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Experimental Analysis on Thermal Efficiency and Heat Loss of the Evacuated Tube Collector with Variable Solar Radition and Wind Speed

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Abstract: The experimental study was performed on a solar water heater- type evacuated tube collector and results were drawn for efficiency and overall heat transfer coefficient along with net heat loss. In this research, the paper calculation was done on the basis of varying solar radiation and wind speed, average values of five readings were taken to get a better output. Maximum and minimum values were analyzed for which the performance of the system would be optimum. The maximum efficiency was found to be 64% at maximum radiation of 750W/m^2 and wind speed of 2m/s, also as solar radiation inversely varies with X factor so at minimum radiation that is 250W/m^2 it was found to be maximum at different wind speed. It can be seen that the overall heat transfer coefficient and net heat loss increases with increasing solar radiation and wind speed so, overall heat transfer coefficient (Ue) was found minimum at radiation of 250 W/m^2 is 0.5039 at 2m/s and maximum at radiation of 750W/m^2 that is 0.55 at 4m/s and Net heat loss (Q) values were 20.65 minimum and 28.25 maximum for corresponding solar radiation and wind speed.

Keywords: Solar water heater, Evacuated tube collector, Efficiency, Overall heat transfer coefficient, Net heat loss.

I. INTRODUCTION

For a country like India having been blessed with immense sunlight, solar energy is one of the most important and rapidly growing sources of renewable energy in India as well as the world today. It is a clean, sustainable, and cost-effective alternative to fossil fuels which have been the primary energy source for many decades. The potential of solar energy is ever-expanding and limitless and it has become an increasingly popular option for households, and industries. With the rapid advancements in technology solar energy is becoming more efficient, affordable, and accessible than ever before. Its application is in various fields such as the heating of buildings, solar distillation, and solar water heating. As mainly used for water heating the heat from sun is trapped using green house effect. The reflective surface transmits short wave and reflect long wave radiation. When the shortwave radiation hits a collectors absorber heat and infrared rays are produced and is trapped inside collector, which is then transffered to the liquid for heating purpose. One such apparatus used for water heating is the Evacuated Tube Collector system which uses solar energy to heat large quantities of water.

This system contains evacuated parallel glass tubes cylindrical in shape inducted with thermally conducted copper tubes in which sunrays hit perpendicularly. Cold water from the storage tank comes to the manifold (header) and then the water travels through evacuated tubes in which it gets heated with the help of solar energy and due to density difference hot water comes up to the manifold which can be stored and used for various purpose. Using evacuated tubes helps to maximize the temperature and improves the efficiency for longer duration. An evacuated tube collector system produces 25%-40% more efficiency as compared to flat plate collector and also due to its cylindrical shape it is able to absorb solar radiation from all directions [1] and its value can be depicted from Table1.Using an evacuated tube collector temperature of the hot water was around 71.66% efficient and efficiency was 60.11% with minimum relative error [2].

With increasing mass flow rate and solar radiation, the thermal efficiency of collector is higher at negative inlet temperature [3]. At higher value of flow rate, the efficiency of evacuated tube collector system varies from 0.12-0.5 and the maximum temperature of air was found to be 56.7°C [4]. It can also be seen that with mass flow rate also affects the thermal performance and maximum useful energy is affected by parameters such as solar radiation and outlet temperature [5]. Also using the reflectors in the evacuated tube collector system, the efficiency increased by 16% and double the reflectors increases its performance [6]. The presence of air thermal resistance raises the temperature by 30°C and its absence reduces the collector efficiency and outer temperature by 10% and 16% [7]. Yearly efficiency of the evacuated tube containing the heat pipe was 0.62 while in forced circulation it reached 0.516 [8].

Apart from the tubes the gain in energy and thermal performance of the system also increases as compared to the normal condition by using the bypass tubes in the storage tank [9].

It can be seen that in the evacuated tube collector system the tubes are connected in series with the manifold which provides high temperature as the Solar radiation increases [10]. Thermal radiation is responsible for the performance of the system and the selective coating helps to increase the performance of the system [11]. Increasing the solar radiation and mass flow rate along with the number of tubes raises the exit temperature but to a limit after which it would maintain a constant value [12]. Radiation directly varies with the water productivity and its maximum value was achieved at a tilt angle of 15 degrees which was 27.21% daily [13]. It can also be seen that the system efficiency is reduced at lower solar radiation and higher energy is released at starting of the day [14]. And because of the solar irradiation, the thermal efficiency of the collector is poorer with a high heat loss coefficient [15]. Solar Radiation highly affects the outlet air temperature as compared to the wind speed and ambient temperature which is of minor importance [16]. The effect of wind speed is that by increasing it by 0.86m/s the efficiency reduces by 67% [17]. And at different parameters for an effective tube length of 1.5m, improved efficiency is achieved for different diameters of tubes [18]. It can be seen that higher solar radiation leads to higher hot water temperature in which collector efficiency was found to be 72% for hot water temperature of 43℃ and ambient temperature of 21℃ [19].

When the losses are considered from the evacuated tube heating system it is less in amount as compared to the storage tank [20]. These losses are raised to 2.7% from the evacuated tube at 0.01-1 MPa and it increases with the increasing temperature [21]. Tubes of the collector in an evacuated tube collector have a higher overall heat transfer coefficient with respect to the varying gas inside the envelope [22]. And the heat loss coefficient from the tube with an aspect ratio of 32.9 is about 0.742W/m^{2}K [23]. Within the daytime, it can be seen the losses are about 1.8 W/m^{2}k and the efficiency can be seen at about 51% [24]. Considering the air gap heat transfer coefficient plays a vital role in facilitating the heat transfer which can be calculated as 9.992W/m^{2}K with the temperature of the copper plate as 107.62℃ [25].

II. MATERIAL AND METHOD

The experimental apparatus of the evacuated tube collector system contains a transparent evacuated tube made up of borosilicate or soda lime glass connected parallel to the header. Reason for using such material of glass because it has optical clarity, corrosion resistance, inert behaviour and it is affordable. Each tube consists of a thicker outer tube and a thinner inner tube which helps in absorbing high solar radiation and impedes heat loss and the calculated result with less overall and net heat loss can be seen in Table 3 and 4. Due to its curved surface, it is able to absorb high amounts of radiation from all direction which helps in improving systems performance also the effect on efficiency with respect to inlet temperature considering ambient and solar radiation effects can be drawn from Table 2 .The trapped air is removed between both the tubes hence it is called vaccum or evacuated, which acts as an insulator and reduces the heat loss either by convection or radiation.

