EVALUATION THE PERFORMANCE OF A HORIZONTAL A PROTOTYPE NATURAL DRAUGHT SOLAR DRYER

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ABSTRACT

In the present work, the experiments were carried out at the Mechanical Power Department, Faculty of Engineering, El-Mansoura University, in the year 2008. An experimental study on a horizontal prototype solar dryer with natural draught of water vapor. The experiments were performed some days during four menthes from March to June. Experimentation started at 9 a.m. and ended at 4 p.m. The present work is aimed to examine the thermal performance of a prototype solar dryer with natural draught under Egyptian climate conditions. In this process, solar radiation striking the wetted black coated bed surface causes evaporation to occur. The vapor transfers from the bed, by convection through the outlet duct to the atmosphere.

The solar dryer under investigation is a simple rectangular basin containing a wetted black wick and covered with a glass layer. A vertical duct is used to remove the water vapor from the solar dryer enclosure. The ambient air is drawn to the system by heating the black wick and the hot and humid air and then vented via a vertical draught tube. Experiments are carried out to examine the variation of system parameters with time. The objective of the experimental work is to study the performance of the dryer and evaluate the effects of ambient conditions on the rate of evaporation of water from the wetted wick. Measurements of solar radiation, ambient air temperature and humidity of inlet and outlet air through the duct are taken during the experimental testes. The mass transfer potential which is defined as the vapor pressure difference between the hot wick and the ambient air inside the system is also evaluated and presented graphically with time. Also, system drying efficiency is defined and plotted with time for a sample of the experimental data. Results have shown that as follows:

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1- *The wetted black wick surface temperature increase with time and reaches a maximum limit in the afternoon, then decreases with time again at the end of the day.*
2- *The wetted black wick surface temperature increase with time and reaches a maximum limit in the afternoon, then decreases with time again at the end of the day.*
3- *The values of absorber surface temperature are higher than that of outlet and inlet streams of air.*
4- *The potential for mass transfer of vapor from the wetted black coated surface to air is proportional to the vapor pressure difference between black coated surface and air stream.*
5- *In most cases, the average of vapor pressure on the wetted black wick reaches a maximum of 41* kN/m^2 *at the noon, which is about 34* kN/m^2 *higher than that of the air stream at dryer exit*
6- *Augmentation of the natural draught can be obtained with higher values of vapor pressure on the black coated surface.*
7- *The variations of drying air temperature at the inlet and outlet of the dryer and the corresponding relative humidity at the inlet and outlet of the dryer was well as the relative humidity of the ambient air.*
8- *The hourly values of outlet air humidity can be used to evaluate the cooling rate of the system, which equals the product of latent heat of water and the mass of water evaporated.*
9- *The solar radiation increases gradually to a maximum value of* $734.38 W/m^2$ *near noon time, and then decreases again to the end of the day*
10- *The heat transfer rates* q_r, q_c, q_e *and* q_{ia} *increases with time and reaches a maximum limit near the noon time, then decreased again to the end of the day.*
11- *The dryer efficiency increases with the increase of solar radiation and decreases with the decrease in the air flow rate. The maximum dryer efficiency 21.95% has been obtained.*

Finally, it must be recorded that no condensation of water vapor on the glass surface observed during experiments. This is a proof that the

vapor pressure difference between air and glass is kept at maximum level by the draught of air. The long term performances of the considered solar air dryer clearly prove that these systems can be used as a source of the hot air for space heating and drying applications for different agriculture crops all over the year.

Keywords: *Natural draught- water vapor- solar dryer.*

INTRODUCTION

Energy in various forms has played an increasingly important role in the world wide economic progress and industrialization. In view of the world's depleting fossil fuel resources, which provide the major source of energy, the development of non-conventional renewable energy sources has received an impetus.

Renewable energy technologies are substantially safer offering a solution to many environmental and social problems associated with fossil and nuclear fuels. Solar energy is one type of renewable energy, which provides obvious environmental advantages in comparison with conventional energy sources. **Raman and Twari (2008)** have shown that amongst available energy sources, solar energy is freely available everywhere, more economical and truly environment friendly than any other available sources of energy. One of the simplest and most efficient way to utilize solar energy is to convert it to thermal energy for heating applications by using solar collectors.

The solar air heater occupies an important place among solar heating devices because of minimal use of materials and low cost. Moreover, because of their simplicity, solar air heaters are most widely used collection device of solar energy. Solar air heaters have low thermal efficiency because of poor convective heat transfer coefficient between the heated air and the absorber plate which leads to higher absorber temperature and hence causes larger losses to the environment **Bhagoria et al. (2002)**. It has been found that the main thermal resistance to the convective heat transfer is due to the formation of boundary layer on the heat transfer surface. Efforts for increasing heat transfer coefficient have been directed towards artificially destroying or disturbing the boundary layer. The thermal efficiency of solar air heaters has been found to be generally poor because of their inherently low heat transfer capability between the absorber plate and the flowing heated air. In order to make the solar air heaters economically viable, their thermal efficiency needs to be improved by enhancing the heat transfer coefficient.

Gao et al (2007) found that the use of selective coating on the absorber plate can substantially enhance the thermal performances of the solar air heaters. On the other hand, using such selective coating on the bottom plates or/and the glass covers does not have such a significant effect on the thermal performances of the heaters.

Traditional exposure to sun drying is the simplest; however, it is associated with low quality product and crop losses. Several successful improvements have been done and studied at developing solar drying systems to offer quality product, shorten the drying time and reduce crop losses. For example, natural convection solar dryers, either cabinet or tunnel type are studied by **Forson et al (2003) and Hossain and Bala (2007)**. Mixed convection type is investigated by **Shanmugam and Natarajan (2006) and Forson et al. (2007)**, while greenhouse type dryers are investigated by **Koyuncu (2006)**. In addition **Karim and Hawlader (2004)** reported that the improvements in solar drying come with a price; the solar drying system becomes too complex and expensive. In many cases, the application of these systems in rural areas and developing countries requires either imported commercial components for solar dryers or imported material to build them.

Solar drying is the most oldest and preferred method for drying agricultural products. Though well developed, and still a good deal of work is continuing in this direction throughout the world**. Shanmugam, and Natarajan (2007)** reported that continuous drying process throughout the day is very important to dry the produces to its safe storage level. However, Prasad and Mullick (1985) indicated that, natural solar drying is bound to be the main way out, for which a scientific study is relevant. This process is based principally on the capability of air to be mixed with large quantities of water vapor. Its thermodynamic background can be clearly explained by using the psychometric chart **Dai et al. (2002)**.

