Indian Streams Research Journal
Vol - I , ISSUE - IV May 2011 : Other **ISSN:-2230-7850**

Article : Thermal performance and analysis of low cost spherical solar still with charcoal absorber : --------

Author : G.Gowrisankar [RVS College of Engineering, Coimbatore, India] R. Jayaprakash [Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore] T. Arunkumar K.Perumal Sanjay Kumar Chandragupt Institute Of Management Chhajubagh, Patna] A.K. Abdul Hakeem [Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore] Sureshkumar [National Institute of Technology, Trichy]

ABSTRACT :

A comparative study was made between the performances of spherical solar still with charcoal absorber. It was studied in the climatic conditions of Coimbatore (11° N latitude), India. The area of the still was 0.30 m2. The still was covered by low density polyethylene sheet of thickness 0.107 mm with 90% of transmittance. The absorbance of water level is further increased by floating charcoal at the surface of the water level. The Nusselt and Grashof Numbers were calculated for both studies. The increase in potable water productivity caused, when using a spherical shape as well as adding charcoal was analyzed.

KEY WORDS :

Spherical solar still, Productivity.

INTRODUCTION :

We may not able to separate the two important words, water and the environment. These are the most essential part of our life cycle. The world is polluted due to the increasing the population and the needs of the human beings. So the whole environment being collapsed at the rapid rate. About 97% of the world water is salt water in the oceans: 3% of all fresh water is in ground water, lakes and rivers, which is supply the most that needed by the human and animals. So every human and animals were depends on the ground water source and the rivers. But these sources are also getting destroyed by the fast growing factories and chemical wastes. The world's water consumption rate is doubling every 20 year, increasing two times the rate of population growth. It is projected that by the year 2025, water demand will exceed supply by 56%, due to persistent regional droughts, shifting of the population to urban coastal cities, and industrial growth. The supply of fresh water is on the decreasing mode, whereas water demand for food, industry and people is on the rising mode. Lack of fresh water reduces economic development and lowers living standards. There is an important need for clean and pure drinking water in many developing countries. Often water sources are brackish (i.e. contain dissolved salts) and/or contain harmful bacteria, hence cannot be used for drinking. In addition, there are many coastal locations where seawater is abundant but potable water is not available. Pure water is also useful for batteries, hospitals and schools. Distillation is one of many processes that can be used for water purification. This requires an energy input like heat; solar radiation can also be a source of energy in this process. Water gets evaporated, and separated as water vapor from dissolved matter, which is condensed as pure water. Desalination powered renewable energy sources can be an ideal solution for small scale communities, where affordable fossil fuel supply is not available [1]. A solar still is a device by which distilled or portable water can be produced from saline water sources like such as sea water or brackish water. Solar stills are normally used to provide small scale portable water needed in remote isolated locations [2]. A review of various designs of solar stills was made by Malik et al., [3]. The different designs of solar stills [4] were studied by Al-Hayek and Badran. Al-Hussaini and Smith used vacuum technology [5], Kalogirou [6] designed a parabolic trough solar stills and El-Sebaii developed triple basin solar stills [7] for enhancing productivity from the solar stills. In order to improve the performance of conventional solar stills, several other designs have been developed such as the double basin type [8], multi basin type [9], inverted trickle [10] and pyramid type [11].

The aim of the work is to study the performance of newly designed spherical solar still with and without charcoal absorber. The distilled water output and efficiency are also compared between both studies.

