A REVIEW ON COMPRATIVE STUDY OF EARTH TUBE HEAT EXCHANGER MATERIALS FOR COOLING OF AIR

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ABSTRACT

Earth tube heat exchanger systems can be used to cool the building in summer climate and heat the buildings in winter climate. 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. 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 Lakshmi Narayan College of Technology, Bhopal. Effects of the operating parameters i.e. air velocity and temperature on the thermal performance of horizontal ground heat exchanger have been studied. For the pipe of 9m length and 0.05m diameter, temperature falling of 3.93^0C-12.6^0C in hot weather and temperature rising of 6^oC-10^oC in cold weather have been observed for the outlet flow velocity 11 m/s. At higher outlet velocity and maximum temperature difference, the system is most efficient to be used.

Keywords- *ETHE, Anemometer, Temperature Auto Scanner, Thermocouple, wire Blower*

INTRODUCTION

Energy is one of the most important global challenges. A large portion of the global energy supply is used for electricity generation and space heating, having the major portion derived from fossil fuels. Fossil fuels are non-renewable resources and their combustion is harmful to the environment, through the production of greenhouse gases, which effects the climate change and other pollutants. Fossil fuel depletion along with pollutant emissions and global warming are important factors for sustainable and environmentally benign energy systems. These concerns have motivated efforts to reduce society's dependence on non-renewable resources, by reducing demand and substituting alternative energy sources. First of all efforts are focused on producing electricity with higher efficiency. Old power plants are more rapidly phased out and replaced by new, more efficient plants. More efficient use of energy not only reduces the consumption of electricity, but also lowers the consumption of non-renewable resources. Renewable energy resources are sought that are more environmentally benign and economic than conventional fossil fuels. Beyond fossil fuels, the earth's crust stores an abundant amount of thermal energy [1]. Geothermal systems are relatively benign environmentally, with the emissions much lower than for conventional fossil fuelled systems. Geothermal energy is the heat from within the earth. Geothermal energy is generated in the earth "score and core is made up of very hot magma (melted rock) surrounding a solid iron centre. High temperatures are continuously produced inside the earth by the slow decay of radioactive materials and this process is natural in all rocks. The outer core is surrounded by the mantle, which is made of magma and rock. The outer layer of the earth, the land that forms the continents and ocean floors is called the crust. The crust is not a solid piece, like the shell of an egg, but it is broken into pieces called plates. Magma comes close to the earth surface near the edges of these plates. We can dig wells and pump the hot underground water to the surface. People use geothermal energy to heat their homes and to produce electricity.

In many cases solar energy is directly or indirectly used to supply heat or electrical energy. Solar gains inside the building are avoided to reduce cooling needs or the size of the air-conditioning unit. Using the earth as a component of the energy system can be accomplished through three primary methods i.e. direct, indirect and isolated. In direct system, the building envelope is in contact with the earth, and the conduction through the building elements (primarily walls and floor) regulates the interior temperature. In indirect system, the building interior is conditioned by air brought through the earth, such as in earth-to-air heat exchangers [2]. The isolated system uses earth temperatures to increase the efficiency of a heat pump by moderating temperatures at the condensing coil. The geothermal heat pump is the example of an isolated system. This thesis will focus on indirect systems. Indirect systems, i.e. earth-to-air heat exchangers, sometimes called ground tubes, or ground coupled air heat exchangers are an interesting and promising technology. Tubes are placed in the ground, through which air is drawn. Because of the high thermal inertia of the soil, the air temperature variations at the ground surface exposed to the exterior climate are damped deeper in the ground. Further a time lag occurs between the temperature variations in the ground and at the surface. At a sufficient depth the ground temperature is higher than the outside air temperature in winter and lower in summer. When fresh air is drawn through the earth-to-air heat exchangers the air is thus cooled in summer and heated in winter. In combination with other systems and good thermal design of the building, the earth to air heat exchanger can be used to preheat air in winter and avoid air-conditioning units in buildings in summer, which results in a reduction in electricity consumption of a building.

