Evolution of Earth Tube Heat Exchanger Cooling of Bhopal City

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ABSTRACT
Earth tube heat exchanger systems can be used to cool the building in summer climate (March to May) and heat the buildings in winter climate (Jan to Feb). In a developing country like India, there is a huge gap in demand and supply of electricity and rising electricity prices have forced us to look for cheaper and cleaner alternative. Our objective can be met by the use of earth tube heat exchangers and the system is very simple which works by moving the heat from the house into the earth during hot weather and cold weather vice-versa. Measurements show that the ground temperature below a certain depth remains relatively constant throughout the year. Experimental investigations were done on the experimental set up in Bhopal. Effects of the operating parameters i.e air velocity and temperature on the thermal performance of horizontal ground heat be exchanger are studied. For the pipe of 9 m length and 0.08 m diameter, temperature falling of 3.93^{O}C-12.6 ^{O}C in hot weather and temperature rising of 6 ^{O}C-10 ^{O}C in cold weather have been observed for the outlet flow velocity 12 m/s. At higher outlet velocity and maximum temperature difference, the system is most efficient to be used.

GENERAL EXPLANATION
Condensate drainage in the tubes is very important for maintaining acceptable air quality. The system is designed to assure no soil moisture or organisms ever enter the tube and possibly pollute the air stream. The preferred method of drainage is a gravity drain to daylight. A sump drain should only be used as a last resort. Alarms and backup power systems that can be employed in the case of sump failure or loss of power to the pump.

The tubes in the trench need to be on at least two-foot centers for 8" tubes. Larger diameter tubes require greater spacing between the tubes. The reason for the spacing is to minimize the chance the tubes will exchange heat with one another rather than with the surrounding soil. For 8" diameter tubes the trench will need to be 8' deep, 10' wide and 100' long. For larger diameter tubes the trench will increase in depth, width, and length. Trenches deeper than 12' will be rare and are dangerous requiring special precautions.

If the tube system is going to perform flawlessly for the life of the house, proper drainage of the trench is of the utmost importance. The bottom of the trench must fall consistently towards the drain and be relatively flat. The bottom of the trench is then filled with 4"-6" of a small diameter (1/2"-1" diameter) pea rock or river rock, washed gravel without the fines is acceptable as a last choice. The pea rock is then covered with a filter cloth so it doesn't get clogged with silt or sediment from the surrounding soil.

The tubes are carefully laid on the filter cloth and staked every 10' or so with the drain slit down. All the tube couplers are taped securely and any cracks or holes are caulked with silicone. The tubes are laid in a serpentine fashion. Ideally the tubes bend at least the diameter of the tube every 6'. This has the effect of preventing the air from flowing in boundary layers inside the tubes. As a result the air crashes around constantly inside the tubes maximizing the air to wall contact for complete heat exchange and, in the summer, removal of excess air moisture through condensation.

When should earth tubes be used?
Best in climates in extreme heat and cold. The high difference between the ambient temperatures and the required indoor temperatures create the best opportunity for earth tubes to produce valuableresults.
Need available land to accommodate the length of tubes.
Great opportunity to place them under the building floor when constructing a newbuilding.

Cooling Model Test:
The air velocity was 12m/s velocity was measured by a portable, digital vane type anemometer. The vane size is 66x132x29.2mm and velocity range 0.3 to 45m/s. The anemometer measures mean air velocity. The volume flow rate of air was 0.0863m^3/s and mass flow rate 0.074 kg/s. The ETHE system was operated for seven hours a 3days 29^{th},30^{th} and31^{st} may-2015 for May month. The tube air temperature at the inlet, middle and outlet, were noted at the inter valofone hour.System was turned on at 10.00 am and shutdown at5pm test in may were carried out on 29^{th},30^{th}and31^{st}2019. The ambient temperature on these three days was very similar. The results of the three days were therefore averaged. Table-5.1(a) shows the data, which is reading of three days and Table-5.1(b) mean of the reading of three days. The ambient temperature started with 32.53^{O}C at 10.00 am and rise to a maximum of 41.10^{o}C at 1 pm. The temperature of air at outlet was 27.71^{O}C at when system s tartedin 10am.The outlet temperature was just above the basic soil temperature (27.22^{O}C), which is measured by temperature auto scanner instrument. The table also shows the COP values. The maximum COP achived at 3 pm i.e 6.790.