The insulation properties of vaccum are such good that while the inner tube temperature raises to its maximum the outer tube remains cold. Due to the vaccum created between the tubes, the overall efficiency of the system is higher and it improves the overall performance of the system. Inside the glass tube, a copper or aluminium fin is attached to the heat pipe which is placed inside the inner tube, fins are covered with a selective absorber coating that helps in transferring the energy to the fluid and raising the temperature of the water to its maximum value which is then used for various purpose such as in residential buildings, commercial applications and can also be used for space heating is the location of the building is off the grid. Nowadays solar water heating system of this type is preferred because they are able to extract heat from air in humid and overcast weather conditions which do not need direct sunlight to operate.

This experimental setup consists of multiple pressure and temperature sensors along with flow control valves and a monitoring screen called control unit that displays processed values which helps in getting accurate results while working with apparatus. The various other devices needed in the function of this experiment contain a radiation meter, IR temperature gun, and Anemometer which is used to measure the solar radiation coming form the halogen fixture, the temperature of the absorber plate, and the wind speed from tower fan, a regulator is provided through which the intensity of the light coming from the source can be varied. Various experiments are performed on the setup with the help of an artificial source of sunlight and its performance and parameters are calculated. The parameters calculated such as heat loss, efficiency and net heat loss, through which results can be verfied to the optimum in the working of setup. Readings can be taking considering the different parametes such as solar radiation, wind speed and ambient temperature and better performance for the given values can be measured. Hence in the given setup below all the different situations were taken into consideration and values were taken out which would give accurate result.

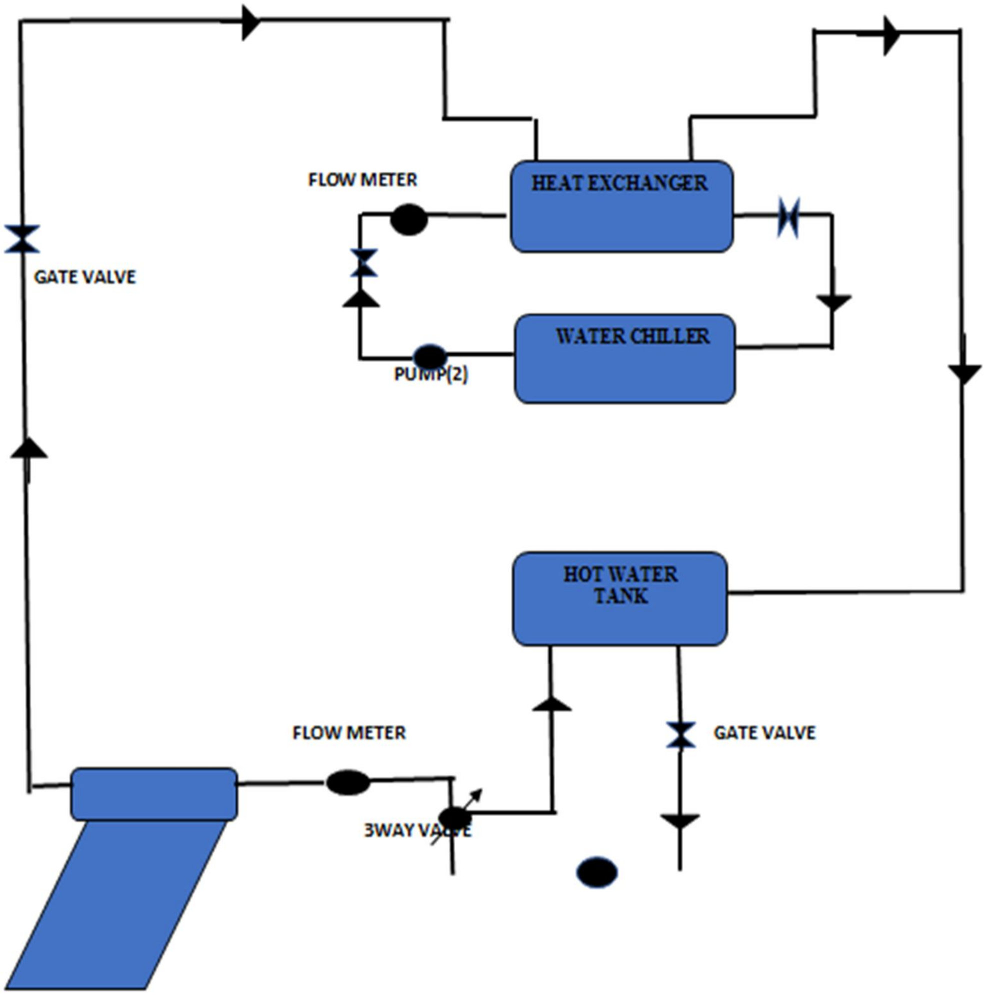


Fig.1. Schematic diagram of Evacuated Tube Collector System

III. WORKING

In the experiment performed the artificial source of sunlight is provided with the help of halogen fixtures whose values can be altered with the help of a dimmer which is used to give varying solar radiation. The cold water is poured into the storage tank and with the help of pump 1 mentioned in Fig.1. the water is transferred to the manifold (header) and then it is distributed to the evacuated tubes, where a source of sunlight is provided with the help of halogen fixtures and water is heated in the evacuated tubes. The tubes contain a heat pipe that helps to heatup the water coming from the manifold and also it collects the solar radiation and converts solar energy in the form of hot water, after the water is heated according to the varying radiation, due to density difference the hot water comes up and it travels upwards to the header. This hot water passes to the storage tank which can be used for various purposes. The setup also contains the heat exchanger, with the help of which the hot water transfers its heat and cold water again from the storage tank repeats its cycle. Some experiments also contain a chiller in another running cycle which helps to keep the water at constant inlet temperature. The operation performed in that cycle is that water from the heat exchanger goes to the chiller where the temperature of the water is lowered to maintain the water temperature at the storage tank. Also experiments can be done when the inlet and outlet temperature would be equal and complete amout of water will get heated at certain time which is calculated with minimum wind speed at higher radiaition at Table 5 and 6. With the help of the experiments performed in the above setup varying the operating values such as solar radiation, wind speed, etc. values can be calculated for which the performance of the system would give an optimum result. This system is preferred because it is reliable, has longevity, provides resistance to (environmental conditions, large variations in temperature, and leakage), is stable, is easy to install, and is effective in energy conservation