1.1 Ground Coupled Heat Exchanger:

A ground coupled heat exchanger is an underground heat exchanger that can capture heat from and dissipate heat to the ground. They use the earths near constant subterranean temperature to warm or cool air or other fluids for residential, agricultural or industrial uses. They are also called earth tubes or earth-air heat exchangers or ground tube heat exchanger. Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and their use can help building meet passive house

- **Closed-Loop Systems Horizontal**
- **Closed-Loop Systems Vertical**
- **Surface Water Pond/Lake**
- **Open-Loop System**

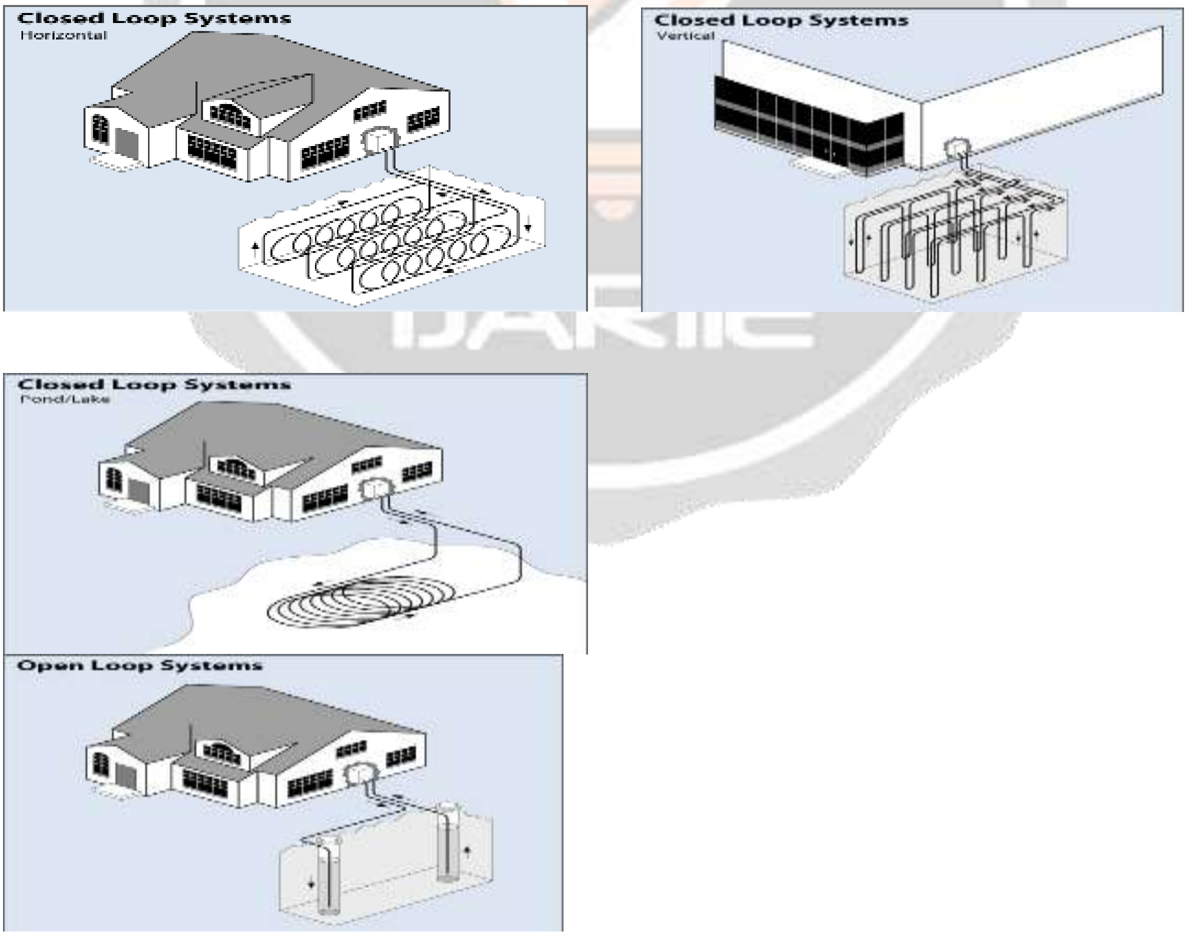

Fig No.1: Earth tube Heat Exchanger install in house

In the case of cooling a building, the ground is the heat sink, and the building to be cooled acts as heat source. In the case of heating, these functions are reversed- the ground becomes the heat source and the building heat sink. Heat is extracted from or rejected to the ground by means of buried pipe, through which a fluid flows. The buried pipe is commonly called ground loop heat exchanger.
They can make significant contributions to reductions in electrical energy usage but in this` system, the actual heat transfer to and from the ground loop heat exchanger varies continuously. due to changing building energy requirements. Despite the changing environmental conditions, the net fall in temperature that can be adjusted with the flow of the air so as to give comfort conditions in the room. The resulting variations impact the coefficient of performance (COP) of the system and thus influence the overall system performance in a significant way