Fabrication details of the spherical solar still :

Fig. 1shows the pictorial view of Spherical Solar Still. Fig. 2 shows the schematic diagram of 0.30 m2 spherical solar still. The total height of the still is about 0.63 m. The still consists of circular basin of diameter 0.60 m which is made up of steel. The circular absorber basin is coated with black paint for maximum absorption of incident solar radiation. The circular basin is fixed at the middle of the spherical aluminum ring like a mesh at radial height of 0.28 m where saline water is stored. The storage capacity of the basin is around 16 litres. The basin in the spherical solar still is fitted without having any physical contact with the top cover made of low density polyethylene sheet. The low density polyethylene sheet of thickness 0.107 mm is spread over the spherical shaped ring like a mesh. A gap of 0.03 m is maintained between the circular basin and top cover. The outer cover of polyethylene is molded over the still without any air gap to prevent vapor leak. The evaporated water which is condensed over the top cover passes between this gap and creeps down towards the distilled water collection segment. The calibrated thermocouples are used to measure the temperature in the basin and also at different places of the still.

Experimental procedure of the spherical solar still :

Experimental measurements are performed to evaluate the performance of the spherical solar still under the clear climatic conditions of Coimbatore, India. (11° N latitude) The basin is filled with 8 litres of water. A layer of charcoal is allowed to float on the surface of the water. The experiment is conducted between 9:00 AM to 5:00 PM and its readings are recorded once in every 30 minutes. The water temperature, air temperature, inner cover temperature and outer cover temperature are recorded at regular intervals of time. As charcoal is acting as a good absorber on the surface, it rises the temperature of the water and so the productivity rate increases to an optimum level. The same study is repeated without charcoal absorber inside the spherical solar still. The water level in the basin is rapidly decreases due to more evaporation of water in clear sunny days. So a water tank is connected to the still and water level is maintained at the same level for all studies. The distillated output of spherical solar still is frequently measured by a measuring jar at regular intervals. The measuring jar is placed at the outlet of the solar still.

Analysis :

The following empirical relation for free convection heat transfer from inside the sphere.

$$Nu_f = \frac{hd}{k_t} = 2 + 0.392 Gr_f^{\frac{1}{4}}$$

$$for 1 £ \; Gr_f \; £ \; 10 \qquad (1)$$

The equation may be modified by

$$Nu_f = 2 + 0.43 (Gr_f \, \mathrm{Pr}_f)^{\frac{1}{4}} \qquad (2)$$

Where

$$Gr = \frac{g b' r^2 X^3 D T}{J^2}$$

$$b' = \frac{1}{(T_f + 273))}$$

$$X = \frac{A}{P}$$

$$T_f = \frac{(T_1 + T_2)}{2}$$

Results and Discussion :

Spherical solar still was constructed and tested experimentally. This type of still receives radiation is transmitted from the spherical transparent surface. This still has added advantage in evaporating the water by floating the charcoal for absorption of radiation. The performance of spherical solar still is studied with two modes of operation, first spherical solar still with charcoal absorber and then without charcoal absorber. Fig. 3 shows the variation of solar radiation with respect to time in both studies. The solar radiation starts to increase in the morning and attains maximum at the noon and tends to decrease in the evening time. The variation of solar radiation is received in the range of 458.86 W/m2 to 1086.00 W/m2 on normal sky days, where still performance is measured with the charcoal absorber. Similarly when the still is studied without charcoal absorber, the radiation is received in the range of 507.23 W/m2 to 1092.00 W/m2. The average solar radiation received for the spherical solar still with charcoal absorber is 835.24 W/m2 similarly the average radiation for without charcoal absorber is 841.27

