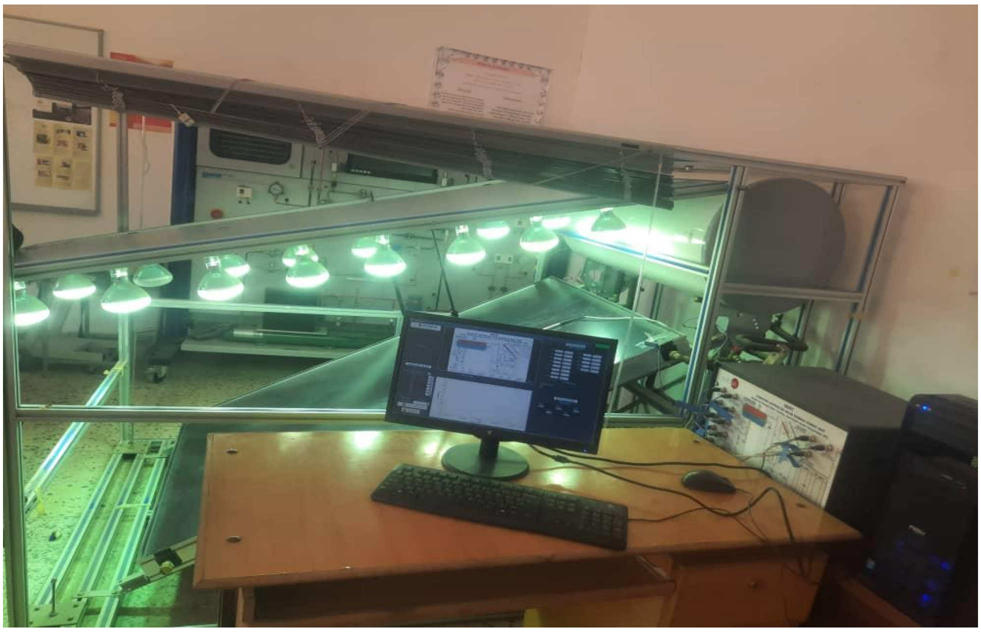

Figure 4 EESTC.

The Computer Controlled Thermal Solar Energy Unit, "EESTC", is a system that transforms solar energy into usable thermal energy

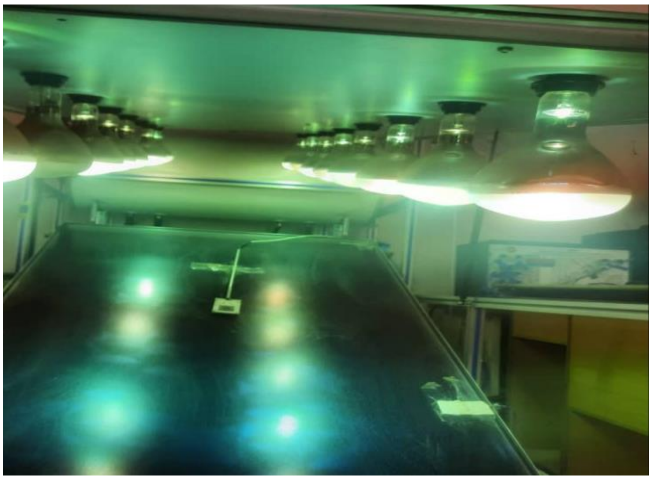

Figure 5 Absorber, sensors Using solarimeter, To measure the intensity of radiation.

finely control and regulate water flow and pressure. The precision is achieved through the fine movement of the shaft,

Practical procedure of experimental:

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Place the lamps panel parallel to the solar collector, adjusting the height of the panel with the height regulators, so that the lamps panel and the solar collector are parallel to each other. This process must be very carefully executed, so none of the lamps are damaged. Turn on a line of lights and write down the temperatures of the primary circuit, as well as of the solar collector. Than Check that when it reaches a certain temperature, the water of the primary circuit starts to circulate by itself and transfers heat to the accumulator. Write down the temperature, and flow values during regular intervals of time. Perform the same practical exercise with all the lights on. Than calculate the efficiency

$$\eta = \dot{m} * C_p (T_o - T_i)/(A * I) \quad \text{.................}(12)$$

T_a=34C° Solar rad. = 400W/m² A=2 m² C_p= 4190 J/Kg.K

Mass flow	T_{out}	$T_{out} - T_{in}$	Efficiency
m^2/min	C°	C°	η
0.015	**37**	**3**	**23**
0.02	**37**	**3**	**31.4**
0.026	**37.2**	**3.2**	**43.5**
0.03	**36.2**	**2.2**	**34.5**

Table 1: Solar rad. = 400W/m²

As shown in figure 6: The relationship between flow rate and efficiency, as the flow rate increases, the efficiency increases to 0.026. We notice a decrease in efficiency as a result of reducing the efficiency of the device and the value of the solar radiation on used.