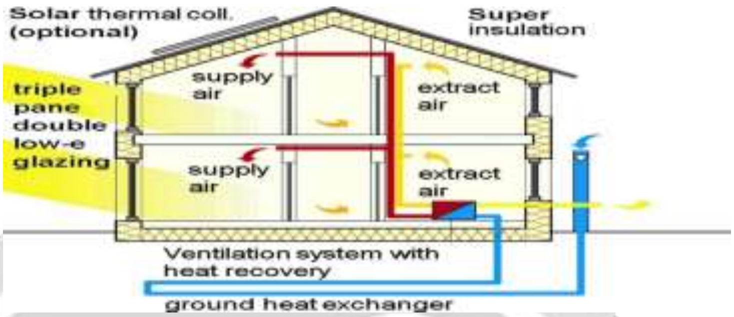

Fig No.2: Earth tube Heat Exchanger install in house

1.2 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 valuable results.
• Need available land to accommodate the length of tubes.
• Great opportunity to place them under the building floor when constructing a new building.

1.2General Explanation
Earth tubes are low technology, sustainable passive cooling-heating systems utilized mostly to preheat a dwelling's air intake. Air is either cooled or heated by circulating underground in horizontally buried pipes at a specified depth. Specifically air is sucked by means of a fan or a passive system providing adequate pressure difference from the ambient which enters the building through the buried pipes. Due to ground properties the air temperature at the pipe outlet maintains moderate values all around the year.

Temperature fluctuates with a time lag (from some days to a couple of months) mainly relative to the depth considered. Temperature values remain usually in the comfort level range (15-27 °C).
This technology is not recommended for cooling of hot humid climates due to moisture reaching dew point and often remaining in the tubes. However there are southern European coastal regions as in Greece where the climate remains hot and dry. In such locations these systems could have impressive results. [4]
The material of a pipe can be anything from thin wall 'sewer' plastic, metal or concrete. However concrete should better be avoided in order not to be dependent on carbon filtration UV sterilization for the musty air coming out of concrete earth tubes.

The effectiveness of a buried pipe system is mainly related to the following parameters:
• Ground temp. at depth of the installed exchanger
• Thermal diffusivity of soil
• Pipe length, width
• Inlet air temp.
• Thermal conductivity of pipes
• Air velocity

An earth-to-air heat exchanger (EAHX) consists in one or more tubes lied under ground in order to cool (in summer) or pre-heat (in winter) air to be supplied in a building. This air is often outdoor air necessary for ventilation, but also useful to partially or totally handle the building thermal loads. The physical phenomenon is simple: the ground temperature is commonly higher than the outdoor air temperature in winter and lower in summer, so it makes the use of the earth convenient as warm or cold sink, respectively. Normally, the soil temperature, at a depth of 5 to 8m under the ground level, remains almost constant throughout the year; its temperature pro le as a function of the depth depends on several factors, such as the physical properties of the soil, these covering and the climate conditions. Given identified two macro-groups of earth tubes, those with opened closed loop.

1.3Advantages and Disadvantages of Ground Heat Exchanger

Advantages:

1. The ground heat exchangers are very simple to use and easy to maintain.
2. In the long run, the low maintenance cost and the electricity cost saving make up for the initial investment.
3. Ground heat exchangers uses only the energy stored in the earth and have no harmful impact on the environment.
4.

Disadvantages:

1. High initial investment cost.
2. Use of ground heat exchangers is recommended in new houses which has excellent insulation and air-tightness.
3. Space requirement is the major hindrance to the adoption of ground heat exchangers.
4. The design and installation of an effective ground heat exchange depends on the local geology and the heating or cooling requirements of the building and to get the benefit of a well-designed system, one needs to consult an expert installer which increases the cost of the system

2.LITERATURE REVIEW

Girja saran and rattan jadhav [1] has conducted experiment on single pass earth tube heat exchanger. They conducted experiment in Ahmadabad Gujarat (2000) India these found. If a single pass earth-tube heat exchanger (ETHE) was installed. and ETHE is made of 50 m long ms pipe of 10 cm nominal diameter and 3 mm wall thickness. ETHE is buried 3 m deep below surface. Ambient air is pumped through it by a 400 w blower. Air velocity in the pipe is 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.