Various designs of solar dryers are developed and tested for their thermal performance. Each differs in design and is developed for a specific product. However, passive type of solar crop dryers is well realized and it overcomes the problems existing in the open sun dryer and cabinet type of dryers **Tiwari, et al., (1997)**.

Solar dryers must be properly designed in order to meet particular requirements of specific products and to give satisfactory performance. Designers should investigate the basic parameters such as dimensions, system temperature, ambient air relative humidity, air mass flow rate and the characteristics of products to be dried. However, full-scale experiments for different products, drying seasons and system configurations are sometimes costly and may not possible. The development of a simulation model is a valuable tool for predicting the performance of solar drying systems. Again, simulation of solar drying is essential to optimize the dimensions of solar drying systems and optimization technique can be used for optimal design of solar drying systems **Bala (1998)**.

In Egypt, the open air solar drying process for agriculture crops is used from long ago. The amount of losses and damage in crops are considerable. Birds and air pollution have also a negative impact on the quality of the dried crops. The level of solar radiation in Egypt is adequate for using cabinet and tunnel type solar dryers for agricultural crops. The time of the drying process is expected to be shorter and the quality of dried crops will be enhanced. The present work is aimed to examine the thermal performance of a prototype solar dryer with natural draught under Egyptian climate conditions. In this process, solar radiation striking the wetted black coated bed surface causes evaporation to occur. The vapor transfers from the bed, by convection through the outlet duct to the atmosphere.

EXPERIMENTAL SETUP AND PROCEDURE

Experimental setup

The experimental setup consists as shown in Fig. 1 of a prototype solar dryer in the form of a rectangular box of base dimensions 1 x 0.5 m and 0.1 m height. The frame of the dryer is made of riveted aluminum. The base which is made from 5 mm thick wood is supported by rubber to prevent leakage. A black-coated wick with the same basin area and 0.5 cm thickness was used as an absorber plate for incident solar radiation.

The dryer is covered with ordinary window glass layer of 3 mm thickness which is used as a transparent cover for the solar dryer to reduce the top heat losses. In addition, the glass cover has many operational and performance advantages as reported by **Nelson and Wood (1990)**. The glazing protects the black-coated bed from rain, birds, insects, dust and reduces contamination by other environmental sources. The glazing also greatly reduces the convective heat loss from the wetted wick due to wind and the infrared radiation to the environment. But a decrease in the water evaporation rate may also occur due to a reduction of the convection mass-transfer coefficient unless the driving potential, which is the vapor pressure difference between the black-coated bed with water and adjacent air, is simultaneously increased.

Ambient air is allowed to get inside the dryer and flow over the wick through an opening of about 135 cm^2 area. The mixture of the air and water vapor was vented through a cylindrical duct of 1.7 m height and 5 cm diameter, which is supported vertically to the edge with the base of dryer as shown in the same figure.

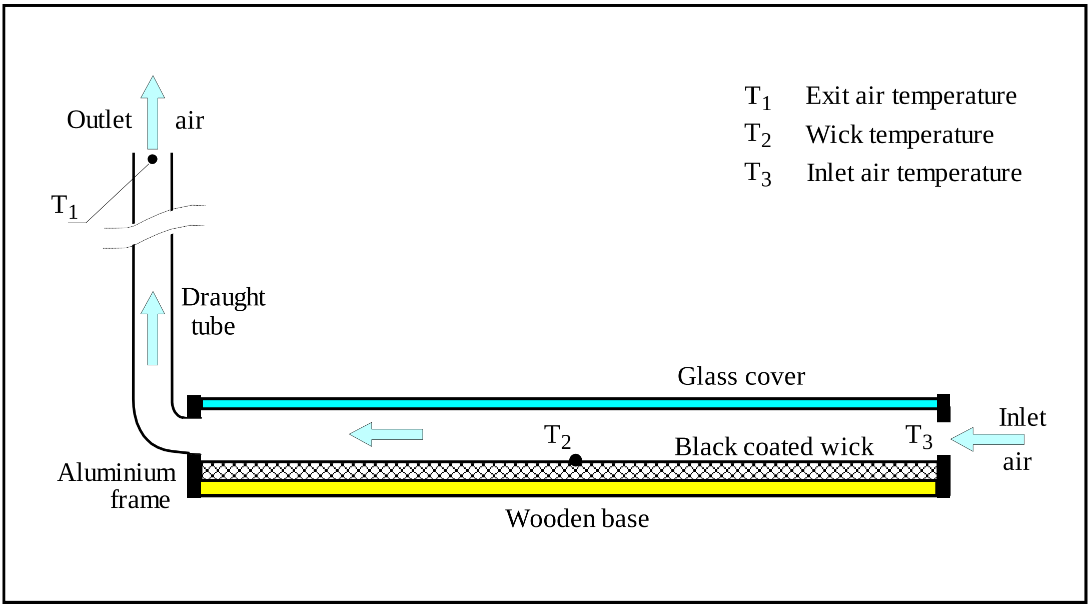


Fig. 1 Schematic diagram of the experimental setup.

Experimental procedure

The experiments were carried out at the Mechanical Power Department, Faculty of Engineering, El-Mansoura University, in the year 2008. The experiments were performed some days during four months from March to June. Experimentation started at 9 a.m. and ended at 4 p.m. An amount of water (200 ml) is sprayed on black wick bed each 1 hour during the experimental run to keep it in wet condition. The falling solar radiation is absorbed by the wetted black wick causing the water to evaporate from it to the inside air. The hot air vapor-mixture inside the solar dryer is moved through the vertical duct by natural draught to the outside.

The setup is suitably instrumented to measure the air velocity and temperatures at different points during the experimental test. The wetted bed surface temperature is measured at the center. Dry and wet bulb temperatures of the air stream entering the duct and ambient air are also measured using dry and wet bulb thermometers. The specific humidity, w (g/kg) is calculated using the psychrometric chart.