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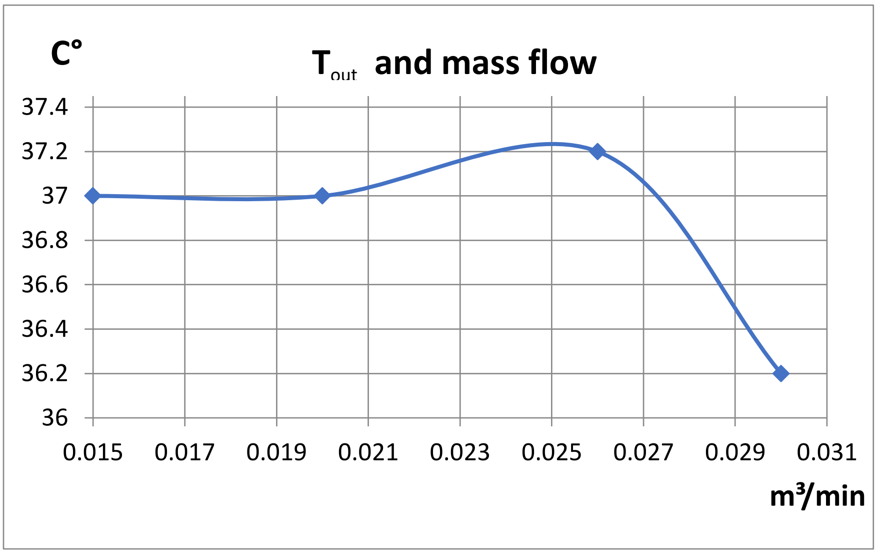

Figure 6 T_{out} and mass flow

As shown in figure **7:** The relationship between (the difference between the inlet and outlet temperatures) and the flow rate of the fluid, whereby when the value of the flow rate reaches 2.6, the two temperatures begin to decrease as a result of the capacity limit of the solar collector.

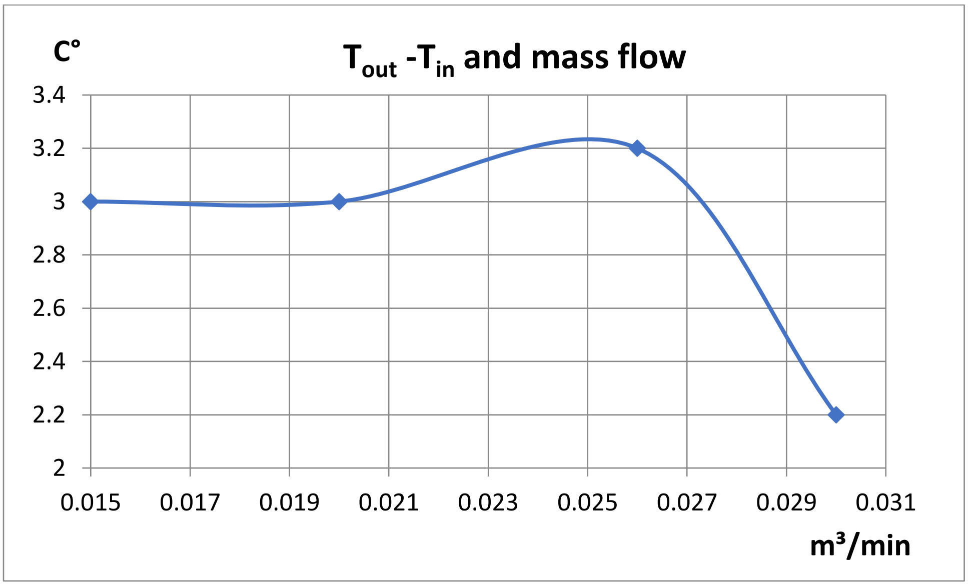

Figure 7 T_{out} -T_{in} and mass flow

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As shown in figure **8:** The relationship between outlet temperature and flow rate, We notice from the curve that as the flow rate increases, the outlet temperature increases, until we reach a certain flow rate of 2.6. The outlet temperature begins to decrease as a result of the solar collector not absorbing thermal energy, and this is normal because the solar collector has a limited capacity.

