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Modelling Heat Transfer in Solar Distiller with Additional Condenser Studying

Nagham T. Ibraheem, Hazim H. Hussain*, Omar L. Khaleed

Atmospheric Sciences Department, College of Science, Mustansiriyah University, Baghdad, IRAQ.

*Correspondent email: Dr.hazim@uomustansiriyah.edu.iq

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ABSTRACT

The sun is the main source of energy that reaches the surface of the earth in the form of electromagnetic radiation called solar radiation and when it reaches the outer surface of the glass hood of the solar distillation, the process of energy transferring as the heat begins. The energy transfer process between parts of solar distillates greatly controls its performance, so the greater amount of energy gained and the less energy lost, leads to higher productivity and efficiency of the solar distillery. In this paper, a mathematical model was constructed to calculate the amount of thermal energy in each part of a monoclinic solar distiller equipped with an additional capacitor during its operation. as a result of this model showed that the temperature, after a series of heat energy exchanges between the glass cover and all the internal parts of the distillate, with the absorbent part at the base of the distillate, exhibited the same behavior, which is increasing in its temperature steadily during the first hours of the day from (32.5-41.7) at (08:30 am) in the morning down to its top value (61.4-76.7) at (02:30 pm) and decline after this hour in the same bullish pattern. this is due to the greater difference between the amount of energy lost and acquired by the absorbent portion during the same daylight hours, as the amount of energy gained increases and the amount of lost energy decreases, leading to the highest energy gain and the least energy lost by the absorbent part at (02:30 pm), except the outer part of the additional condenser, which followed a similar behavior of air temperature, with its temperature gradually increasing slightly during the first hours of the day from (27) at (08:30 am) until it reached its peak (36.2) at (01:30 pm), then it decreases after this time slightly. This slight rise and slight decrease are due to the constant state of thermal balance between the two ends of the additional condenser by the heat exchange process between the outer part of the additional condenser and the cooling water.

KEYWORDS: Heat energy; heat transfer; solar distiller.

الخلاصة

الشمس هي مصدر الطاقة الرئيسية التي تصل إلى سطح الارض على شكل اشعاع كهرومغناطيسي يدعى بالاشعاع الشمسي، وفور وصوله الى السطح الخارجي من لغطاء الزجاجي للمقطر الشمسي تبدأ عملية انتقال هذه الطاقة كحرارة، حيث تتحكم عملية انتقال الطاقة بين اجزاء المقطرات الشمسية بشكل كبير بادائها، فكلما ازدادت كمية الطاقة المكتسبة وقلت كمية الطاقة المفقودة ازدادت انتاجية وكفاءة المقطر الشمسي. في هذا البحث تم بناء نموذج رياضي لحساب كمية الطاقة الحرارية في كل جزء من اجزاء مقطر شمسي احادي الميل مزود بمكثف اضافي اثناء عمله، حيث اظهرت نتائج هذا النموذج ان درجة الحرارة وبعد سلسلة من عمليات تبادل الطاقة الحرارية بين الغطاء الزجاجي وجميع أجزاء المقطر الداخلية مع الجزء الماص في قاعدة المقطر تسلوك سلوكا واحدا وهو ارتفاع درجة حرارتها ارتفاعا مضطردا خلال الساعات الاولى للنهار من (32.5-41.7) عند الساعة (08:30) صباحا وصولا الى ذروتها (61.4-76.7) عند (02:30) مساءًا لتعود الى الانخفاض بعد هذه الساعة وبنفس نمط الارتفاع تقريبا وهذا يعزى الى ازدياد الفرق بين كمية الطاقة التي يفقدها ويكتسبها الجزء الماص خلال نفس ساعات النهار حيث تزداد كمية الطاقة المكتسبة وتقل كمية الطاقة المفقودة وصولا الى اعلى طاقة يكتسبها واقل طاقة يفقدها الجزء الماص عند الساعة (02:30) مساءا، باستثناء الجزء الخارجي من المكثف الاضافي الذي اتبع سلوكا مشابها لسلوك درجة حرارة الهواء بارتفاع درجة حرارته تدريجياً بشكل بسيط خلال ساعات النهار الاولى من (27) عند الساعة (08:30) صباحا ووصولا الى ذروته (36.2) عند الساعة (01:30) مساءا لينخفض بعد هذا الوقت انخفاض طفيف هذا الارتفاع البسيط والانخفاض الطفيف يعود الى حالة التوازن الحراري الثابتة تقريبا بين طرفي المكثف الاضافي بفعل عملية التبادل الحراري بين الجزء الخارجي من المكثف الاضافي وماء التبريد.