IV. SPECIFICATIONS

A. *Material Specification For The Evacuated Tube Collector System*

Components	Material	Insulation/Coating
1) Evacuated Tubes	Borosilicate	CU-Sputtering
2) Manifold	-	Polyurethane Foam
3) Storage Tank	SS316 grade 28 finish non magnetic	55 mm PUF cladding by SS mirror
4) Heat Exchanger Tank	Copper	External glass wool jackets

B. *Calculation Parameters Of Evacuated Tube Collector System*

Parameter	Sub-Parameter	Specifications
1) Halogen Fixtures	a) Quantity b) Power c) Dimmer	36 5400W 1-phase,25 A
2) Evacuated Tube Collector	a) Number of Tubes b) Capacity c) Length d) Outer Diameter e) Absorptance	10 100 LPD 1800mm 58mm >90%
3) Storage Tank	a) Water Heater b) Capacity	3000Watt 50 litres
4) Heat Exchanger Tank	Capacity	50 litres
5) Measurement Unit	a) Temperature Meter b) Flow Meter	0-200°C 0-15LPM
6) Chiller Tank	Capacity	0.3 TR
7) Water Pump	Capacity	0.3HP
8) Fan	Type	Tower Fan
9) Accessories	a) Radiation Meter b) IR temperature Gun c) Anemometer	Measures Radiation of halogen Measures Temperature of glass Measures wind Speed
10) Manifold	Single sided 100 LPD manifold for 10 tubes	

V. GOVERNING EQUATIONS

These are the equations used for the calculation of the various parameters while performing the experiment and which would be further helpful in calculation considering variable solar radiation and wind speed from lower value to the higher one and detecting that for whose value the system would give optimum result. The calculating parameters consist of efficiency, over all heat loss cofficient, heat transfer cofficient from tube and to the ambient temperature the net heat loss from the evacuated tube.

The fromulae for calculating such parameters are described below:

Efficiency of Evacuated Tube Collector can be calculated by using the formulae given below

$$\eta = \frac{\textbf{Useful energy gain}}{\textbf{Totalincidentradiation}} = \frac{\dot{m}\mathbf{Cp(Th,o-Th,i)}}{\mathbf{IbAc}} \qquad (1)$$

and the heat loss cofficient from the evacuated tube of the system can be driven out by

$$U e = \frac{1}{\left(\frac{1}{hga}+\frac{1}{hpg,e}\right)} \qquad (2)$$

also, the heat loss coefficient between the absorber plate and outer glass covering can be taken out by following formulae

$$hpg,e = \sigma Ep(Tp^2 + Tg^2)(Tp + Tg) \qquad (3)$$

the heat transfer cofficient between the glass surface to the ambient can be calculated by

$$\boldsymbol{h}g\,a = Nua * \frac{Ka}{D2} + \sigma\, Eg\,(Tg^2 + Ta^2)(Tg + Ta) \quad (4)$$

and Net heat loss can be Q from the tube can be given by

$$Q = AcUe(Tp - Ta) \qquad (5)$$

Mostly the experiment focuses on calculation of losses and efficiency to the variable value and finding the better result from the above equation.

VI. RESULTS

The experiments were performed in the laboratory considering variable parameters such as solar radiation and wind speed and the optimized results were drawn for maximum and minimum values using the methodology and governing equation for increasing inlet water temperature from the initial value. Following wind speed and radiation were considered for purpose of optimum result.
Wind Speed: 2m/s ,3m/s ,4m/s
Solar Radiation :250 W/m^2 ,450 W/m^2 ,550 W/m^2,650 W/m^2,750 W/m^2
Result 1 Depicts the graph between efficiency vs radiation at different wind speed

Table1. Observation table for Efficiency at different wind speed and different radiation level.

S.N.	Radiation (I) (W/m2)	Efficiency (η) at 2m/s Wind Speed	Efficiency (η) at 3m/s Wind Speed	Efficiency (η) at 4m/s Wind Speed
1	250	0.603789573	0.576324618	0.530987667
2	450	0.61994	0.598223342	0.553229642
3	550	0.632456	0.603703683	0.587270651
4	650	0.63947	0.616634721	0.591535978
5	750	0.642364	0.621859296	0.594150754

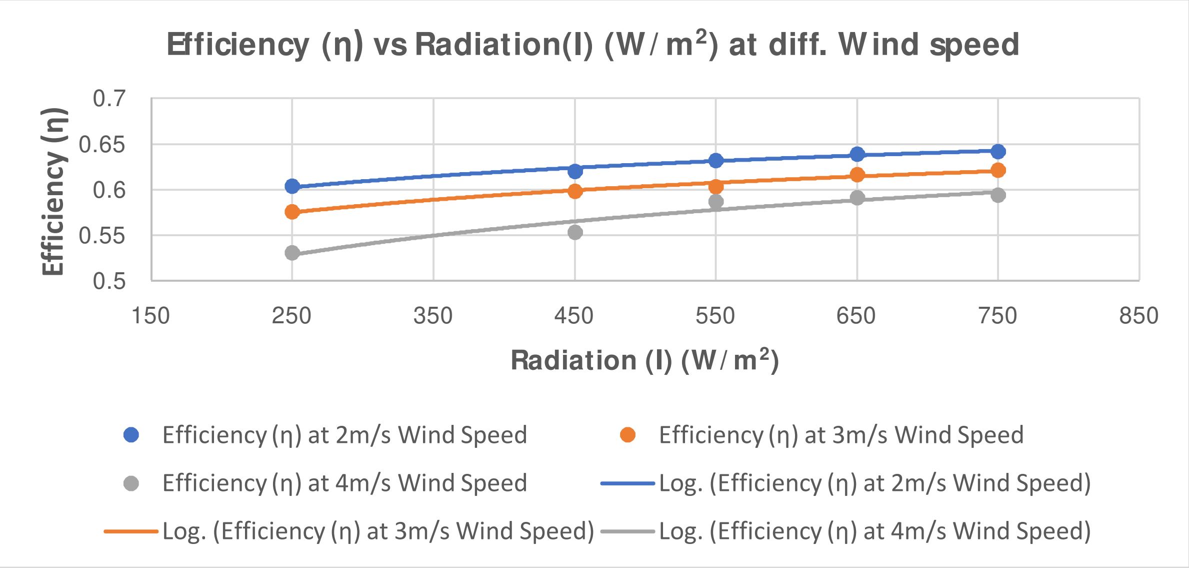


Fig. 1. Comparative graph for efficiency at different radiation level and wind speed

Fig. 1. The graph is plotted between the efficiency and variable solar radiation. This graph shows the comparative result of effieicny varying with low, medium and high wind speed range and solar radiation.