A hot wire anemometer (Airflow, model TA5, accuracy ±2%) is employed to monitor the air velocity in the dryer and the air duct. This anemometer was also used to monitor the wind speed. The air velocity in the solar dryer and the air duct were also recorded during the experiments. The air flow rate was calculated using the measured air velocity at the dryer outlet. Solar radiation intensity on the horizontal surface is measured by recording the short circuit direct current of a calibrated solar cell using a digital millimeter. The performance of the solar dryer is evaluated by measurements each half hour time interval during the day time.

GOVERNING EQUATIONS

The potential for mass transfer from the surface of the wetted black wick in the solar dryer is the vapor pressure difference between the wick surface and the air inside. The vapor pressure on the wick surface can be evaluated in terms of the wick temperature which is the same as that of water in the wick. As in the conventional solar still, the vapor pressure in the gap between water surface and glass cover gradually increases with temperature rise. However, release of vapor from the wick surface is augmented with increasing vapor pressure difference between water in the wick surface and air inside the dryer. This means that continuous removing of vapor from the wick decreases the vapor pressure difference, which is the driving potential for the mass transfer process. The vertical duct removes the produced vapor and keeps the vapor pressure in the gab at a lower level, which consequently enhances the evaporation of water from the wick. On the other hand, to simplify the analysis, the **Dunkle model (1961)** used for solar still can be applied in this case and the glass temperature in the model will be replaced by the inside air temperature **(Darwish, et al 1995)**.

The energy balance on the system can be carried on a control volume and yields the energy conservation equation is given as,

$$q_{ia} = q_r + q_c + q_e + \alpha_g H_s \qquad (\mathrm{W/m^2}) \qquad (1)$$

Where, q_{ia} is the heat lost by convection and radiation together from inside basin to environment ($\mathrm{W/m^2}$), q_r, q_c, and q_e are the radiation, convection and evaporation heat transfer rates($\mathrm{W/m^2}$), respectively, α_g is the absorptance of glass cover (0.1) and.H_s is the total solar radiation intensity on the horizontal surface($\mathrm{W/m^2}$).

The radiation and convection heat transfer rates from water in the wick surface to glass (q_r and q_c) can be evaluated as follows:

$$q_r = 0.9\sigma\left|(T_w)^4 - (T_i)^4\right| \qquad (\mathrm{W/m^2}) \qquad (2)$$

$$q_c = 0.8831\left[(T_w - T_i) + \left[\frac{P_w - P_{wi}}{0.265 - P_w}\right](T_w)\right]^{1/3}(T_w - T_i) \qquad (\mathrm{W/m^2}) \qquad (3)$$

Where, σ Stefan-Boltzmann constant ($56.7\mathrm{x}10^{-9}$ $\mathrm{W/m^2\,k^4}$), T_w and T_i are the wetted black wick and inside air temperature (°k), respectively, p_w and p_i are vapor pressure of the wetted black wick at T_w and vapor pressure of the inside air at T_i($\mathrm{MN/m^2}$).

The evaporation heat transfer rate, q_e which determines the rate of water evaporation as follows :

$$q_e = 1.92 \times 10^{-3} \left[\left(T_w - T_i\right) + \left(\frac{p_w - p_{wi}}{0.265 - p_w} \right) \left(T_w\right) \right]^{1/3} \left(p_w - p_{wi}\right) L_w \quad (W/m^2) \qquad (4)$$

Where, L_w latent heat of evaporation at T_w(kJ/kg) .

The mass of evaporated water, m_v can be evaluated from,

$$m_v = m_a\left(\omega_o - \omega_i\right) \qquad (kg/s) \qquad (5)$$

Where, ω_i and ω_o are specific humidity of air at inlet and outlet(g/kg), respectively and m_a is dry air flow rate(kg/s), which is given by:

$$m_a = \rho V A_t \qquad (kg/s) \qquad (6)$$

Where, ρ is air density(kg/m^3), V is air speed at draught tube(m/sec). and A_t, is draught tube cross section area(m^2).

An important factor for solar dryer is the system efficiency η_d (%) , which can be defined as,

$$\eta_d = \frac{m_v\ L_w}{H_s\ A_s} \qquad (\%) \qquad (7)$$

Where, A_s, is wick surface area (m^2).

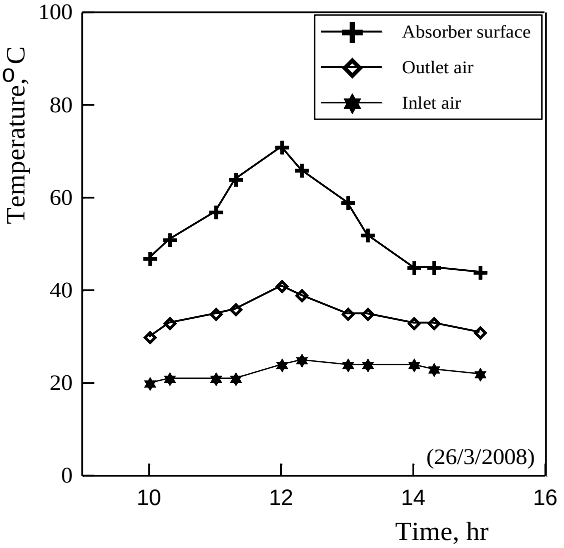
These equations are used to evaluate the values q_{ia}, q_r, q_c, and q_e. The dryer efficiency can be also calculated from equation (7).

RESULTS AND DISCUSSION

Experimental tests were carried out during the period from March to June 2008. Natural draught of water vapor from wetted black wick using solar energy was experimentally investigated during some selected days of system operation. Hourly recorded temperatures (wick surface, outlet air and inlet air temperatures) and calculated results are presented in terms of different measured specific humidity and vapor pressure of outlet and air humidity and (absorber surface vapor pressure, outlet air vapor pressure and inlet air vapor pressure), respectively. Air speed at draught tube and solar radiation intensity on the horizontal surface were also recorded.

Typical results of hourly variation of different values of absorber surface temperature, outlet air temperature and inlet air temperature for different days of system operation are presented graphically in Fig. 2. In all cases, it can be observed that the absorber surface temperature increases with time and reaches a maximum limit around the noon time, then decrease again at the end of the day. It is clear that the absorber surface temperature is always higher than that of outlet and inlet air streams. Moreover, it can be observed that the outlet and inlet air temperature are nearly parallel where the temperature increases gradually with the increase in the daytime. The temperature profile of black coated wick indicates that the energy is continuously stored in the wetted black wick, which will result in successive increase in temperature in the afternoon period. The potential for mass transfer of vapor from the black coated surface of the wick to the air is the vapor pressure difference between black coated surface and air stream.