W/m2. Figs. 4-5 show the variation of temperature with respect to time for two experiments. The rise in water temperature ranges from 39°C to 62°C, 32°C to 60°C for air temperature, 29.5°C to 35.5°C for room temperature, 33 to 38°C for outer cover temperature, 31.9°C to 36°C for ambient air temperature without charcoal absorber. Similarly the rise in water temperature ranges from 40°C to 68°C, 38°C to 62°C for air temperature, 29.5°C to 37°C for room temperature, 33 to 37°C for outer cover temperature, 33°C to 41°C for ambient temperature in spherical solar with charcoal absorber. These temperature variations in this study show that temperature of the still with charcoal absorber is more than the still without charcoal absorber. Since the charcoal absorbs more radiation and it increases the water temperature to a higher value. Fig. 6 shows that the variation of efficiency with respect to time in both studies. The maximum efficiency is observed as 18 % for without charcoal still and 25.34 % for with charcoal absorber. Fig. 7 shows the variation water collection with respect to time for both the studies. The distillates yield around 2.3 liters/m2/day without charcoal absorber and 2.8 liters/ m2/day for with charcoal absorber. Fig .8 shows the variation of latent heat with respect to time. It is found in the range of 2406949 Kg-1 to 2400985 Kg-1 without charcoal absorber inside and 2421479 Kg-1 to 2396424 Kg -1 is observed with charcoal absorber inside the still. Figs. 9-10 show the variations of Grashof number and Nusselt number with respect to time for spherical with charcoal absorber. It concludes that Grashof number and Nusselt number increase with respect to time. Grashof number is found as 87091 to 322746 and the Nusselt number found as 3.3 to 4.66 in the charcoal absorber study. Similarly Figs. 11-12 show that the variations of Grashof number and Nusselt number with respect to time for still with without charcoal absorber. Grashof number is found as 61476 to 245904 and the Nusselt number found as 3.0 to 4.5 for without the charcoal absorber study. Grashof value is found to increase steadily during warm up period and then it starts to decrease with respect to decrease in water temperature. After attaining the higher temperature, the Nusselt number value maintains a steady state. Fig .13 shows the variation of saturated vapor pressure (N/m2) with respect to water temperature. From this graph we can easily verify the saturated vapor pressure values for the water temperatures.

Conclusion :

The maximum efficiency is observed as 18 % for without charcoal and 25.34 % for with charcoal absorber. . The distillates yield around 2.3 liters/m2/day for without charcoal absorber and 2.8 liters/ m2/day for with charcoal absorber. The driving force of the solar distillation technique is the difference between temperature of water in the still basin and temperature of the cover (Tw-Tc). It can

ISSN:-2230-7850

be concluded that the spherical solar still will be more economical on small scale production to provide drinking water in remote areas.

Glossary :

A	Area (m^2)
M_w	Mass of Water (kg)
g	Acceleration due to gravity (m/s^2)
V	Wind Speed (m/sec)
T_a	Air temperature (^oC)
T_1	Hot surface temperature (^oC)
T_2	Surrounding air temperature (^oC)
T_w	Water temperature (^oC)
T_f	Fluid average temperature (^oC)
P	Perimeter of the surface
T_{amb}	Ambient temperature (^oC)
T_{sky}	Sky temperature (^oC)
T_c	Top Cover Temperature (^oC)
C_{pa}	Specific Heat of Air at Constant Pressure (J/Kg ^oC)
Nu	Nusselt number
Pr	Prandlt number
ΔT	Temperature difference (^oC)
k	Thermal conductivity

Greek

β Thermal expansion coefficient

□ Partial mass density of water vapor (Kg/m^3)

£ Latent Heat (^{o}C)

□ Stefan-Boltzmann constant (5.6697 x 10^{-8} W/m^{2o}K^4)

□ Glass absorptive

µ Dynamic viscosity of the fluid, Pa.s

REFERENCES :

[1] L. Grancia Rodriguez, Desalination by wind power, Wind Engineering. 28, (2004) 453.

[2] Cappelletti GM, An experimental with plastic solar still, Desalination. 142 (2002) 221-227.

[3] Malik MAS, Tiwari GN, Kumar A, Sodha MS, Solar distillation, a predict study of a wide range of solar and optimum design, construction and performance. New York, Pergamon press, (1982).

[4] Al-Hayek, Badron OO, The effect of using different designs of solar stills on water desalination, Desalination. 169 (2004) 121-127.

[5] Al- Hussaini H, Smith LK, Enhancing of solar still productivity by vacuum technology, Energy Conversion Management, 36 (1995) 1047-1055.