Inlet Temp, Middle And Outlet Temp. Of ETHE (May-2019)									
Date	29.05.2019			30.05.2019			31.05.2019		
Time	T_a	Tm	To	Ta	Tm	To	Ta	Tm	To
10:00	32.46	30.18	27.72	32.62	30.20	27.81	32.51	30.31	27.62
11:00	34.54	30.21	27.74	34.64	30.24	27.62	34.53	31.57	27.74
12:00	37.48	30.52	27.53	37.81	30.63	27.42	37.87	30.53	28.08
13:00	41.28	30.72	27.50	41.74	30.81	27.48	39.96	31.76	27.36
14:00	40.84	30.68	27.48	40.92	30.72	27.45	40.86	30.63	27.34
15:00	39.75	30.42	27.46	39.83	30.53	27.57	39.92	30.65	27.42
16:00	38.73	30.39	27.51	38.64	30.44	27.46	39.34	30.34	27.56
17.00	38.42	31.13	27.51	38.31	31.21	27.84	38.12	30.53	27.31

Inlet, Middle and Outlet Temp. Of EARTH (May-2019)

LITERATURE REVIEW

Girja saran and rattan jadhav[1] has conducted experiment on single pass earth tube heat exchanger, They conducted experiment in Ahmedabad Gujrat (2000) in India. These found, if a single pass earth-tube heat exchanger (ETHE) was installed and ETHE was made of 50 m long ms pipe of 10 cm nominal diameter and 3 mm wall thickness. ETHE was buried 3 m deep below surface. Ambient air is pumped through it by a 400 W blower. Air velocity in the pipe was 11 m/s. Air temperature is measured at the inlet of the pipe, in the middle (25 m), and at the outlet (50 m), by thermisters placed inside the pipe. Cooling tests were carried out three consecutive days in each month. On each day system was operated for 7 hours during the day and shut down for the night. Heating tests were carried out at night in January.

Fabrizio Ascione et al [2]: The experiment was conducted at three different cities of Italy and the performance evaluation was done for ground heat exchanger in both summer and winter conditions. The following conclusions were made out:

The ground heat exchanger placed in the wet/humid soil gave the more encouraging results than the other two ground heat exchangers.

Different materials like PVC, metal and concrete were used as tube materials showed no effect on the performance of the ground heat exchanger.

Ground heat exchangers were tested at different air speeds but low speed of 8 m/s was preferred as it decreases the pressure drop inside the tubes and fan energy requirements.

Vikas Bansal et al [3] investigated the performance of horizontal earth pipe air heat exchanger for winter heating and effect of flow velocity and material of the pipe. A transient and implicit model was developed to predict the performance of the earth air heat exchanger. The 23.42 m long earth tube was used and gave the heating in the range of 4.1-4.8^{O}Cfor flow velocities of 2-5 m/s. In this study it was concluded that the performance of the earth pipe air heat exchanger system did not got affected by the material of the buried pipe, so therefore a cheaper material can be used for making the pipe.The graphical representation of Temperature distribution along the length of the pipe for exit

W.H. Leong et al [4] studied the effect of soil type and moisture content on ground heat pump performance and found that the performance of a ground heat pump system depended strongly on the moisture content and the soil type (mineralogical composition). Alteration of soil moisture content from 12.5% of saturation to complete dryness decreased the ground heat pump performance, and any reduction of soil moisture within this range has a devastating effect. The Graphical Representation of Variation of the average COP vs degree of soil saturation

Weibo Yang et al [5] studied a two region simulation model of vertical U-tube ground heat exchanger and its experimental verification and divided the heat transfer region of GHE into two parts at the boundary of borehole wall, and the two regions are coupled by the temperature of borehole wall. He concluded that the outlet fluid temperature of GHE, borehole wall temperature and COP of heat pump all dropped deeply during the startup time, and then the drop extent gradually became tardiness when the operation time exceeds about 200 h and the performance of the GCHP system was very unstable during the starting stage and was strongly affected by the ground initial temperature. But it reached quasi-steady state when the operation time exceeded the starting stage and then got affected mainly by the variation of building load.