However, vapor pressure of inlet air is relatively constant, for a given period of system operation; therefore the vapor pressure on the black coated surface is the most important parameter. Augmentation of the natural draught, for the proposed system, can be obtained with higher values of vapor pressure on the black coated surface. The variation of evaluated values of specific humidity (outlet and inlet air humidity) and the variation of evaluated values of vapor pressure on the black coated surface and that of the air stream at dryer inlet and outlet is illustrated in Fig 3 for different days of system operation.



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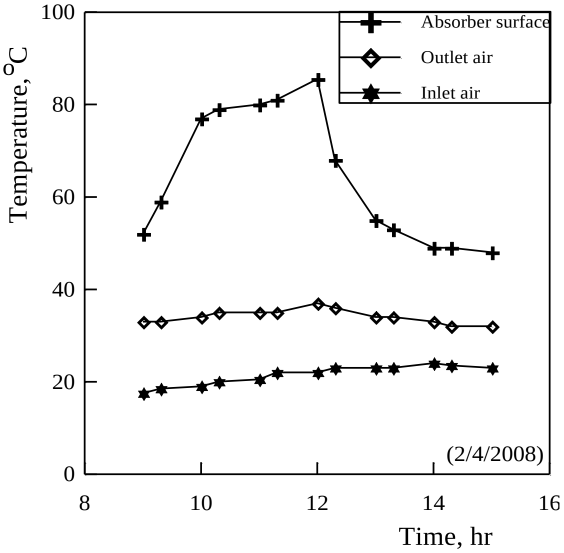

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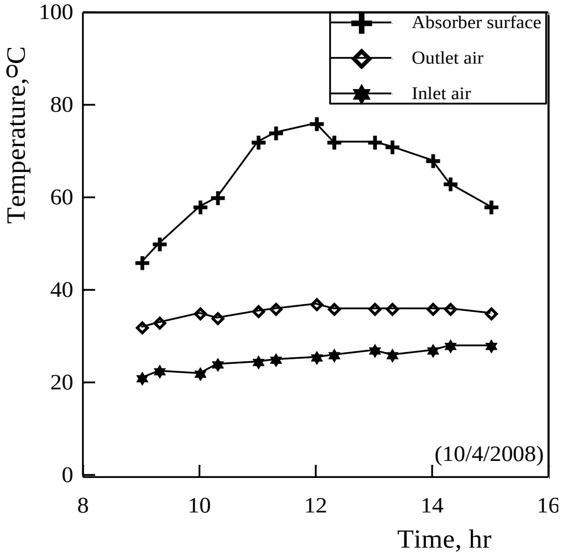
Temperature, oC
Time, hr
Absorber surface
Outlet air
Inlet air
(10/4/2008)
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100
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12
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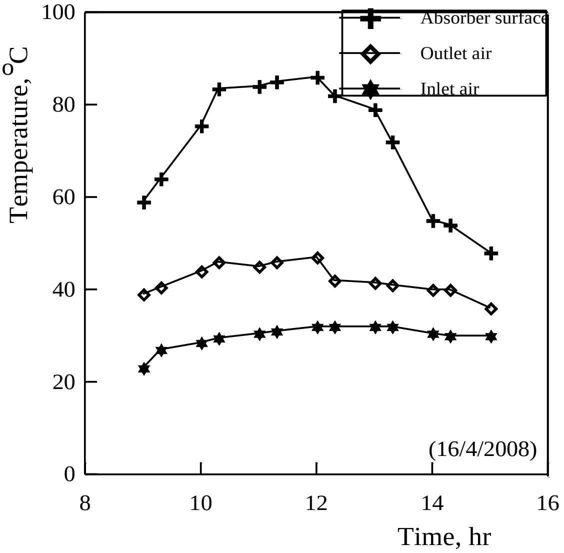
(2-c)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Time, hr
Absorber surface
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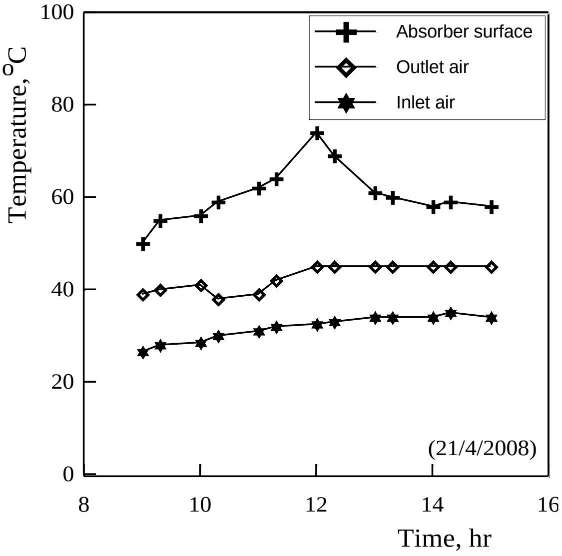
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Absorber surface
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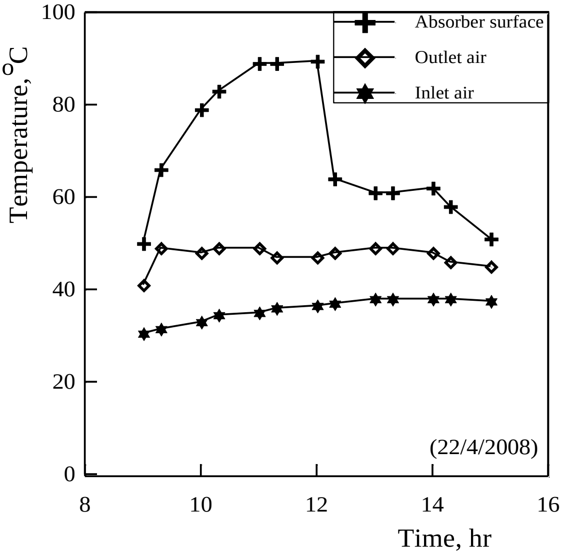
Temperature, oC
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Absorber surface
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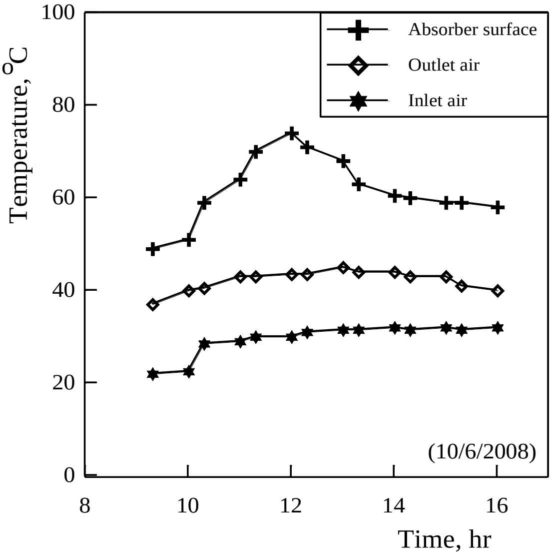