According to the experiment performed the efficiency of the system is maximum at low wind speed that is 2m/s and higher solar radiation 750 W/m^{2}K that is 64% and minimum for wind speed 4 m/s and solar radiation 250W/m^{2}k that is 53%.
Result 2 Draws the result between the efficincy vs the X factor at differerent radiation and wind speed

Table 2. Observation table for efficiency v/s X factor for different wind speed and radiation level

X = (Ti-ta)/I at 2m/s	Efficiency (η) at 2m/sWind Speed	X = (Ti-ta)/I at 3m/s	Efficiency (η) at 3m/s Wind Speed	X = (Ti-ta)/I at 4m/s	Efficiency (η) at4m/sWind Speed
0.02952	0.603789573	0.0388	0.576324618	0.04248	0.530987667
0.019111111	0.61994	0.022844444	0.598223342	0.0236	0.553229642
0.016472727	0.632456	0.021418182	0.603703683	0.021381818	0.587270651
0.014553846	0.63947	0.021418182	0.6216634721	0.020123077	0.591535978
0.014	0.642364	0.01776	0.621859296	0.01904	0.594150754

Fig. 2. Comparative graph for efficiency v/s X factor at different radiation level at different wind speed

Fig. 2. Depicts the graph between efficiency and X factor. By the experimental results the conclusion was drawn that efficiency inversely varies with radiation level. At lower radiation level X factor would me maximum that at 250W/m^2 this factor is 0.02952.and at higher radiation level that is 750 W/m^2 minimum value was seen as 0.014 for 2m/s, for 3m/s maximum and minimum values drawn were 0.0388 and 0.01766 similarly for 4m/s it was found to be maximum 0.04248 and minimum 0.01904.

Result 3 draws the result between the overall heat transfer cofficient with respect to different radiation and wind speed

Table 3. Observation table for overall heat loss coefficient at different radiation level and wind speed

S.N.	Solar Radiation (I) (W/m2)	Overall Heat Loss Coeff. (Ue) at 2m/s wind speed	Overall Heat Loss Coeff. (Ue) at 3m/s wind speed	Overall Heat Loss Coeff. (Ue) at 4 m/s Wind speed
1	250	0.503956854	0.504630713	0.506717941
2	450	0.512921987	0.520280165	0.522091884
3	550	0.522787045	0.530073251	0.536420178
4	650	0.531740066	0.538997179	0.548078414
5	750	0.539212381	0.550198936	0.555304529

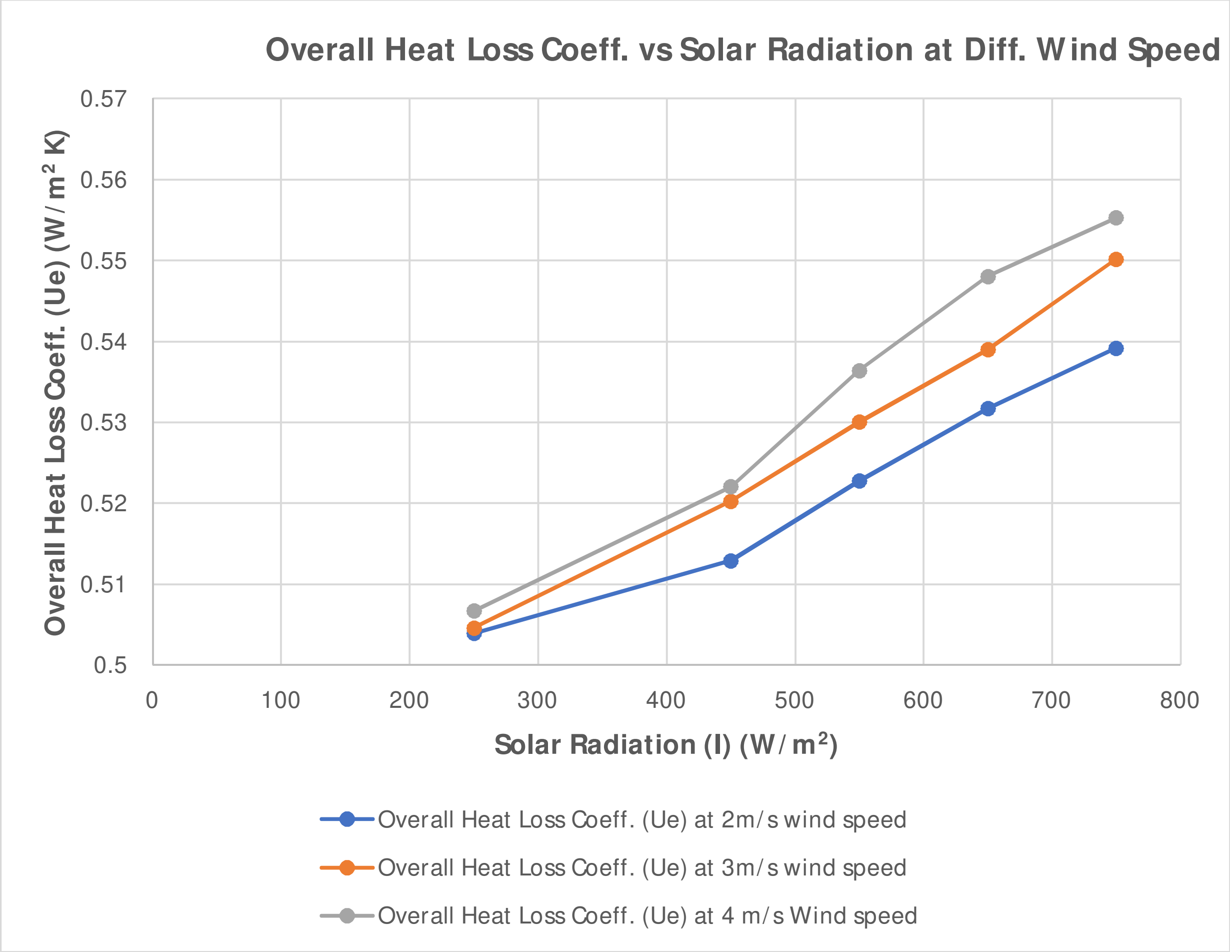


Fig. 3. Comparative graph of overall heat loss coefficient with respect to solar radiation at different wind speed