[6] Kelogirous S, Use of parabolic trough solar energy collector for sea water desalination, Applied Energy, 60 (1998) 58-88.

[7] El-sebaii AA, Thermal performance of a triple basin solar still, Desalination. 174 (2005)23-37.

[8] Al-Karaghouli AA, Alnaser WE, Experimental comparative study of the performance of single and double basin solar still, Applied Energy.77 (2004) 317-325.

[9] Tiwari GN, Singh SK,Bhatnagra VP, Analytical thermal modeling of multi basin solar still, Energy Conversion and Management. 34(12) (1993) 1261-1266.

[10] Badron AA, Inverted trickle solar still, Effect of heat recovery, Desalination. 133 (2001) 167-173.

[11] Kabeel AE, Water production from air using multi shelves solar lass pyramid system, Renewable Energy. 32 (2007) 157-72.

 ISSN:-2230-7850

[12] M.A.S. Malik, G.N Tiwari, A. Kumar and M.S. Sodha, Solar Desalination. Pergamon Press, New York, 1974.

[13] J.A. Duffie and W.A. Beckman, 1974. Solar Energy Thermal Process, John Wiley and Sons, New York.

Fig. 1 Pictorial view of Spherical Solar Still

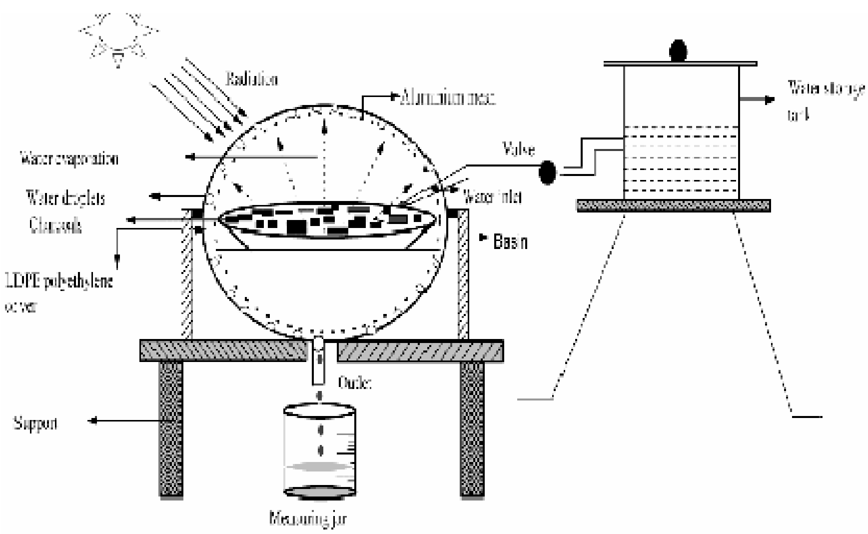


Fig. 2 Schematic view of a Spherical Solar Still

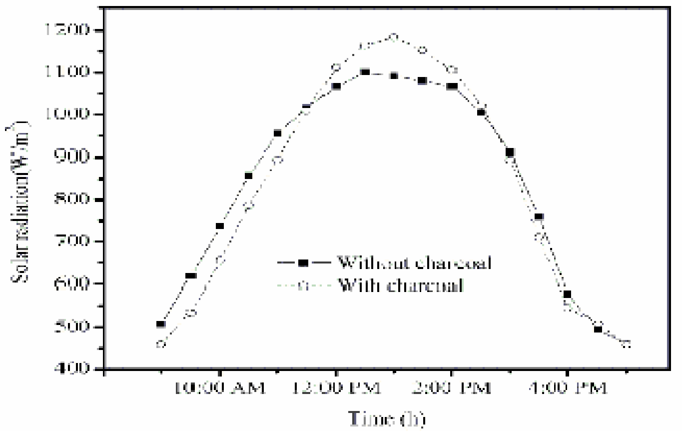


Fig . 3 Variation of solar radiation with respect to time

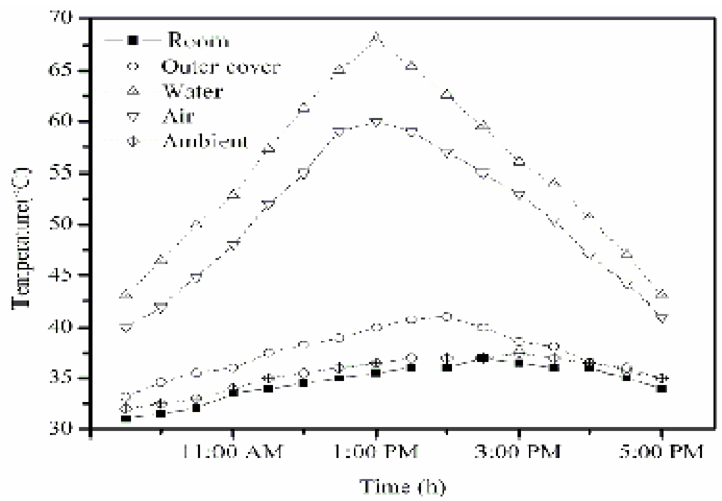


Fig . 4 Variation of temperature with respect to time for still with charcoal absorber

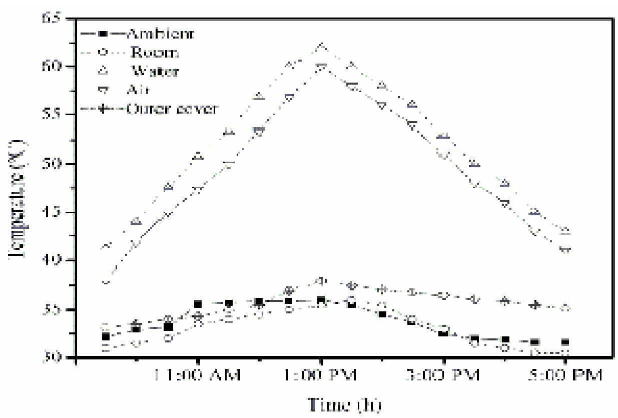


Fig .5 Variation of temperature with respect to time for still without charcoal

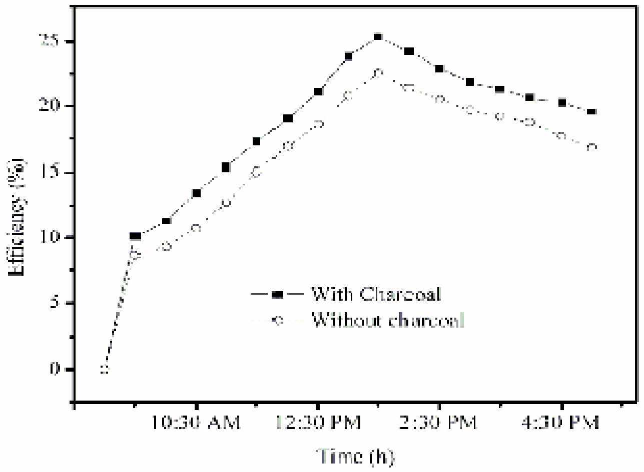
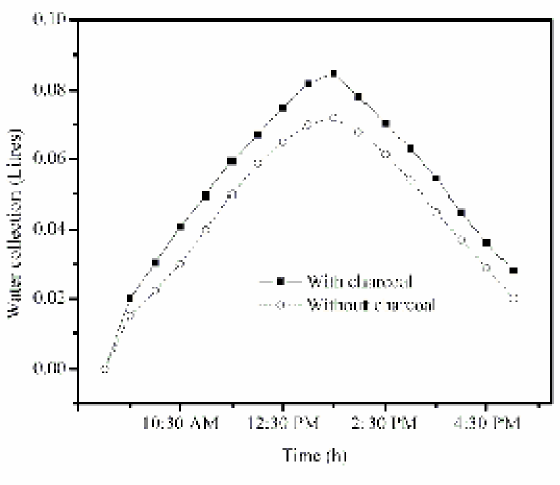