(2-g)

Fig. 2 Variation of temperatures during daytime

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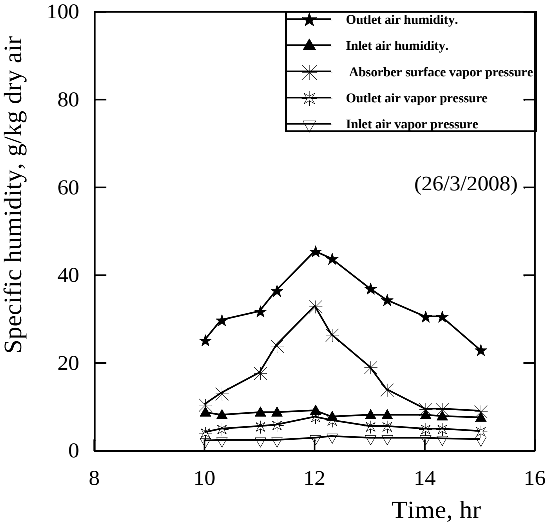
In most cases, the average of vapor pressure on the wetted black wick reaches a maximum of 41 kN/m^2 at the noon, which is about 34 kN/m^2 higher than that of the air stream at dryer exit. This shows that the drying potential of the wetted black wick is increased and maintains the temperature level well above the ambient temperature. The decrease in temperature of the wetted black wick after the peak is mainly due to the fall in solar radiation and heat losses to the ambient air circulated through the draught.

It can be observed that the profile of vapor pressure on the black coated surface agrees with that of black coated temperature, these values are higher than that of inlet and outlet streams of air. Also, it can be seen that the difference in vapor pressure between inlet and outlet air streams is nearly constant. In the morning, the absorber surface temperature rapidly increases and consequently the vapor pressure of water on the wetted black wick also increases. It can be shown that the mass of water evaporated increases gradually and the accumulation continuous in the afternoon period. The continuous natural draught in the afternoon period results from the successive increase in black coated surface temperature, which can be explained as follows: when water is evaporated from the wetted black wick, consequently its thermal capacity increase, therefore its temperature increases and the dryer functions as a solar pond. This can be understood from the temperature profile of the wetted black wick in the basin. Moreover, the wetted black wick surface acted like free water, so that the cooling produced by evaporation was important. The rewetting behaviors of the black wick surface were then investigated. In the beginning of drying cycle, the rate of moisture evaporation loss is very high and decreases as the drying proceeds. . Enhancement of the convection mass transfer rate can be attained by continuous removal of vapor from the dryer. Therefore, natural draught of vapor from the dryer is carried out with the help of adding the water, which is a vertical duct supported on the dryer surface.

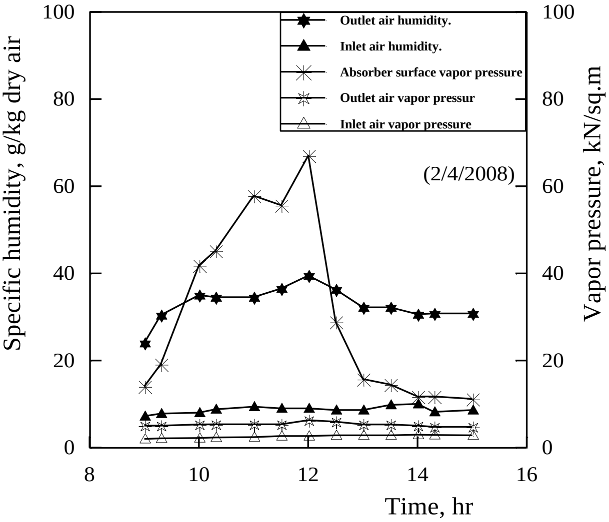
The variation of calculated values of the specific humidity at the outlet and inlet of the air stream with time at dryer for a typical experimental run is shown in the same figure for different days of system operation. The difference between inlet and outlet air humidity depends on the inlet conditions. The decrease in inlet humidity of air stream increases the potential of mass transfer. It can be observed that the difference between inlet and outlet humidity increases with increases inlet moisture content.

The variations of drying air temperature at the inlet and outlet of the dryer and the corresponding relative humidity at the inlet and outlet of the dryer as well as the relative humidity of the ambient air are also shown. The drying air temperature recorded a maximum value at noon while the specific humidity showed a minimum. However, the ambient temperature and relative humidity were the lowest and the highest, respectively. It is observed that at the end of the day of the experiment the inlet and the outlet air temperature show the same trend. This is likely due to the fact that energy required for evaporation is relatively small at the end of the drying process and the temperature difference is mainly from heat losses. For the specific humidity, it is also observed that after 15:00 h, the difference between the inlet and outlet relative humidity is small because the moisture released from the wetted black wick is relatively low due to low radiation.

On the same figure, the variation of specific humidity during daytime, which is given in g/kg dry air, is also presented. The hourly values of outlet air humidity can be used to evaluate the cooling rate of the system, which equals the product of latent heat of water and the mass of water evaporated. However, the air dry bulb temperature increases as the specific humidity reduces. This is due to the heat generated in the process as a result of water vapor condensation in the air. The air wet bulb temperature as seen in these figures remains constant.