Fig. 3. Experimental result drawn with respect to overall heat loss coefficient and solar radiation with variant wind speed tells that at lower solar radiation and wind speed the losses are small as compared to the values at high wind speed and high radiation. At wind speed 2m/s and solar radiation 250W/m^2 heat loss coefficient was found to be 0.5039 W/m^2k and at wind speed 4m/s and high radiation that is 750 W/m^2 heat loss coefficient was found to be 0.555 W/m^2k.

Result 4 Draws the result between the net heat loss with respect to changing solar radiation at different wind speed

Table 4. Observation table for Net heat loss with respect to solar radiation at different wind speed

S.N.	Solar Radiation (I) (W/m2)	Net Heat Loss (Q) at 2 m/s Wind speed	Net Heat Loss (Q) at 3 m/s Wind speed	Net Heat Loss (Q) at 4 m/s Wind speed
1	250	20.65344127	21.20558188	21.33705855
2	450	21.92950313	22.47560026	22.72215923
3	550	23.86007531	24.04402731	25.73605484
4	650	25.70572708	26.35815478	27.1194355
5	750	26.70659081	27.12897254	28.25023397

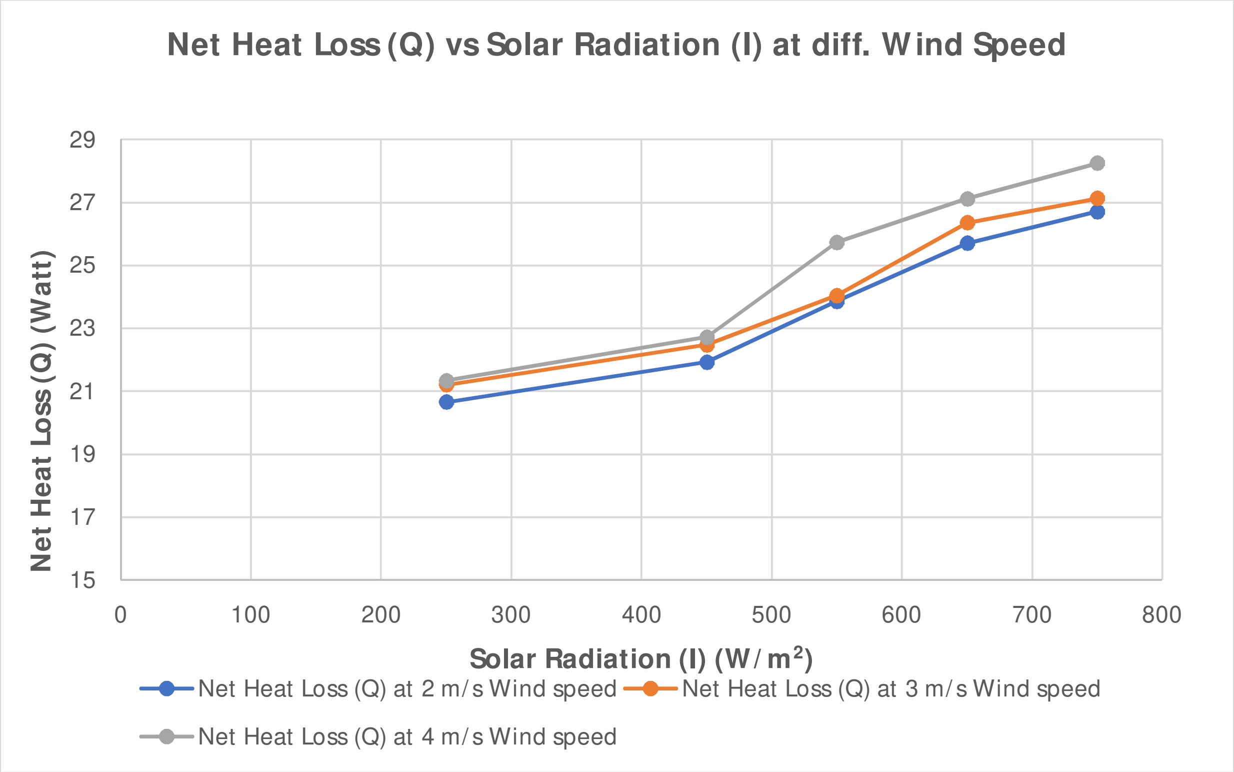


Fig. 4. Comparative graph of Net heat loss with respect to solar radiation at different wind speed.

Fig. 4. In this graph the experimental result concluded that the net heat loss increases with wind speed and solar radiation at wind speed 4m/s and solar radiation 750 W/m^2 the net heat loss was found to be maximum at value 28.259 Watt and at wind speed 2m/s and solar radiation 250 W/m^2 it was found to be 20.65 Watt.

Result 5 Draws the result between the inlet temperature and outlet temperature at radiation of 550W/m^2 at minimum wind speed of 2 m/s

Table 5. Observation table for inlet and outlet temperature with respect to time at solar radiation 550 W/m^2 and wind speed 2m/s.