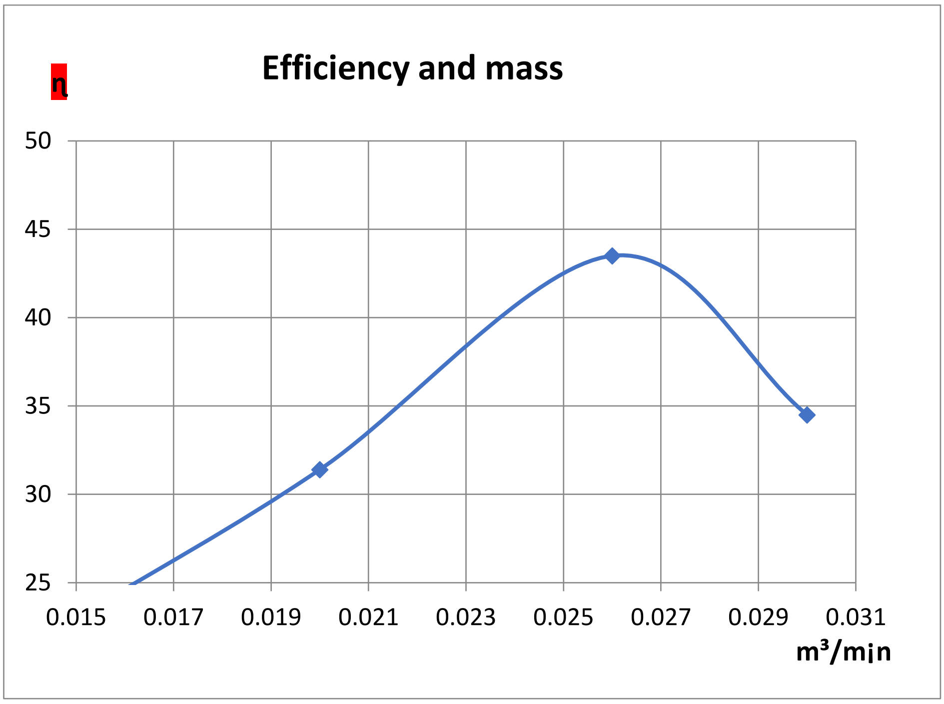

Figure 8 Efficiency and mass flow

$$\eta = \dot{m} * C_p (T_o - T_i)/(A * I) \quad \ldots\ldots\ldots\ldots\ldots..(13)$$

T_a=34C° Mass flow rate =0.026 m^3/min C_p=4190 J/Kg

A=2 m^2

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Solar rad W/m²	T_{out} - T_{in} C°	T_{out} C°	Efficiency η
100	0.4	34.4	21.0
150	0.8	34.8	29.0
200	1.1	35.1	30.0
250	1.4	35.4	30.5
300	1.9	35.9	34.5
350	2.4	36.4	37.0
400	3.0	37.0	40.0

Table 2: Mass flow rate =0.026 m³/min

As shown in figure **9:** The relationship between solar radiation and efficiency. At 400 solar radiation, we notice that the greater the radiation, the greater the efficiency, and this is based on the direct relationship.

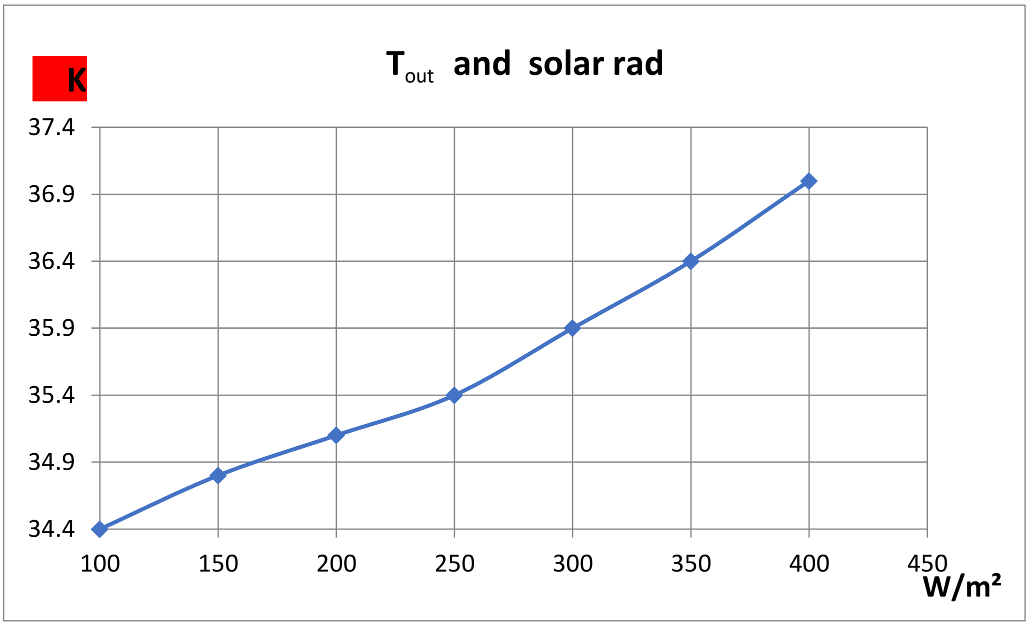

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Figure 9 Tout and solar rad

As shown in figure **10:** The relationship between solar radiation and (difference between inlet and outlet temperatures) and as we notice, both sides increase, this is due to natural conditions.