INTRODUCTION

An understanding of the design, operational and atmospheric factors affecting the performance, operation and productivity of the distillery that contribute to determining the quality and efficiency of the solar distillery needs to be integrated with the understanding of the different thermal (thermodynamic) processes that occur outside and inside the distillery during the distillation process, through which it is possible to know the energy losses that The distillate is exposed to it, which affects the productivity of the distiller and the efficiency of the distillation, so the smaller the energy losses lost to the distillate, the higher the distiller's productivity and efficiency [1].

Despite the apparent simplicity of the desalination process using solar distillates, this process takes place through a complex series of physical processes, which include aspects related to different ways of transmitting radiation, such as convection and conduction, as well as aspects related to the process of evaporation and how the vapor diffuses and condensed. The thermal processes begin when the solar radiation falls on the outer glass surface of the distillation, as the solar energy falling on the distillate passes through several stages of reflection and absorption. The role of the water surface, which absorbs the bulk of this energy and reflects part of it, and then the black evaporation body at the base of the distillate absorbs and reflects the remainder of this energy [2].

After these processes, the long wave radiation of absorbed energy begins with long wave radiation from the water in the distillation basin and the evaporation body (the absorbent body) as it is absorbed or escaped by the glass cover, which is impermeable to the long wave radiation, so the cap absorbs all this energy, please. Moreover, the thermal energy is transferred from the water and the body of evaporation at the base of the distiller to the glass cover through the confined air between them through convection and through the successive processes of evaporation and condensation that release the latent heat of vaporization is the water vapor, which is received by the inner surface of the glass cover. This energy is transferred by conduction to the outer surface of this covering and then transferred to the periphery by convection and radiation. In addition to these processes, there is heat entering and leaving the distillate called the sensible heat. The distillate supplies it through the feed water and loses it through the distilled water coming out of the distillation apparatus [3]. Figure 1 shows the processes of energy transfer inside and outside the monoclinic solar distiller [4].

In addition to these processes, a thermal storage process occurs inside the distillate from water and the absorbent body located at the base of the distillate, and as a result of the process of continuous variation in the intensity of solar radiation and many other factors, each of the distillate as an independent standing unit and what it contains is constantly exposed to an increase and decrease in the internal energy. Enthalpy that each part contains distilled [5].

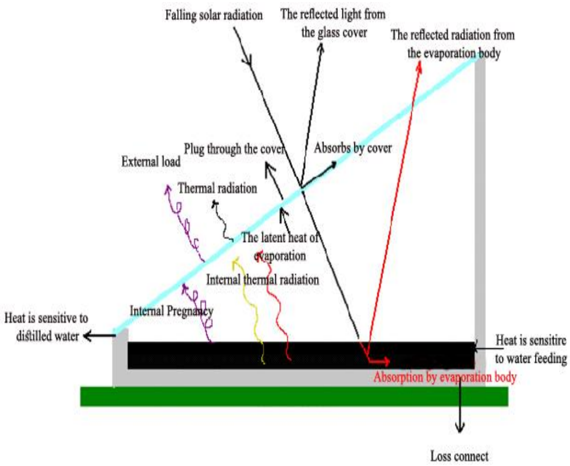

Figure 1. Thermal transfer in solar distillation [4].