Time (min)	Th(out)	Th(in)
0	34.3	30
10	34.5	30.1
20	34.6	30.5
30	34.8	30.6

40	35.7	31.7
50	35.8	31.8
60	36.2	32.3
70	36.6	32.5
80	37.2	33.6
90	37.4	33.9
100	37.5	34
110	37.6	34.5

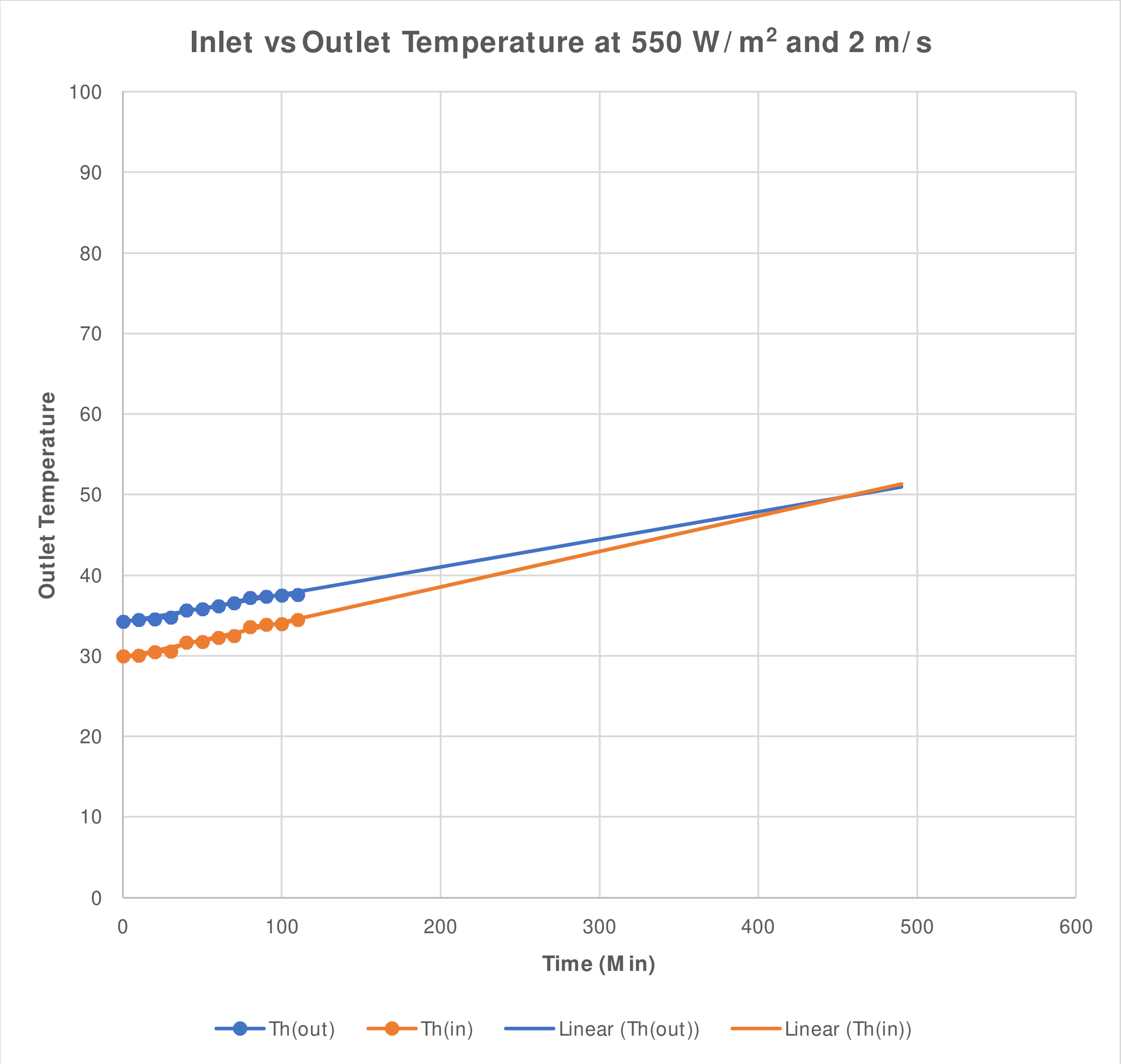


Fig. 5. Graph for inlet and outlet temp with respect to tome at wind speed 2m/s and solar radiation 550W/m^2.

Fig. 5. Experimental results depict that at radiation 550W/m^2 and 2m/s wind speed a time will come when inlet and outlet temperature would be equal, that means no further heating of water will occur after time of 450 minutes at temperature rise of 50.

Result 6 Draws the result between the inlet temperature and outlet temperature at radiation of 750W/m^2 at minimum wind speed of 2 m/s

Table 6. Observation table for inlet and outlet temperature with respect to time at solar radiation 750 W/m^2 and wind speed 2m/s.

Time (min)	Outlet Temperature (To)	Inlet Temperature (Ti)
0	38	31.7
10	38.3	32
20	38.7	32.6
30	39.3	33.3
40	39.5	33.7
50	40.4	34.8
60	41	35.6
70	41.5	36.2
80	41.9	36.9
90	42.4	37.7
100	43.5	38.7
110	43.9	39.2

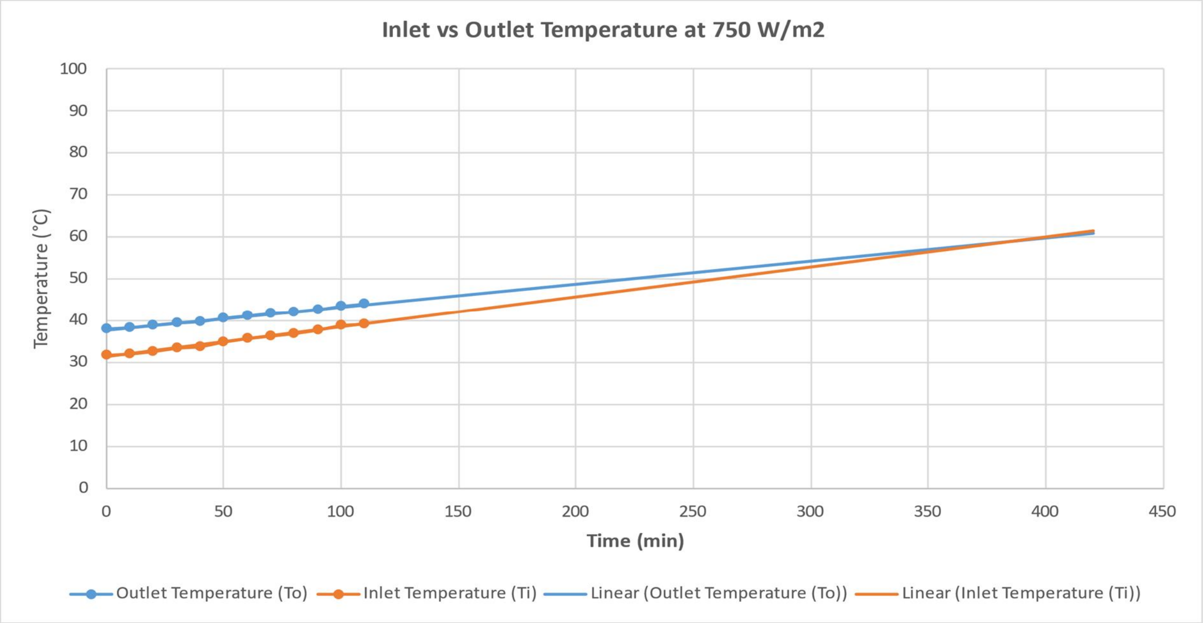


Fig. 6. Graph for inlet and outlet temp with respect to tome at wind speed 2m/s and solar radiation 750W/m^2.