Rakesh Kumar et al [6] designed and optimized earth-to-air heat exchanger using a genetic algorithm and found the impact of four inputs humidity, ambient temperature, ground surface temperature and ground temperature at burial depth on outlet temperature of earth-air heat exchanger was studied through sensitivity analysis. Outlet temperature was significantly affected by ambient air temperature and ground temperature at burial depth.

Kyoungbin Lim et al [7] performed the experiment to measure the thermal performance of ground heat exchanger. Thermal response test using a vertical borehole heat exchanger at two different locations was done. The property of the rock at two regions was same but the value of thermal conductivity and thermal resistance was different, the reason for this was due to the groundwater flow, difference of borehole length and the weather variation during the measured period. Study also concluded that ground temperature remains stable over the borehole depth of 3m.

ArvindChel et al [8] investigated the performance evaluation and life cost analysis of earth to air heat exchanger integrated with adobe building for New Delhi composite climate. The following conclusions were made from the experiment:

The adobe house has considerable energy saving potential for Indian climatic conditions. These adobe houses can be easily adopted for all locations, especially in hot and dry climatic regions of semi-urban and rural areas all over the world for achieving the thermalcomfort.

Jyotirmay Mathur et al [9] studied the performance of the earth-air-tunnel heat exchanger by integrating with evaporative cooler at the outlet. The Experimental set-up of integrated EATHE- evaporative cooling system. Year round hourly analysis was done at the integrated system in Ajmer (Rajasthan) and found that integrated system performed better than simple earth air tunnel heat exchanger but during 17 pre-monsoon and monsoon period i.e from June to September, it was not able to treat sufficiently the ambient air to make it thermally comfortable. The graphical representation of temperature variation along the length of tunnel in winter conditions for air velocity of 5m/s and temperature variation along the length of tunnel in summer conditions for air velocity of 5m/s.

G. Colangelo et al [10] investigated the performance of horizontal ground heat exchanger for different configurations. Three different configurations namely linear, helical and slinky has been studied at different depths and effect of velocity has been studied. The CFD simulations have been carried out for depth up to 2.5 m for summer and winterconditions.

Akio Miyara et al [11] performed the experiment to study the different configurations of vertical ground heat exchangers with a steel pile foundation. The double tube, U tube and multi tube ground heat exchangers were used for the experiment to investigate the heat exchange rates at different flow rates. The performance of the ground heat exchangers was evaluated at different flow rates of 21, 41, 81/min.

Fabrizio Ascione et al [12] the energy performances using an earth-to-air heat exchanger for an air conditioned building have been evaluated for both winter and summer. By means of dynamic building energy performance simulation codes, the energy requirements of the systems have been analyzed for different Italian climates, as a function of the main boundary conditions (such as the typology of soil, tube material, tube length and depth, velocity of the air crossing the tube, ventilation air flow rates, control modes). The earth-to-air heat exchanger has shown the highest efficiency for cold climates both in winter and summer.

Thomas Woodson1 et al [13] has done case study on Earth-Air Heat Exchangers for Passive Air Conditioning in son 2012 and examines the ground temperature gradient and the performance of an EAHX performance in Burkina Faso. Ground temperature measurements were made at depths of 0.5 m, 1.0 m and 1.5 m. At the hottest time of the day, 15:00, the average outside temperature was 39.0°C, but the average temperature 1.5 m underground was 30.4°C. A clear phase shift was observed between the maximum outside temperature and the maximum ground temperature: The time of the day when the outside temperature is highest corresponds to the time when the underground temperature was lowest. The EAHX was 25 m long,1.5m underground and used a 95 m^3/hr ventilator. It was able to cool the air drawn in from the outside by 7.6°C.

A study conducted by Michael Sivak (2009) estimates that 24 of the top 50 metropolitan cities are in the developing world and are in warm climates. One city alone, Mumbai, has a cooling need equal to one quarter of the USA. It is predicted that by the end of the 21^{st} century, the energy used for indoor cooling will be 40 times greater than it is today. This will cause the total CO_2 emissions to rise from 0.8 Gt C in 2000 to 2.2 Gt C in 2100 (Issac and van Vuuen, 2009).Burkina Faso, a landlocked country in western Africa, is an example of a developing country with a major cooling demand. In the northern part of the country, temperatures can reach 50°C, and in the south, temperatures can reach:

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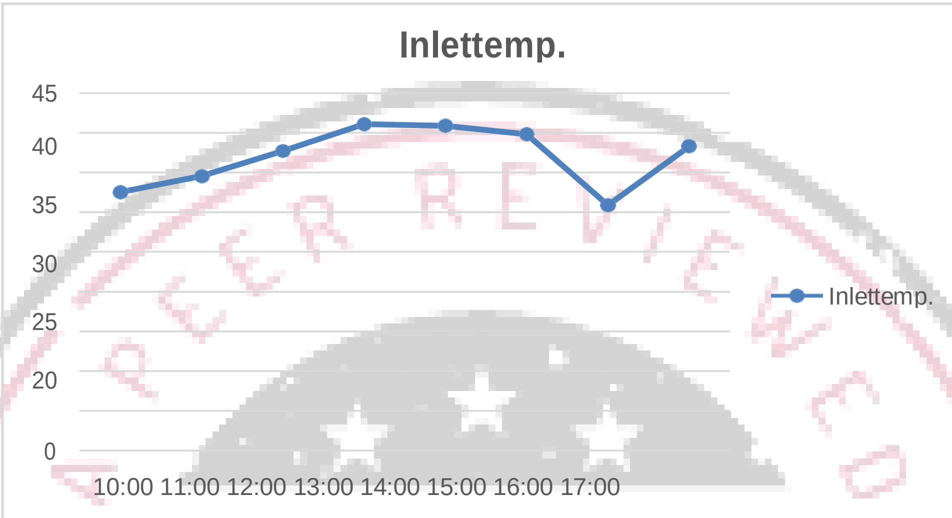
Manoj kumar Dubey et al [20] has conducted experiment on Earth Air Heat Exchanger in Parallel Connection in june2015 in MANIT Bhopal. When ambient air is drawn through buried pipes, the air is cooled in summer and heated in winter, before it is used for ventilation. The earth air heat exchanger can fulfill in both purpose heating in winter and cooling in summer. This paper investigates the experimental studies on earth air heat exchanger system in parallel connection in the summer climate

Vikas Bansal and Jyotirmay Mathur [21] has conducted experiment on Performance enhancement of earth air tunnel heat exchanger using evaporative cooling in march 2008,if a thermal model has been developed to investigate the potential of using the storage capacity of the ground for cooling with the help of an earth to air heat exchanger (EAHE) system integrated with evaporative cooler. Parametric studies performed for the EAHE coupled with the evaporative cooler illustrate the effects of buried pipe length, pipe diameter, volumetric flow rate of air, number of pipes and surface-to-volume (S/V) ratio on the outlet temperature of the EAHE. An analytical solution has been derived by considering the fundamental equation of energy, heat transfer and psychrometry, for predicting the temperature at the outlet of EAHE. The results of the EAHE coupled with evaporative cooling are compared with that of EAHE without evaporative cooling for different S/V ratio and bypass factor. It is observed that the length of the EAHE pipe is reduced significantly as much as 93.5% for obtaining desired temperature at the outlet of the EAHE by the integration of evaporative cooling with EAHE. Reduction in the length of buried pipe is also noted with decrease in bypass factor of evaporator cool.

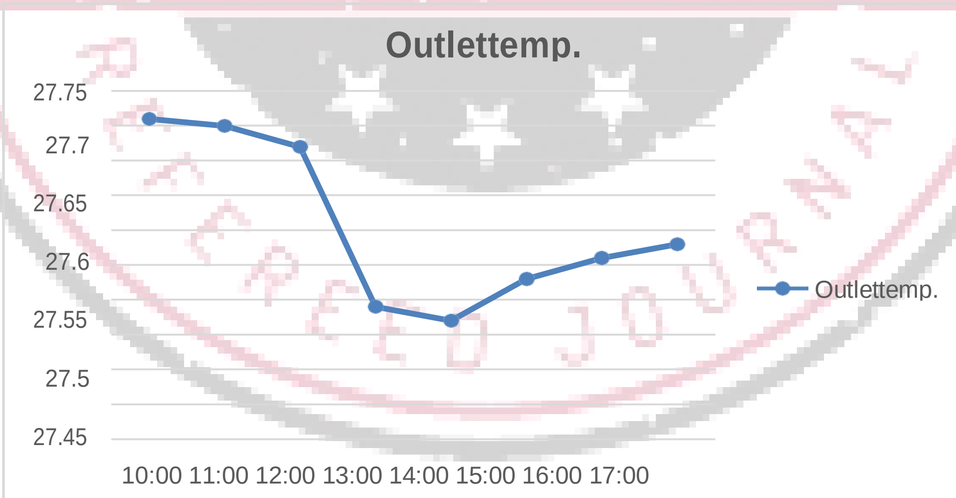
EXPERIMENTAL RESULTS (Graphical Representation)