PROPOSED METHODOLOGY

To analyze the process of energy transmission in a solar distillation several hypotheses have been imposed that facilitate the construction of a mathematical model for this transition and each part of the distillate as follows : (the device works in a state of complete thermal equilibrium [5], that the energy input to the distilled is equal to the energy out of it and there is no gradient in the temperature during both the transparent cover and thin layer of condensate vapor due to the low thermal flux of each and lack of thickness of both the glass and the thin layer of steam condensate [6].

Tripathi & Tiwari did in 2004; a mathematical study for distributing solar radiation into Distillers single slop through Radiation refraction process during enter it to Distilled Depending on azimuth angle and length angle and Latitude and length of place As a result of the refraction of radiation can play an important role for length angle low solar , by studying the effect of the height of the northern wall of the distillator and the distillation width and its length on the refractive index of radiation the following results were obtained [7]:

*The refractive index rate increases with the rise of the northern wall and this function is increased with rate 266% during length increasing from 21-5 cm to 101-5 cm because radiation amount falling on the wall is increasing when it length increases, and product pipe is increased with increasing the height of the wall.

* Increasing the distillate width decreases the refractive function and productivity.

* There is no effect in increasing distillate length on the refractive function or on its productivity.

Triwari did in year 2005 another study, by conducting a numerical simulation inside the laboratory of three solar currents with angles and its outer glass cover 45^o, 30^o, and 15^o, this was aimed to study effect of glass cover of solar trimmers on heat transfer and mass of energy inside steam-still by observing evaporation process and convection transfer, the temperature is controlled through thermal source and the temperature ranged between 80- 40 percentage [8].

Results of mathematical model gave several indicators:

*Distillate output increases by increasing the degree of distilled water at an angle 30^0, the model gaves the highest evaporation rate and thermal load at this angle.

*Load rate and evaporation for high temperature agreed with Dunkles model, which considered the first model to simulate this process.

In the case of thermal equilibrium at the glass cap of the distillate [9], we find that

$$Qe+Qr+Qc+Qgs=Qgh+QgL \quad (1)$$

Qgs is the intensity of solar radiation absorbed by the cover (Wm^{-2})

Qgh is the Energy lost due to overheating of the hood (Wm^{-2})

QgL is the heat flow from the distillate cover to the outside environment as a result of absorbing heat radiation (Wm^{-2})

equ.1 represent the energy balance on the cover

Assume that the intensity of solar radiation that passes through the transparent glass cap of the distillate is Qa ($W\ m^2$) this energy in an absorbing body in equilibrium can be written as [10]:

$$Qa = Qw + Qb + Qc + Qr + Qe \quad (2)$$

Qw is the intensity of solar radiation used to raise the temperature of the thin water layer on the surface of the absorbent object (Wm^{-2})

Qb is the thermal energy lost through the base of the basin and the walls of the distillate (Wm^{-2})

Qc is the thermal Convection flow (Wm^{-2})

Qr is the radiation heat flow from the water surface to the transparent cover (Wm^{-2})

Qe is the energy consumed in the evaporation process (Wm^{-2})

Equ. 2 represent the Energy Balance of the Absorber Body, so the Energy Balance on The Condenser can be given by [11]:

$$QI\text{-}cond+Qr\text{-}cond+Qc\text{-}cond+Qe\text{-}cond = Qcond\text{-}ca+Qcond\text{-}cw \quad (3)$$

QI-cond is the solar energy absorbed by the condenser (Wm^{-2}).

Qr-cond is the thermal energy absorbed by the condenser as a result of the long wave radiation emitted from the absorbing body at the base of the basin (Wm^{-2}).

Qc-cond is the thermal energy absorbed by the condenser as a result of the heat flow from the absorbent body at the base of the basin (Wm^{-2}).

Qe-cond is the thermal energy absorbed by the condenser as a result of condensation of water vapor (Wm^{-2}).