Fig. 6. Experimental results depict that at radiation 750W/m^2 and 2m/s wind speed a time will come when inlet and outlet temperature would be equal, that means no further heating of water will occur after time of 380 minutes, and the temperature rise of 60°C.

VII. CONCLUSION

1) The efficiency of the system increases with solar radiation and decreases with increasing wind speed that is it is considered maximum for 750W/m^2 and 2 m/s velocity as 64%.
2) Efficiency inversely varies with X factor for as the radiation is maximum the value of X factor decreases and for minimum radiation its value increases and its value reached minimum as 0.014.

3) The overall heat loss coefficient of the evacuated tube increases with increasing wind speed and higher solar radiation, it should have lower value which was found to be 0.5039W/m^2K at 250W/m^2 radiation and 2m/s wind speed.
4) The Net heat loss from the evacuated tube is also raised with the high value of wind speed at a higher radiation level considering its minium value as 20.65 Watt.
5) The inlet and outlet temperature of the system would be equal at which increasing radiation level as less time would be taken to heat the maximum amount of water it was found at 750W/m^2 radaiton and minimum 2m/s wind speed which took 6 hrs approx to reach the temperature of about 60℃.
6) From the above results it can be concluded that for better performance of the system varying solar radiation from minimum to maximum would give better results with minimum effect of wind speed.

VIII. NOMENCLATURE

U_e = heat loss coefficient of evacuated tubes (W/m^2K)
h_{ga} = heat transfer coefficient between glass surface to ambient(W/m^2K)
$h_{pg,e}$ = heat transfer coefficient between the absorber surface and outer glass tube. (W/m^2K)
σ = Boltzmann constant
E_p = Emissivity of plate
E_g= Emissivity of glass tube
T_p= Plate temperature (℃)
T_g= Glass temperature (℃)
N_{ua} = Nusselt number
$\dot{m}$ = Mass flow rate (Kg/sec)
C_p= Specific heat of water (K J /k_g K)
T_{ho}= Header outlet temperature (℃)
T_{hi}= Header inlet temperature (℃)
I_b = Incident radiation (W)
A_c =Area of collector (m^2)

REFRENCES

[1] Dilip Mishra, Dr. N.K. Saikhedkar [2014]. Evacuated U- tube solar water heating system – A Descriptive Study. www.ijirset.com.
[2] Xianhua Nie, Li Zhao, Shuai Deng, Xueyin Lin [2017]. Experimental study on thermal performance of U- tube evacuated glass tubular solar collector with low inlet temperature. https://doi.org/10.1016/j.solener.2017.04.030.
[3] Sanjeev Kumar, Ashish Kumar, Avadhesh Yadav [2014]. Experimental analysis of thermal performance of evacuated tube at different flow rate https://doi.org/10.1080/19397038.878001.
[4] Yan Gao, Qunli Zhang, Rui Fan, Xinxing Lin, Yong Yu [2013]. Effects of thermal and mass flow rate on forced -ciculation solar hot-water system: Comparison of water-in-glasss and U-pipe evacuated tube solar collectors. https://doi.org/10.1016/j.solener.2013.10.014.
[5] Saleh Abo- Elfadl, Hamdy Hassan, M.F El- Dosoky [2020]. Enerdy and exergy assessment of integrating reflectors on thermal energy storage of evacuated tube solar collector -heat pipe system. https://doi.org/10.1016/j.solener.2020.09.009.
[6] Phrut Sakulchangsathatai, Chaiwat Wannagosit, Pradit Terdtoon [2017]. Theoretical and experimental investigation of the evacuated tube solar water heater system. phrut@eng.cmu.ac.th
[7] Liangdong Ma, Zhen Lu, Jili Zhang, Ruobing Liang [2010]. Thermal performance analysis of the glass evacuated tube solar collector with U-tube. https://doi.org/10.1016/j.buildenv.2010.01.015.
[8] Altin Maraj, Andonaq Londo, Alemayehu Gebremedhin, Coskun Firat [2019]. Energy performance analysis of a forced circulation soalr water heating system equipped with a heat pipe evacuated tube collector under the Mediterranean climate conditions. https://doi.org/10.1016/j.rene.2019.03.109
[9] Mohammad Jowzi, Farzad Veysi, Gholamabbas Sadeghi [2019]. Experimental and neumerical investigations on the thermal performance of a modified evacuated tube solar collector: Effect of the bypass tube. https: //doi.org/10.1016/j.solener.2019.03.063
[10] B. Kiran Naik, Mrinal Bhowmik, P. Muthukumar [2018]. Experimental investigation and neumerical modelling on the performance assessments of evacuated U- tube soalr collector systems. 10.1016/j.renene.2018.09.066.
[11] Madhulesh Yadav, Dr. N.K. Saikhedkar [2017]. Simulation modelling for the performance of Evacuated tube solar collector. DOI:10.15680/IJIRSET.2017.0604120.
[12] Mahmoud B. Elsheniti, Amr Kotb, Osama Elsamni [2019]. Thermal performance of a heat pipe evacuated -tube solar collector at high inlet temperature. https://doi.org/10.1016/j.applthermalemg.2019.03.106.
[13] Qays A. Rashak, Ala'a A. Jassim, Husam N. Khanfoos [2016]. Improving the productivity of soalr still evacuated tubes. www.IJEE.IEEFoundation
[14] Abdellah Shafieian, Mehdi Khiadani, Ataollah Nosrati [2018]. Thermal performance of an evacuated tube heat pipe solar water heating system in cold season. https://doi.org/10.1016/j.applthermaleng.2018.12.078

[15] Y. Gao, R. Fan, X.Y. Zhang, Y.J.AN, M.X. Wang, Y.K. Gao, Y.YU [2014]. Thermal performance and parameter analysis of a U-pipe evacuated solar tube collector. http://dx.doi.org/10.1016/j.solener.2014.05.023

[16] Alicja Siuta- Olcha, Tomasz Cholewa, Kinga Dopieralska Howoruszko [2020]. Experimental studies of thermal performance of an evacuated tube heat pipe solar collector in polish climatic conditions. https://doi.org/10.1007/s11356-020-07920-3

[17] Pierre-Luc Paradis, Daniel R. Rousse, Stephane Halle, Louis Lamarche, Guillermo Quesada. Thermal modelling of evacuated tubes- solar air collectors. Pierre-luc@t3e.info.