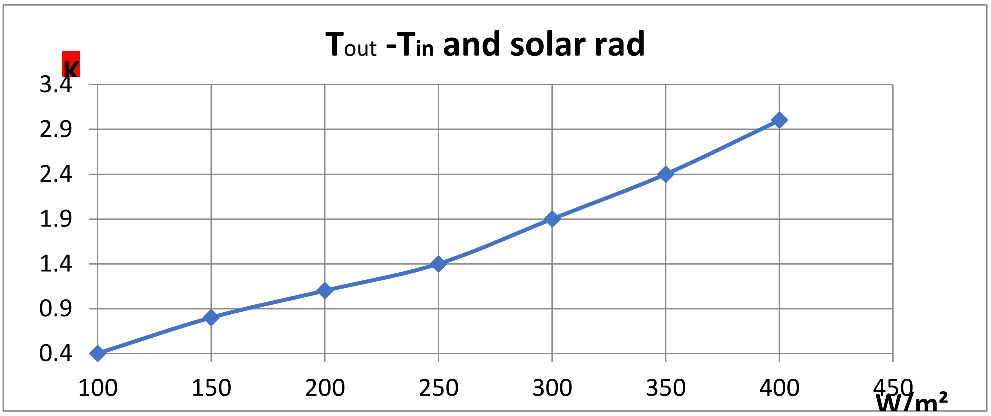

Figure 10: T$_{out}$ -T$_{in}$ and solar rad

As shown in figure **11:** We note the relationship between outdoor temperature and solar radiation

The increase in the value of both parties, and this degrades the direct relationship.

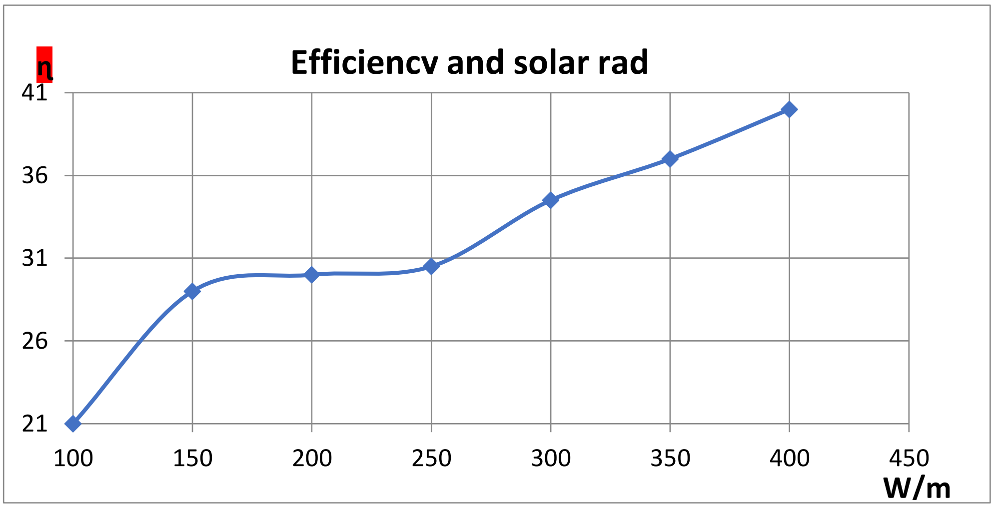

Figure 5.11: Efficiency and solar rad

The thermal efficiency of the solar water heater has been studied experimentally by Computer Controlled Thermal Solar Energy Unit, "EESTC”. This study is done to measure the performance of the solar water heater of thermal energy capability,

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The optimal flow rate is determined in order to reach the maximum efficiency is 0.026 m/min.

Conclusion

The Experimental measurements indicate that the water in the tank was heated by the solarimeter to be absorbed by the solar collector. Moreover, the water temperature measurements at different points. Solar water heating utilizing thermosiphon is attractive, because it eliminates the need for a circulating pump. Results indicate that the design of the thermosiphon solar water heating system was a success. Furthermore, the experimental apparatus described in this paper is a valuable addition to the laboratory. The experimental apparatus is portable, and it can be used as an instructional experimental apparatus for demonstrating basic heat transfer principles and thermo-siphon concept

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