Qcond-ca is the thermal energy that the condenser loses by conducting it to the surrounding air outside the distillation (Wm^{-2}).

Qcond-cw is the thermal energy lost by the condenser by conducting the cooling water outside the distillation (Wm^{-2}).

RESULTS AND DISCUSSION

1. The data were taken from an experiment on a solar distiller conducted in 2016.
   - Glass cover temperature unity C^0.
   - Evaporator temperature unity C^0.
   - Condenser temperature unity C^0.
   - The intensity of solar radiation falling on the horizontal surface units WM^{-2}.
2. Find mathematical equations for the heat transfer on each part of distilled parts.

The basic idea of the distillate solar operation depends on the existence of a heat-insulated basin, where is saltwater with shallow depth in its base which is usually black. the upper surface is tightly closed using sloping board made of transparent material (like glass or plastic)[12], where the basin is established with a position that extends along the line between the East and the West and its upper surface tilts at the angle equal to the latitudes of the place, though the transparent surface of the distillate will be exposed to sun light all day, then the Short-wave solar beam (3-0.1)micron will pass through the transparent surface, this beam will raise the temperature of the components of the basin which results in producing heat waves with wavelength of 32 micron [13], the transparent surface does not allows access ,so they are captured inside the distillate and this is known as greenhouses phenomenon, which raises the temperature inside the distillate . This works on heats the water in the base then evaporates it. Since the surface is made of transparent material , it does not Absorb large amount of solar energy and it loses part of its heat as well because of the contact of the surface with the air, there for its temperature is less than the water in the base [14], which leads for the load currents that transports the vapor ,that was made of the surface of the water, to the transparent surface , where the vapor is collected on the internal surface of the transparent surface because of its relatively coldness ,creating distilled water which descends with the slope of the surface by the gravitational force and the strength of adhesion with the surface material, so the distilled water descends to the collecting passage then to the water distillation tank [15].

The amount of energy absorbed from the distilled parts was calculated in working hours through the device designed in the Department of Atmospheric Sciences, Figure 2 illustrates the temperature change of the parts of the solar distillation with the temperature of ambient air, where (T1) is the temperature of the surface of the outer glass cover for each hour of the day. (T2) is the surface temperature of the internal glass cover for each day of the day (T3) is the surface temperature of the evaporator (the radiation absorbent body) per hour of the day, (T4) is the temperature of the air and steam mixture inside the distillate for each hour of the day (T5) is the temperature of the outer portion from the extra capacitor of the distillate, for every hour of the day, (T6) is the temperature of the inner portion of the extra capacitor for the distillate, and each hour of the day, (T7) is the ambient temperature of the distillate for each hour of the day, T5 is lower than all values of the temperature measurements of the portion's being outer of the extra capacitor is placed in water while the value of T4 to form all the measurements recorded is due to the decrease or retention of the solar energy inside the distilled with water vapor. Distilled parts change temperature with an ambient temperature.

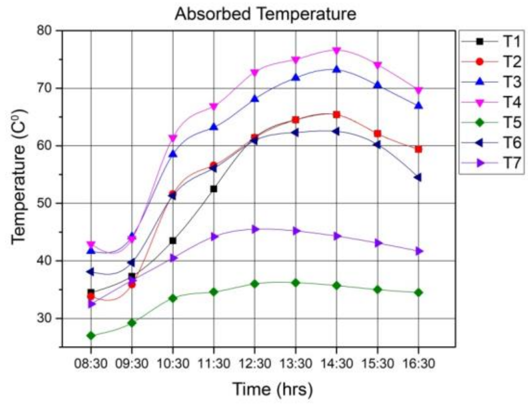

Figure 2. The temperature change of the parts of the solar distillation with the temperature of ambient air.