Fig. 6 Variation of efficiency with respect to time



 ISSN:-2230-7850

Fig .7 Variation of water collection with respect to time

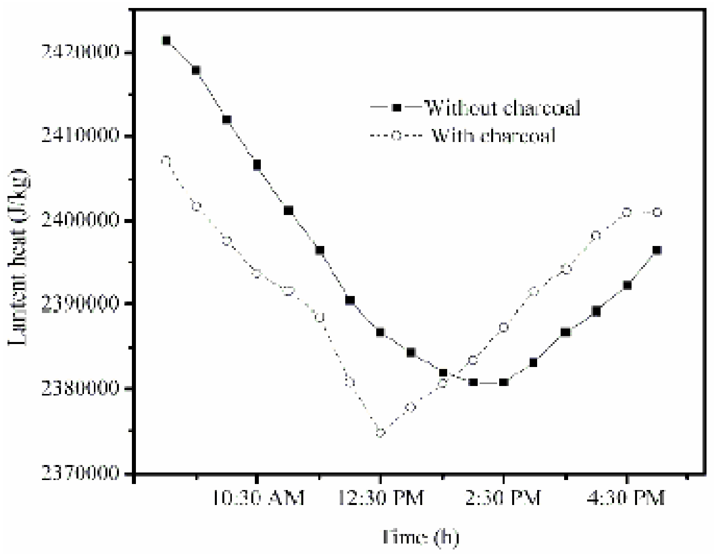


Fig .8 Variation of Latent heat with respect to time

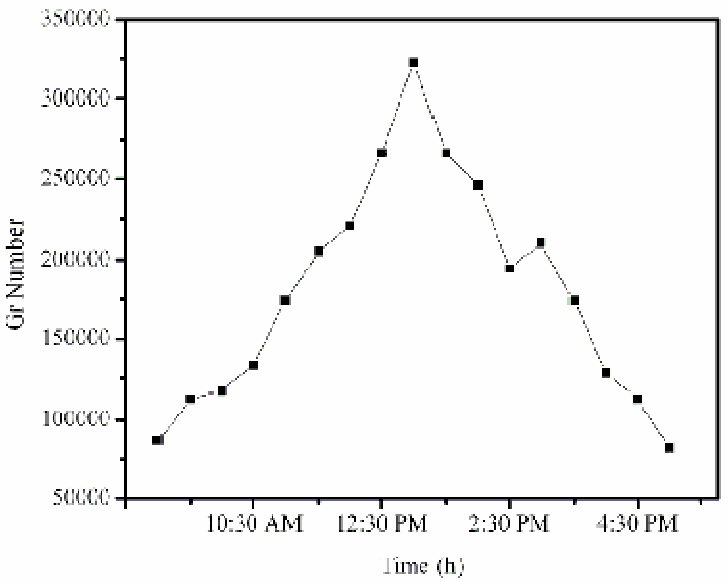


Fig. 9 Variation of Grashof Number (charcoal absorber) with respect to time

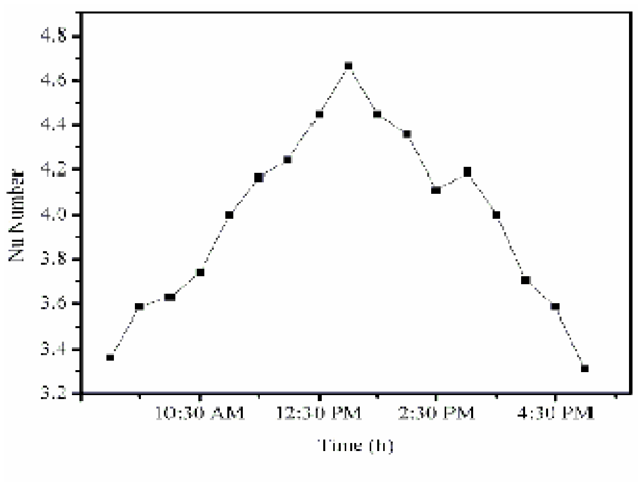