[18] Adel A Ghoneim [2016]. Performance optimization of evacuated tube collector for solar cooling of a house in hot climate. https://dx.doi.org/10.1080/14786451.2016.1256886

[19] Sander Hlaing, Myat Myat Soe [2014]. Design calculation and heat transfer analysis of heat pipe evacuated tube soalr collector of water heating. ww.ijsetr.com.

[20] AED Ibrahim, Mohd Tariq, Hassan Issa, Husam Sabeeh, Mohannad Ali [2014]. The heat losses experimentally in the evacuated tubes solar collector system in baghdad Iraq climate. https://www.researchgate.net/publication/333038634

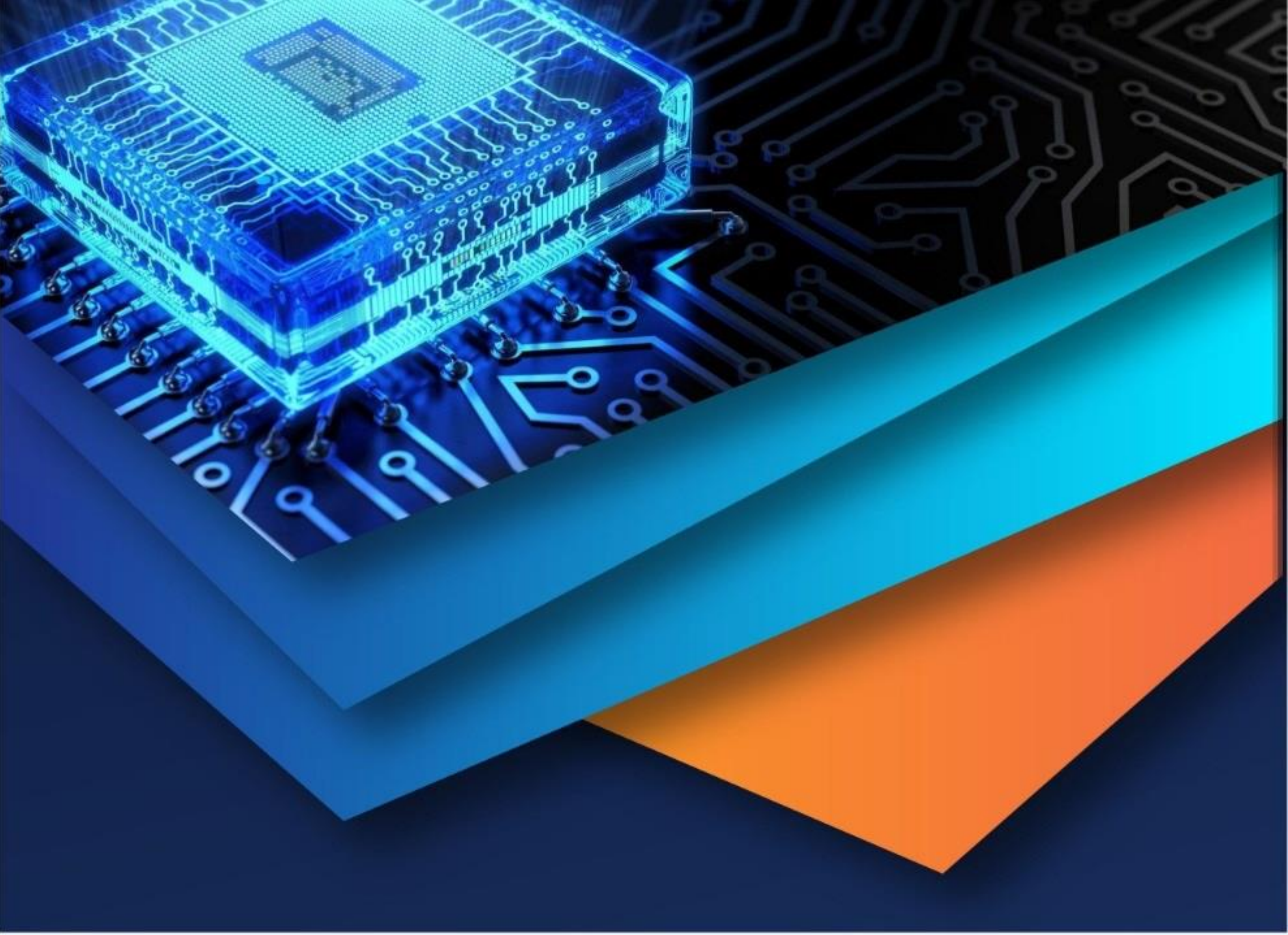
[21] Zhao Hui-zhong, Lui Zhen-yan, Zhang Min, Huang Chen, Wang Li-Hui, Zou Zhi-Jun. [2014]. A mechanical and experimental study on the heat loss os solar evacuated tube. DOI: 10.1007/s12204-009-0052-0.

[22] Abdul Waheed Badar, Reiner Buchholz, Felix Ziegler. Experimental and theoretical evaluation of the overall heat loss coefficient oa a vaccum tube solar collector. awbadar@gmail.com

[23] Abbas Ahmed Hassan [2013]. Evaluation of convective heat transfer and natural circulation in an evacuated tube solar collector. Abbas_ahmed__1985@yahoo.com

[24] Harsh Kadyan [2018]. Performance analysis of evacuated tube collector. http://www.ripublication.com

[25] Siddharth Arora, Shobhit Chitkara, R. Udayakumar, Muhammad Ali. [2011]. Thermal Analysis of evacuated solar tube collector online http://www.academicjournals.org/JPGE



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