Figure 3 shows the thermal balance between the amount of energy lost from the absorbed part and the amount of energy gained from the absorbed part since the amount of energy lost is higher than the amount of energy absorbed since the beginning The daytime until it reaches its highest value (550 w/m^2) at (01:00 pm), and begins with a gradual decrease with an increase in the amount of energy absorbed until it reaches its highest levels (525 w/m^2) at (02:30 pm), this shows that the amount of energy acquired by the absorbed body depends on the amount of energy trapped inside the solar distillery. The higher the energy gained, the greater the absorption process.

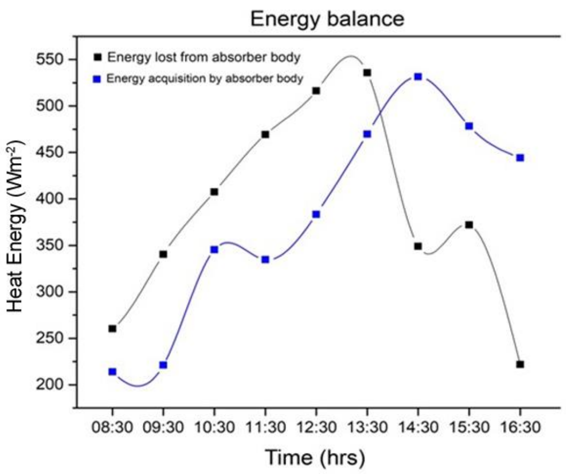

Figure 3. The energy balance of the absorber body.

Figure 4 shows the amount of energy falling on the outer surface of the distillate and the amount of absorption obtained in the inner part of the distillate as the fallen solar energy begins to rise at the beginning of the day It reaches a peak of (660 w/m^2) at (02:30 pm), while the amount of radiation absorbed is at its highest value (655 w/m^2) at (01:00). The difference between the amount of incident radiation and the energy absorbed can also be observed at (09:00 am). The amount of energy falling on the surface is higher than the amount of energy absorbed from the inner part of the distillate until we reach the inversion stage in values at (11:30 am), as the amount of absorption is higher than the amount of energy reaching the outer surface of the distillate, and this process shows that the distillate has reached a limit Saturation from the absorption of solar energy and its concentration on the surface of the saltwater at the base of the solar distillery. The difference between the amount of solar energy falling on the outer surface of the distillate and the amount of energy absorbed from the inner surface is relatively close with a slight rise in the energy of the radiation. Solar and also the values are at their highest levels (700 w/m^2) at (02:00 pm).

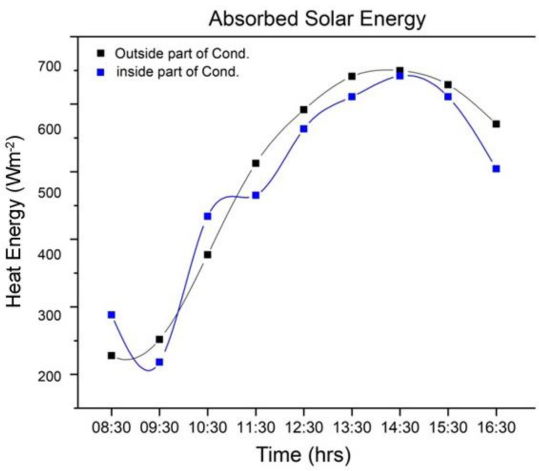

Figure 4. The absorbed solar energy by the distillate.

CONCLUSION

1- The energy transfer process in the solar distillation with an additional condenser passes through three main stations:
- First: the glass cover.
- Second: the absorbent part at the base of the distillate.
- Third: the two ends of the additional condenser inside and outside the distillation.

2- The model proved that the difference between the amount of energy received and lost in the absorbent part of the solar distiller had a significant effect in controlling the temperature of the internal distillation parts.

3- The thermal balance that was calculated through the mathematical model of energy transfer between the two ends of the auxiliary condenser, the inner part and the outer part cooled with water contributed to making the temperature of the additional condenser lower than the rest of the distillate parts, thus turning into a basic condensation point more important than the condensation on the adopted inner glass cover In the work of solar distillates.

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