1. TIME & INLET TEMP. (MAY-2019)



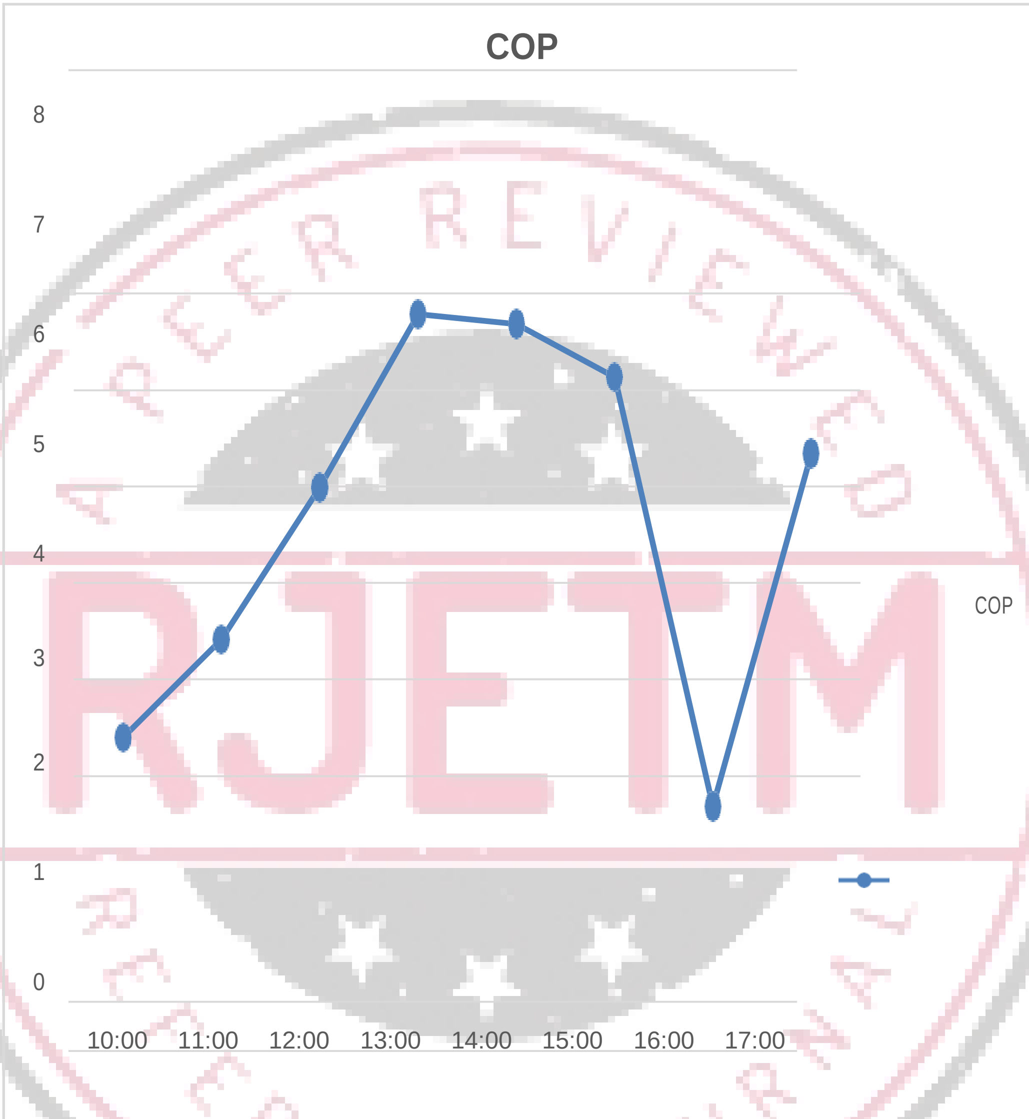
Variation of Inlet temperature with time