(3-a)



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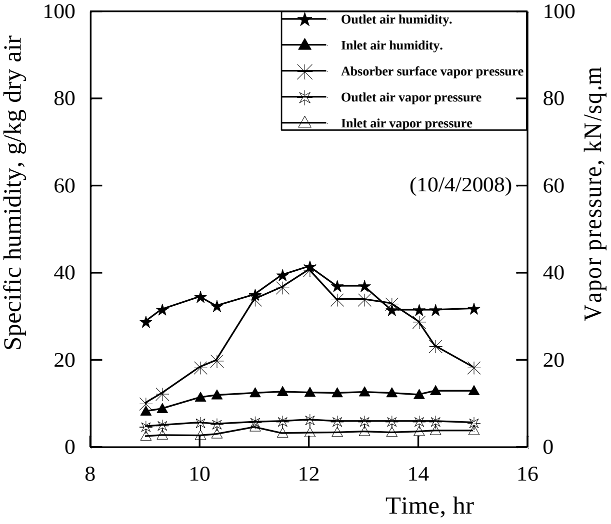

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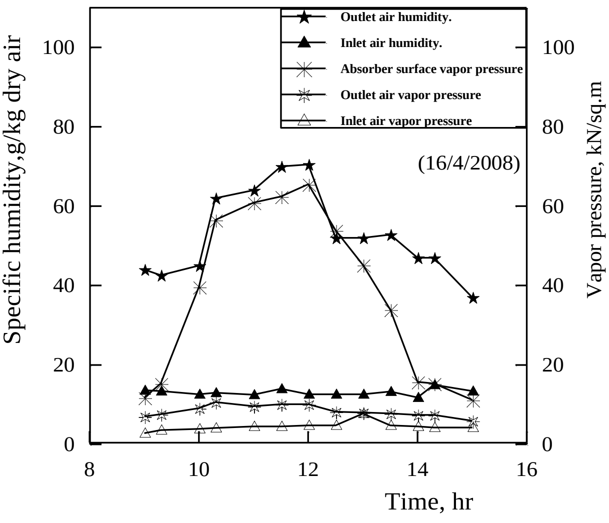
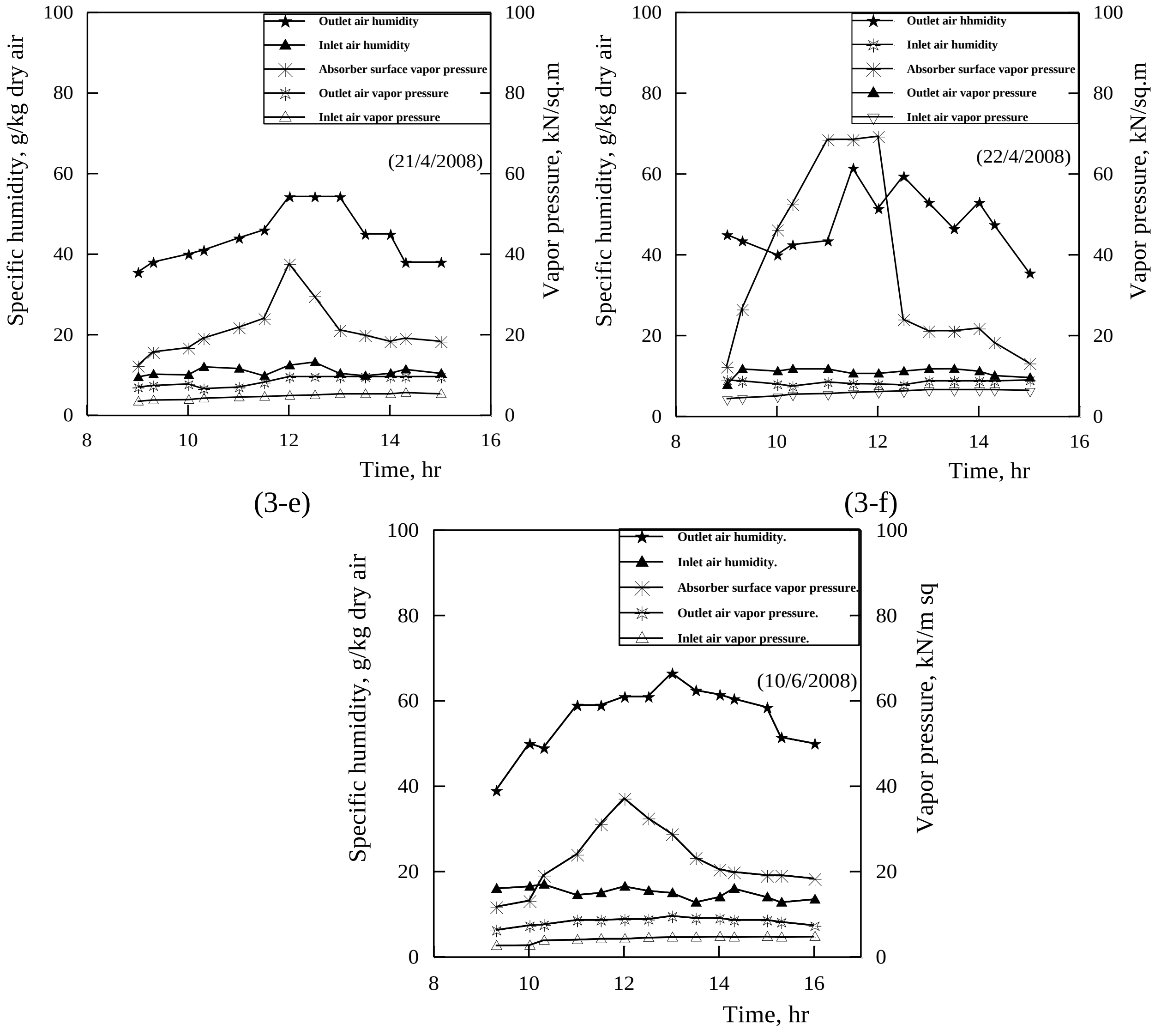


(3-d)



(3-e)

(3-f)

(3-g)

Fig. 3 variation of specific humidity and vapor pressure during daytime

Figure 4 shows the hourly values of solar radiation on a horizontal surface during a selected clear sky day (10/6/2008). It can be shown that the solar radiation increases gradually to a maximum value of 734.38W/m^2 near noon time, and then decreases again at the end of the day. This figure shows also the effect of incident radiation on the evaporation rate. This relation play a decisive role in the system efficiency, where the efficiency increases with the increase of solar incident radiation and decreases with the decrease in the flow rate of air.