Thomas Woodson1 et al [2] 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, 1.5 m underground and used a 95 m3/hr ventilator. It was able to cool the air drawn in from the outside by 7.6°C.

W.H. Leong et al [3] 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. soil degree of saturation

Vikas Bansal and Jyotirmay Mathur [4] 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 cooler.

Fabrizio Ascione et al [5]: 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.

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.

Weibo Yang et al [8] 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.

Akio Miyara et al [9] 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 2, 4, 8

3.DESIGN PARAMETERS

3.1Tube depth

The ground temperature is defined by the external climate and by the soil composition, its thermal properties and water content. The ground temperature fluctuates in time, but the amplitude of the fluctuation diminishes with increasing depth of the tubes, and deeper in the ground the temperature converges to a practically constant value throughout the year. On the basis of temperature distribution, ground has been distinguished into three zones.

Fig 3.1 General Tube

- Surface zone: This zone is extended up to 1m in which ground is very sensitive to external temperature.
- Shallow zone: This zone is extended up to 1-8 m depth and temperature is almost constant and remains close to the average annual air temperature.
- Deep zone: This zone is extended up to 20 m and ground temperature is practically constant.

Soil temperature at a depth of about 10 feet or more stays fairly constant throughout the year and stays equal to the average annual temperature [34]. After a depth of 3-4 m in the ground, temperature remains nearly constant

3.2Tube length, tube diameter and air flow rate

The total surface area of the ground coupled air heat exchangers is a very important factor in a overall cooling capacity, which can be increased by two ways, either increasing the tube length or tube diameter [8]. Optimum tube diameter varies widely with tube length, tube costs, flow velocity and mass flow rate. A diameter should be selected that it can balance the thermal and economic factors for the best performance at the lowest cost.

The optimum is determined by the actual cost of the tube and the excavation. Excavation costs in particular vary greatly from one location and soil type to another. The optimum tube length was determined by passing the air from the blower at different lengths. The air was passed through the inlet at the minimum speed of the blower i.e 7 m/s and at the length of 9m, the outlet velocity was 1.8 m/s, any further increase in length used to reduce the velocity at outlet which was not required. The 5 cm diameter pipe was considered for the experiment.

3.3Tube material

Various factors need to be considered while deciding upon the material of the pipe for this system. There can be many options while selecting the material of the pipe to be used with the system. As the pipe has to be buried underground, it is not easy to replace the pipe often.

Hence the longevity of the pipe is of utmost importance while taking care of the heat transfer characteristics of the system. There was a wide range of materials available for the selection for use in our system.

- **Mild Steel (MS)**
- **Copper**
- **Aluminium**
- **Concrete**
- **Poly-vinyl Chloride (PVC)**

4.EXPERIMENTAL SET UP

4.1Description of Set-Up

For the experimental work we used MS pipe of 5 cm diameter and was buried at a depth of 3meters. A blower was used to drive the air through the pipe which was circulated throughout the pipe. A vane type anemometer and thermocouple was used to measure the velocity and temperature of the air respectively. The thermocouple was attached with the Temperature Sensor .

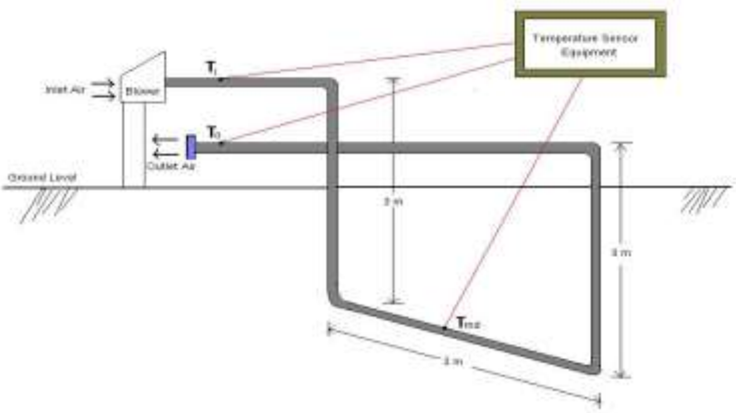

Figure 4.1: Schematic Representation of Experimental Set up

The experimental set-up in the figure 5.1 consists of the 5 cm diameter MS pipe buried below the ground level at a depth of 3 m. At a depth of 3 m, the pipe is spread horizontally for a length of 3m. The total length of the experimental set-up is 9 m.