2. TIME&OUTLETTEMP.(MAY-2019)



Variation of Outlet temperature with time

3. TIME & COP (MAY-2019)



Variation of COP with Time

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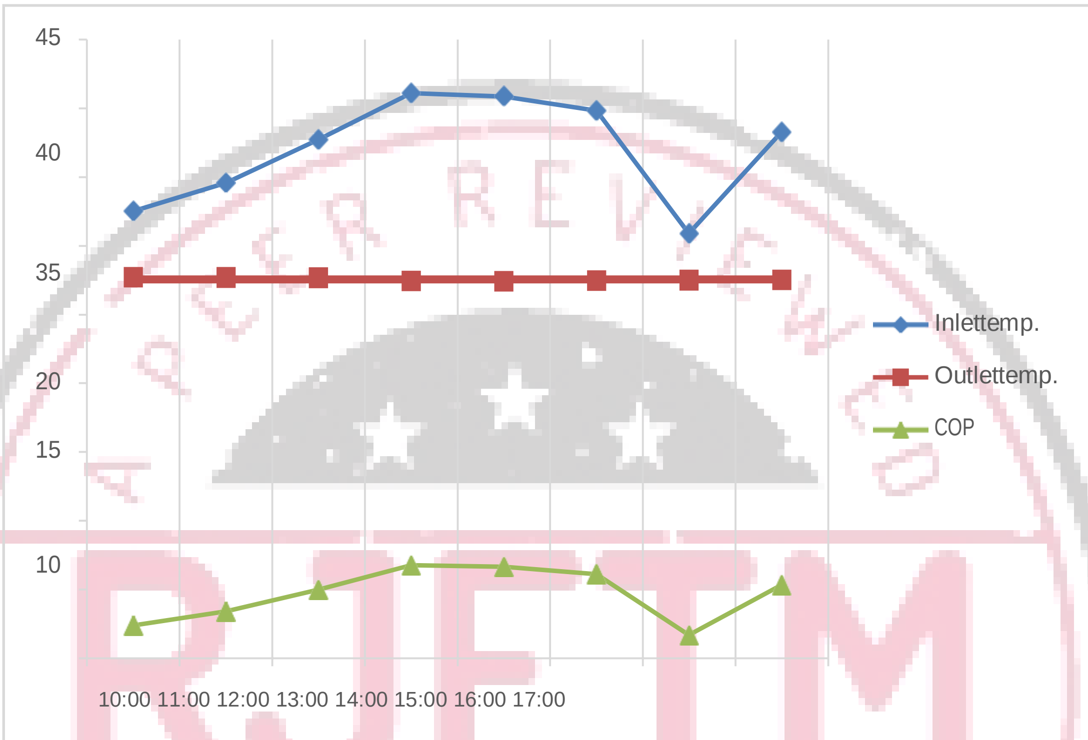
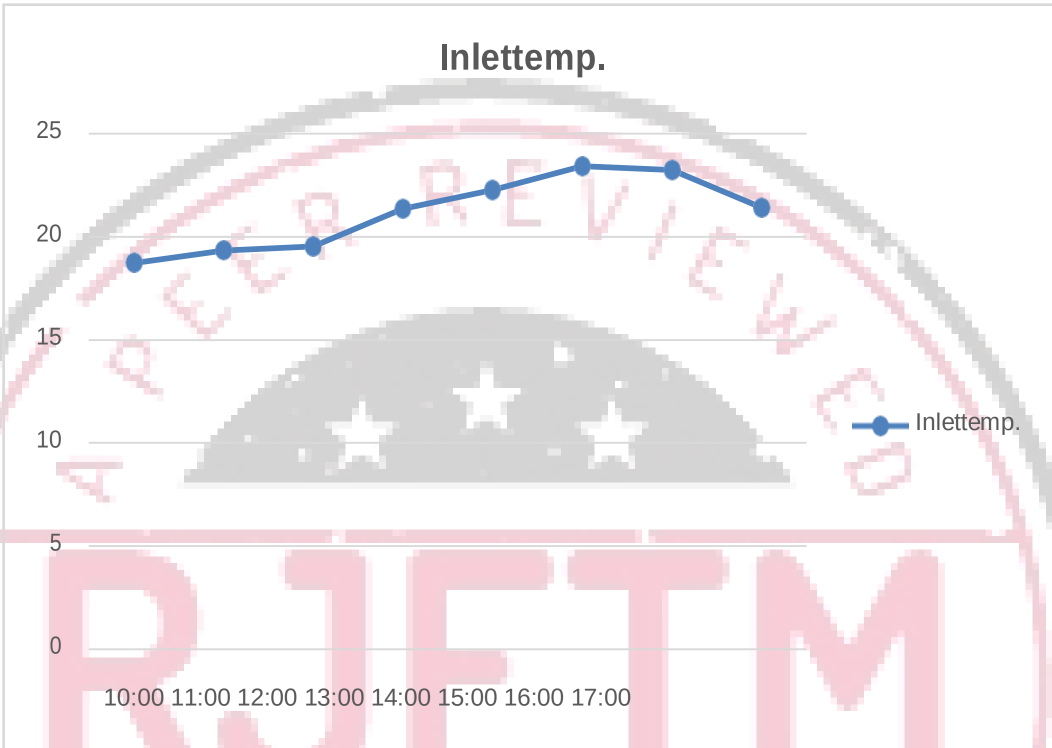
4. TIME, INLET,OUTLETTEMP&COP(MAY-2019)