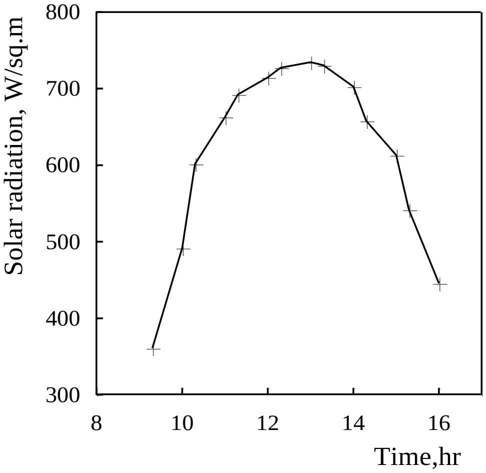


Fig.4 Solar radiation during daytime at (10/6/2008).

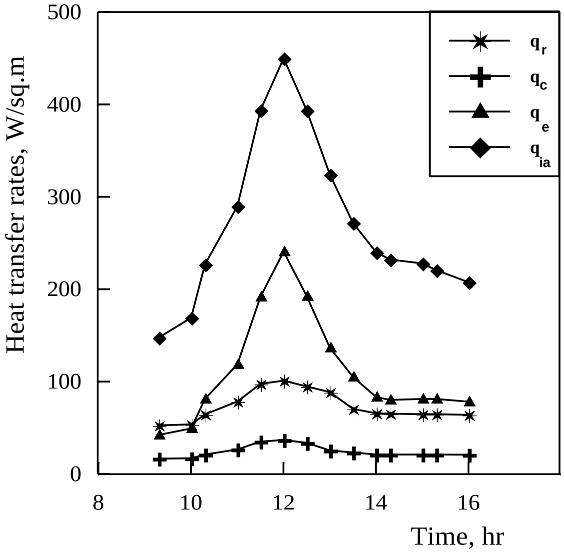


Fig. 5 Variation of heat transfer rates during daytime at (10/6/2008).

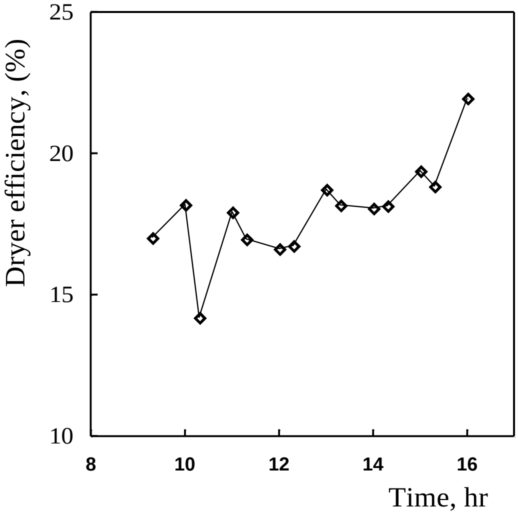


Fig. 6 Variation of dryer efficiency during daytime at (10/6/2008).

The variation of the heat lost by convection and radiation together from inside to the ambient air q_{ia}, the radiation, convection and vaporation heat transfer rates q_r, q_c, and q_e respectively for one clear sky day experiment (10/6/2008) as an example is illustrated in Fig. 5. It can be seen that the heat transfer rates q_r, q_c, q_e and q_{ia} increases with time and reaches a maximum limit near the noon time, then decreased again at the end of the day. The evaporation heat transfer rate depends mainly on the wetted black wick temperature (T_w) and inside air temperature (T_i).

The dryer efficiency for the same day experiment (10/6/2008) is presented in Fig. (6). It can be observed that the dryer efficiency increases with time during the day time. The dryer efficiency increases with increasing the mass of evaporated water inside dryer from the wetted black wick (m_v). The dryer efficiency depends also on solar radiation intensity (H_s) and wick surface area (A_s). The maximum dryer efficiency value attained that day was 21.95% at 16 hr. The lower value of the dryer thermal efficiency is probably due the lower natural draught capacity.

CONCLUSIONS

A prototype natural-draught solar dryer has been designed and tested to study the effect of the climatic conditions during the daytime on the system performance. From the discussion and analysis of the experimental data, the following conclusions can be summarized: The wetted black wick surface temperature increase with time and reaches a maximum limit in the afternoon, then decreases with time again at the end of the day.

1. The values of absorber surface temperature are higher than that of outlet and inlet streams of air.
2. The potential for mass transfer of vapor from the wetted black coated surface to air is proportional to the vapor pressure difference between black coated surface and air stream.
3. In most cases, the average of vapor pressure on the wetted black wick reaches a maximum of 41 kN/m^2 at the noon, which is about 34 kN/m^2 higher than that of the air stream at dryer exit
4. Augmentation of the natural draught can be obtained with higher values of vapor pressure on the black coated surface.
5. The variations of drying air temperature at the inlet and outlet of the dryer and the corresponding relative humidity at the inlet and outlet of the dryer was well as the relative humidity of the ambient air.
6. The hourly values of outlet air humidity can be used to evaluate the cooling rate of the system, which equals the product of latent heat of water and the mass of water evaporated.
7. The solar radiation increases gradually to a maximum value of 734.38W/m^2 near noon time, and then decreases again to the end of the day
8. The heat transfer rates q_r, q_c, q_e and q_{ia} increases with time and reaches a maximum limit near the noon time, then decreased again at the end of the day.
9. The dryer efficiency increases with the increase of solar radiation and decreases with the decrease in the air flow rate. The maximum dryer efficiency 21.95% has been obtained.

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REFERENCES

Bala, BK., (1998) “Solar drying systems.” Udaipur: Agrotech Publishing Academy.

Bhagoria, JL., JS. Saini and SC. Solanki, (2002) “Heat transfer coefficient and friction factor correlations for rectangular solar air heater duct having transverse wedge shaped rib roughness on the absorber plate”, Renewable Energy, 25:341–69.

Dai, Y.J., R.Z. Wang, and H.F. Zhang, (2002) " Desalination”, 142: 107 .

Darwish, M. A., M. Mohamed, A. Abd elrazik, and S Elside, (1995)” Salt water desalination engineering systems”, Abd el Aziz University, Saiudia Arabia part 6, pp. 249-295.

Dunkle, R.V., (1961) ”Solar water distillation: the roof type still and a multiple effect diffusion still”, International Heat Transfer Conference, University of Colarado, U S A, Part 5, pp. 895-902 .