The outlet pipe is covered with a sheet which acts as a insulation and prevents any variation in the air coming through the outlet pipe and for L bends have been used in the experimental set up.

Figure 4.2: Experimental set up

4.2 Procedure for Experimentation:

To start the experimentation, the blower was switched on and the air was let to pass through the pipe for some time till the steady state was achieved. The velocity at the inlet and outlet was calculated with the help of vane type anemometer. The thermocouple wire was attached at inlet portion middle portion and outlet portion. The Thermocouple wire is attached with temperature auto scanner which continuously displays the readings of thermocouple. The above procedure was repeated with different ambient conditions, this is achieved by conducting the experiment 3day of summer season (29, 30, 31MAY-2019) and 3day of winter season (6, 7, 8th Jan-2019). All the data thus obtained is compiled into a single table. The graphs are plotted for various sets of observations obtained from the experiment. The total cooling and heating has been calculated for flow velocities 11m/s by the following equation:

For Summer Climate

Qc = mCp(Tinlet – Toutlet)

For winter climate

Qc = mCp(Toutlet –Tinlet)

Where m= mass flow rate of air through the pipe

Cp= specific heat capacity of air

Tinlet= inlet temperature of air

Toutlet= outlet temperature of air.

Coefficient of performance (COP) of the system has been calculated from the following Expression:

For Summer Climate

COP= mCp(Tinlet – Toutlet)/ Power Input (1)

For winter climate

COP= mCp(Toutlet –Tinlet)/ Power Input (2)

4.3 INSTRUMENTS USED:

- **Anemometer**
- **4.3.1. Anemometer:** Vane type anemometer was used for measuring the velocity of the air. A vane anemometer which uses a small fan is turned by air flowing over the vanes. The speed of the fan is measured by a revolutions counter and converted to a wind speed by an electronic chip. Hence, volumetric flow rate taken 0.0863 m3/s otherwise it may be calculated if the cross-sectional area is known.

Figure 4.3: Vane type Anemometer

It has 13mm LCD display screen and temperature range is from 00C to 500C. It is extremely light weight instrument weighing 260 g and velocity range is from 0.40 m/s to 45 m/s with an accuracy of ±0.2% + 0.1 m/s.

- **Temperature Auto Scanner**

It displays the temperature encountered by the Thermocouple attached with the instrument.

Figure 4.4: Temperature Auto Scanner

- **Thermocouple wire**
- **Blower**

Specifications:

DISPLAY	4-1/2 Digit, Segment; 0.56" Height; Red L.E.D
ACCURACY	1% of full scale or ± 10 % 20C
RESOLUTION	0.010C up to 2000C
SENSOR BREAK PROTECTION	Display Starts Blinking
POWER SUPPLY	180-230 V AC
NO. INPUT CHANNEL	10
DIMENSIONS	96 x 96 x 130 mm

Table 4.1: Specifications of Temperature Auto Scanner

5.EXPERIMENTAL RESULT FOR SUMMER & WINTER SEASON

5.1(a) Cooling Model Test (GI PIPE)

The air velocity was 11 m/s. Velocity was measured by a portable, digital vane type anemometer .The vane size is 66 x 132 x29.2 mm and velocity range 0.3 to 45 m/s. The anemometer measures mean air velocity. The volume flow rate of air was 0.0863 m3/s and mass flow rate 0.0269 kg/s. The ETHE system was operated for seven hours a 3 days 28, 29&30 May-2019) for May Month. The tube air temperature at the inlet, middle and outlet, were noted at the interval of one hour. System was turned on at 10.00 AM and shut down at 5 PM. Tests in May were carried out on 28th, 29th, and 30th 2019). The ambient temperature on these three days was very similar. The results of the three days were therefore averaged. Table-1(a) shows the data, which is reading of three days and mean of the reading of three days. The ambient temperature started with 30.73oC at 10.00 AM and rose to a maximum of 40.13oC at 2 PM. The temperature of air at outlet was 26.8oC at when system started in 10am.. The outlet temperature was just above the basic soil temperature (26.6oC).