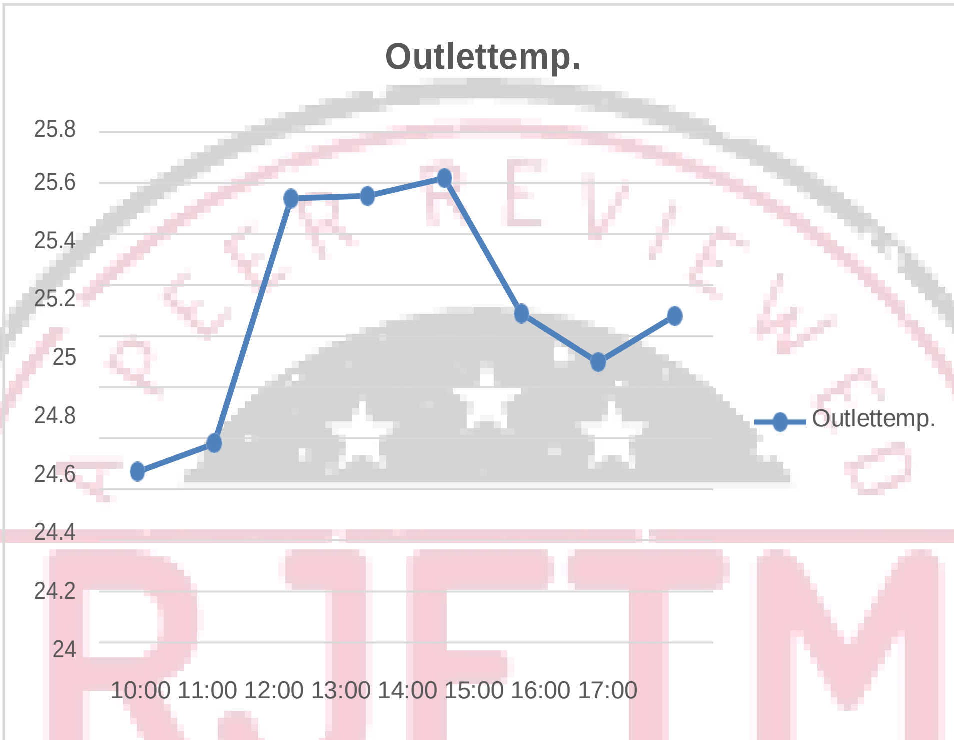
Variation of Inlet, Outlet Temp. & COP with Time