Forson, FK., MAA., Nazha, and H. Rajakaruna, (2003) ” Simulation and experimental studies on a single pass, double duct solar air heater”, Energy Conversion Management, 44:1209-27.

Forson FK., MAA., Nazha, FO., Akuffo and H. Rajakaruna, (2007) ” Design of mixed-mode natural convection solar crop dryers: application of principles and rules of thumb.” Renewable Energy 32;2306–19.

Gao W., L., Wenxian L., Tao and X. Chaofeng, (2007)” Analytical and experimental studies on the thermal performance of crosscorrugated and flat-plate solar air heaters", elseiver Applied Energy 84, 425–441.

Hossain MA. and BK. Bala, (2007) "Drying of hot chilli using solar tunnel drier", Solar Energy, 81:85–92.

Karim MN. and MNA. Hawlader,(2004) "Development of air collectors for drying applications. Energy Conver Manage 45:329–44.

Koyuncu T., (2006) "An investigation of the performance improvement of greenhouse-type agricultural dryers", Renewable Energy, 31:1055-71.

Nelson, D. J. and B. D. Wood, (1990) "Evaporation rate Model for a Natural Convection Glazed Collector/Regenerator", Trans ASME Journal of Solar Energy Engineering, Vol. 112, pp. 51-57.

Prasad K. and SC. Mullick, (1985) "Heat transfer characteristics of a solar air heater used for drying purpose." Applied Energy 12: 83–93.

Raman ,V and G.N. Tiwari, (2008) "Life cycle cost analysis of HPVT air collector under different Indian climatic conditions", Energy Policy, 36:603-611.

Shanmugam V. and E. Natarajan, (2006) "Experimental investigation of forced convection and dessicant integrated solar dryer", Renewable Energy, 31:1239–51.

Shanmugam V. and E Natarajan, (2007) "Experimental study of regenerative desiccant integrated solar dryer with and without reflective mirror" Applied Thermal Engineering, 27:1543–1551.

Tiwari, G.N., P.S. Bhatia, A.K. Singh, and R.K. Goyal, (1997) "Analytical studies of crop drying cum water heating system", Energy Conversion and Management, 38:751-759.

الملخص العربى

تقييم أداء نموذج مجفف أفقي شمسي يعمل بالسحب الطبيعي

***د/ صفية مصطفى الجيار**

تمت هذه الدراسة العملية بقسم هندسة القوى الميكانيكية-كلية الهندسة-جامعة المنصورة بهدف اختبار الأداء الحراري لنموذج مجفف شمسي يعمل بالسحب الطبيعي لبخار الماء تحت الظروف

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الجوية المصرية. هذا المجفف عبارة عن حوض مستطيل يحتوى على قطعة فتيل أسود مبلل ومغطى بطبقة من الزجاج. المجفف مثبت بأحد جوانبه مجرى رأسي لسحب بخار الماء المتصاعد من قطعة الفتيل الأسود المبلل في المجفف بسبب الإشعاع الشمسي المتساقط عليها والذي أدى إلى سخونتها. تم قياس شدة الإشعاع الشمسي ودرجة حرارة الهواء الجوى ورطوبة الهواء الداخل إلى المجفف والخارج من المجرى أثناء الاختبارات العملية. تم عمل التجارب العملية خلال أيام مختارة بداية من الساعة التاسع صباحا إلى الساعة الرابعة مساءا أثناء أربع شهور من شهر مارس ألي شهر يونيه سنة ٢٠٠٨ لاختبار اختلاف ظروف التشغيل مع الزمن وذلك بهدف دراسة أداء المجفف وتقييم تأثير العوامل الجوية على معدل تبخير الماء من قطعة الفتيل الأسود المبلل. كما تم تقييم منحنيات فرق ضغط البخار بين سطح الفتيل الساخن والهواء الجوى داخل المجفف مع الزمن.و أظهرت أهم النتائج التي تم عرضها بيانيا كالتالي:

١. تزداد درجة حرارة الفتيل الأسود المبلل مع الزمن وتصل أقصاها عند الظهر ثم تقل مرة أخرى في نهاية اليوم٠

٢. قيم درجة حرارة السطح الماص أعلى من قيم درجات الحرارة عند مدخل ومخرج مجرى الهواء ٠

٣. جهد انتقال كتلة البخار من السطح الأسود المبلل إلى الهواء يتناسب مع فرق الجهد بين السطح الأسود ومجرى الهواء٠

٤. في أكثر الحالات, يصل أقصى متوسط لضغط البخار على سطح الفتيل الأسود ٤١كيلو نيوتن/م^{٢} عند الظهر وهذه القيمة أعلى بحوالي ٣٤ كيلو نيوتن/م^{٢} عند نهاية مجرى هواء المجفف٠

٥. يتم الحصول على زيادة السحب الطبيعي مع ارتفاع قيم ضغط البخار على السطح الاسود٠

٦. يكثر اختلاف درجة حرارة الهواء الجاف والرطوبة النسبية عند مدخل ومخرج المجفف مع الرطوبة النسبية للهواء الجوى

٧. يستخدم قيم الهواء الرطب الخارج لتقييم معدل تبريد النظام والذي يساوى حرارة الماء الكامنة للمنتج وكتلة الماء المتبحر٠

٨. تزداد الأشعة الشمسية تدريجيا إلى أقصى قيمة(٧٣٤,٣٨) وات/م^{٢} عند الظهر ثم تقل مرة أخرى عند نهاية اليوم٠

٩. تزداد معدلات انتقال الحرارة بالإشعاع والحمل والتبخير مع الزمن وتصل إلى أقصاها عندا لظهر ثم تقل مرة أخرى عند نهاية اليوم ٠

١٠. تزداد كفاءة المجفف مع زيادة الأشعة الشمسية وتقل مع قلة معدل سريان الهواء٠وصلت أقصى كفاءة للمجفف الشمسي ٢١,٩٥٪٠

أخيرا, يلاحظ أثناء التجارب عدم حدوث تكثيف لبخار الماء على سطح الزجاج مما يدل على فرق ضغط البخار بين الهواء والزجاج ليحفظ أقصى مستوى بمجرى الهواء٠يتضح طوال مدة أداء مجفف الهواء الشمسي أن تلك الأنظمة تستخدم كمصدر للهواء الساخن لتدفئة الأماكن وتطبيقات تجفيف المنتجات الزراعية المختلفة على مدار العام ٠