Table-5.1(a) Inlet Temp, Middle and Outlet Temp. Of ETHE (May-2019)

Date	29.06.2019			30.06.2019			31.06.2019		
Time	**T_a**	**Tm**	**To**	**Ta**	**Tm**	**To**	**Ta**	**Tm**	**To**
10:00	30.5	29.1	26.8	30.7	29.1	26.8	31.0	29.0	26.8
11:00	33.7	29.2	26.8	33.8	29.2	26.8	33.5	29.1	26.7
12:00	36.4	29.5	27.2	36.6	29.5	27.1	36.7	29.3	27.1
13:00	37.8	29.5	27.0	37.7	29.5	27.2	37.4	29.4	27.1
14:00	40.8	29.7	27.1	39.9	29.7	27.1	39.7	29.6	27.2
15:00	40.4	29.7	27.2	39.8	29.7	27.1	39.8	29.5	27.1
16:00	39.8	29.8	27.1	39.8	29.8	27.2	39.9	29.7	27.3
17.00	39.6	29.9	27.2	39.5	30.0	27.	39.7	29.8	27.2

Table-5.1(a) Inlet Temp, Middle & Outlet Temp. of ETHE (May-2019)

FOR SUMMER SEASON (MAY-2019)

Area = π x $d^2/4$= π x 0.05x0.05/4=0.00196 m2

Density of air = 1.225 kg/m3
Specific heat capacity of air,
Cp= 1007 J/kg K
Total cooling, Qc = mCp(T inlet – T outlet)

Coefficient of Performance, COP = = mCp(T inlet – T outlet)/Power Input [24]
Mass flow rate, m = density x area x velocity=0.0269 [25]
Power Input = 125 W

1.Time:10:00
Inlet temperature, T inlet: 30.730C
Outlet temperature, T outlet: 26.80C

Velocity at outlet: 11 m/s
Qc = 106.45W
COP = 0.851

2.Time:11:00
Inlet temperature, T inlet: 34.33.20C
Outlet temperature, T outlet: 26.760C
Velocity at outlet: 11 m/s
Qc = 205.05 W
COP = 1.640

3.Time:12:00
Inlet temperature, T inlet: 36.560C
Outlet temperature, T outlet: 27.130C
Velocity at outlet: 11 m/s
Qc = 255.43 W

COP = 2.043

4.Time:13:00
Inlet temperature, T inlet: 37.630C
Outlet temperature, T outlet: 27.100C

Velocity at outlet: 11 m/s
Qc = 285.23 W
COP = 2.281

5Time:14:00
Inlet temperature, T inlet: 40.130C
Outlet temperature, T outlet: 27.130C
Velocity at outlet: 11 m/s
Qc = 348.62 W

COP = 2.817

6.Time:15:00
Inlet temperature, T inlet: 400C
Outlet temperature, T outlet: 27.130C
Velocity at outlet: 11 m/s
Qc = 341.30W
COP = 2.788

7.Time:16:00
Inlet temperature, T inlet: 39.80C
Outlet temperature, T outlet: 27.20C
Velocity at outlet: 11 m/s

Qc = 337.78 W
COP = 2.73

8.Time:17:00
Inlet temperature, T inlet: 39.60C

Outlet temperature, T outlet: 27.130C
Velocity at outlet: 11 m/s
Qc = 478.58 W
COP = 2.70

Average Inlet Temp, Middle And Outlet Temp. Of ETHE(MAY 2019)

Time	Ta=T i	T mid	To	COP
10:00	30.73	29.06	26.8	0.851
11:00	34.33	29.16	26.76	1.640
12:00	36.56	29.43	27.13	2.043
13:00	37.63	29.46	27.10	2.281
14:00	40.13	29.66	27.13	2.817
15:00	40.00	29.63	27.13	2.788
16:00	39.8	29.76	27.2	2.730
17:00	39.6	29.9	27.13	2.702

Table 5.1(b): Average Inlet Temp, Middle And Outlet Temp. Of ETHE (MAY-2019)

5.1(a) EXPERIMENTAL RESULTS (Graphical Representation)