5. TIME&INLETTEMP.(JAN-2019)



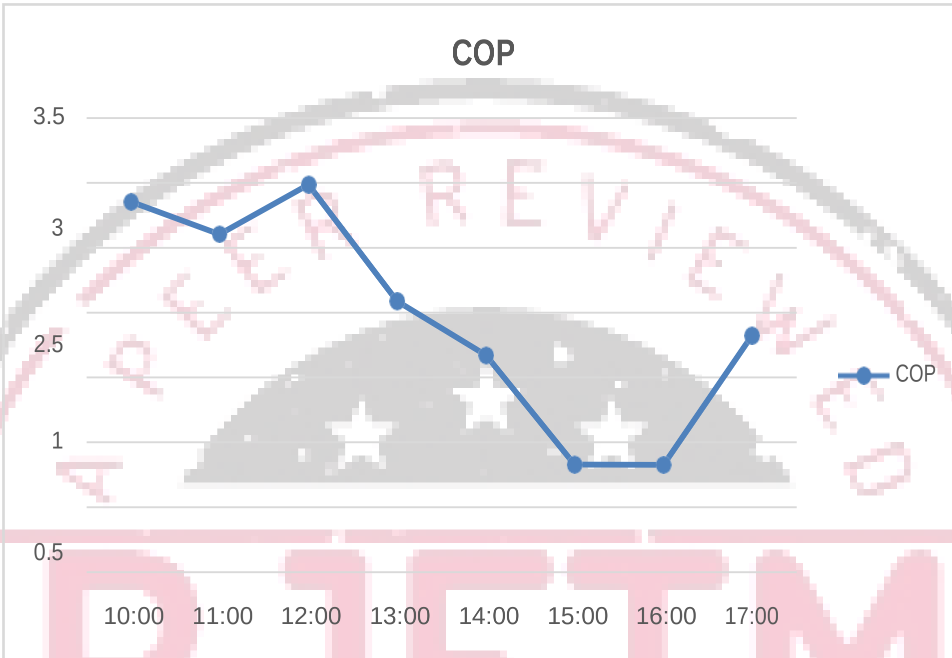
Variation of Inlet Temp. with Time

6. TIME & OUTLET TEMP. (JAN-2019)



Variation of Outlet Temp. with Time

7. TIME & COP(JAN-2019)



Variation of COP with Time

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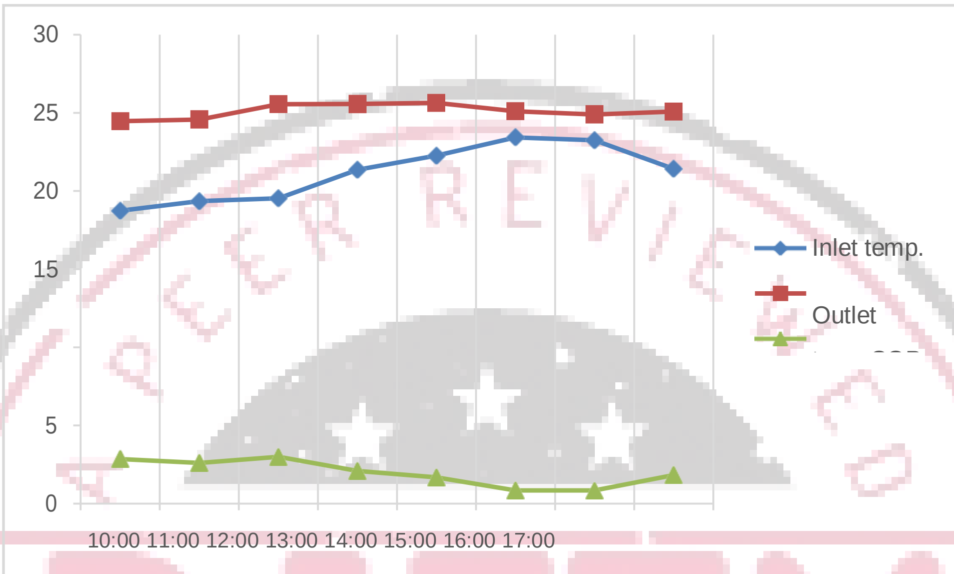
8. TIME, INLET, OUTLET TEMP. & COP (JAN-2019)



Variation of Inlet, Outlet Temp. & COP with Time

Explanation of the results:

After done the calculation in the previous chapter, we can see that the results are quite encouraging. The results are summarized under the following points:

For the pipe of 9 m length and 0.08 m diameter, temperature rise of 3.23^{O}C-6.1^{O}C has been observed for the outlet flow velocity 12m/s.

The maximum COP obtained in summer season is 6.790 at time 1:00 Pm and the maximum COP obtained in winter season is 2.987 at time 12:00Noon.

The COP of the system varies from 1.685 - 6.790 in summer season and 0.826 - 2.987 in winter season in outlet velocity 12m/s.

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