Fig.10 Variation of Nusselt Number (charcoal absorber) with respect to time

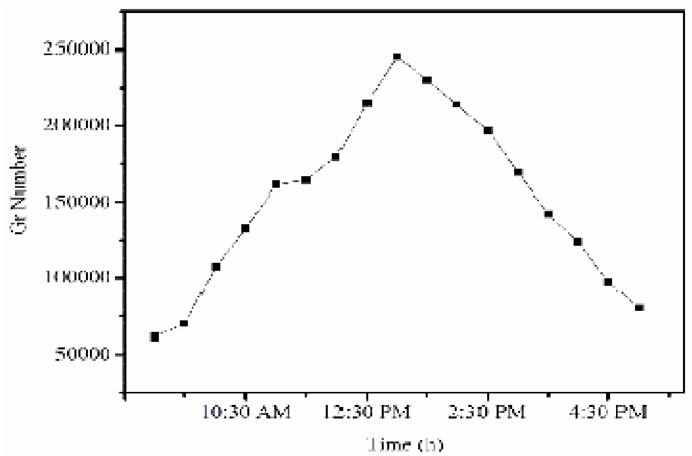


Fig.11 Variation of Grashof Number (without charcoal absorber) with respect to time

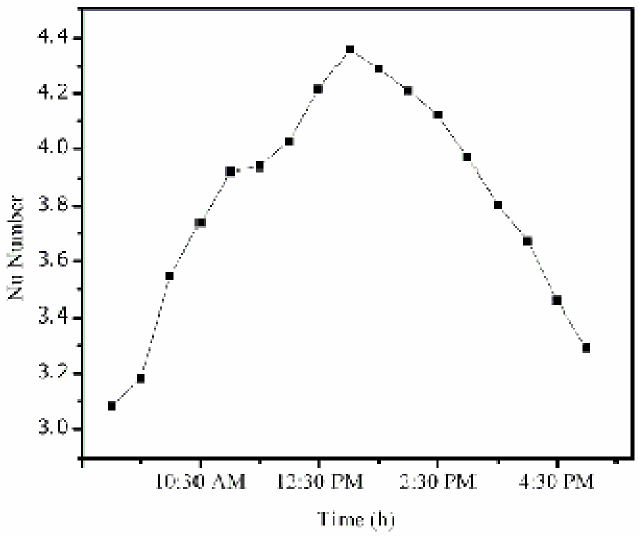


Fig.12 Variation of Nusselt Number (without charcoal absorber) with respect to time

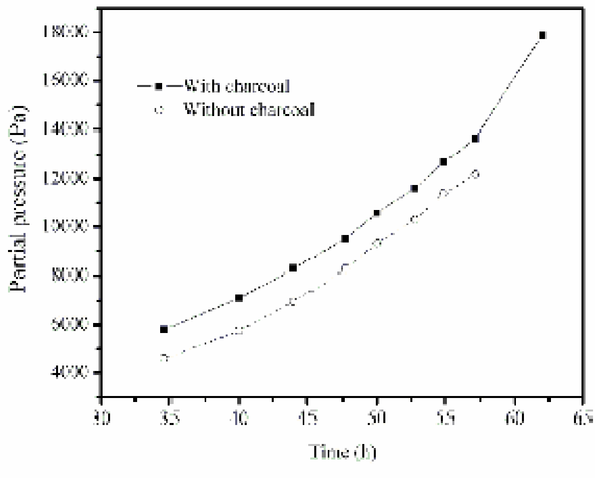


Fig .13 Variation of saturated pressure with respect to temperature