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

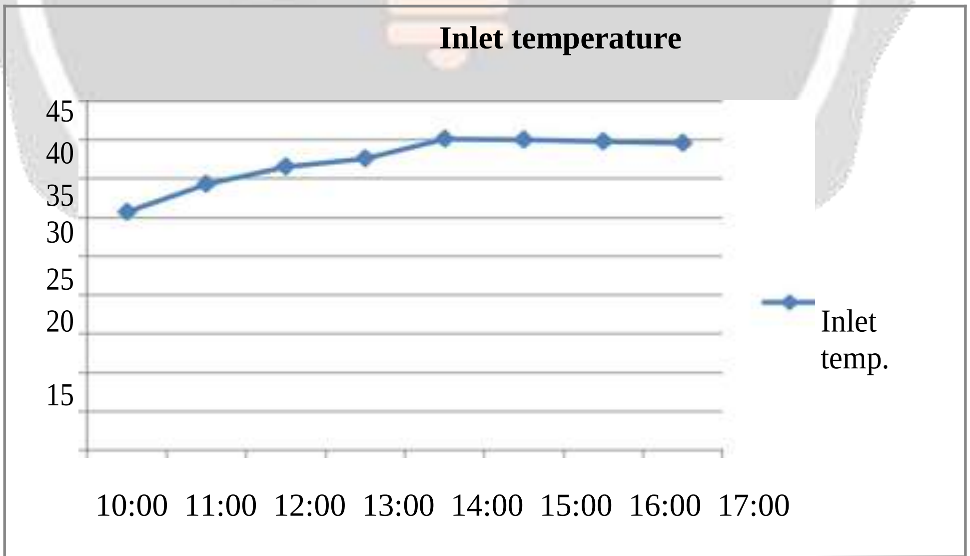

Fig. No. 5.1 Variation of Inlet temperature with time

2. TIME & OUTLET TEMP (MAY-2019)

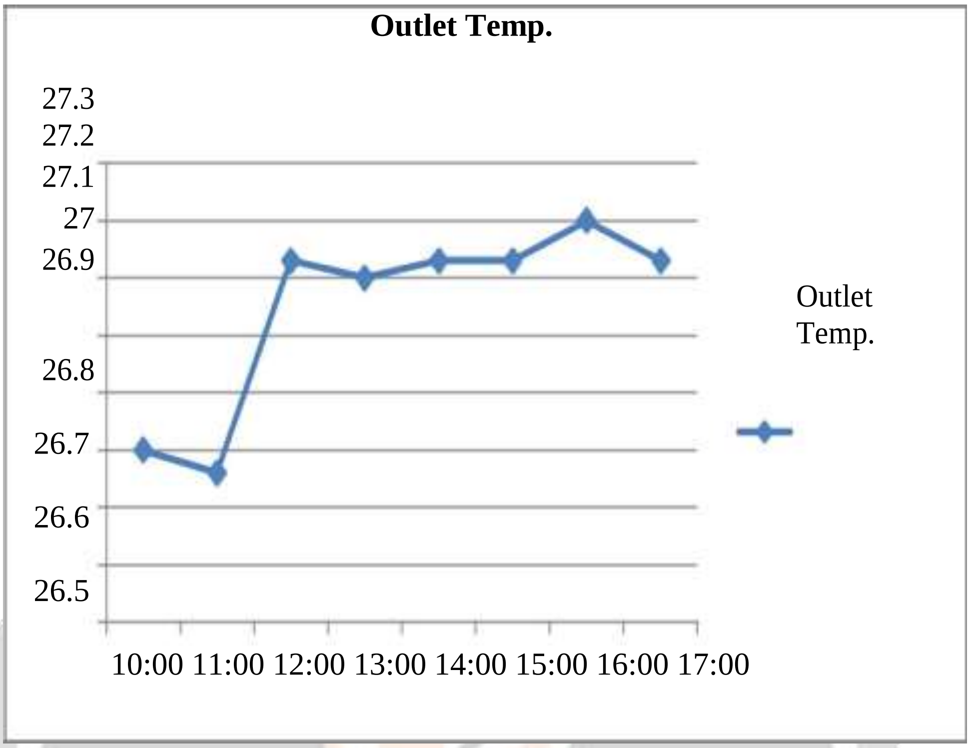

Fig. No. 5.2 Variation of Outlet temperature with time

3. TIME & COP (MAY-2019)

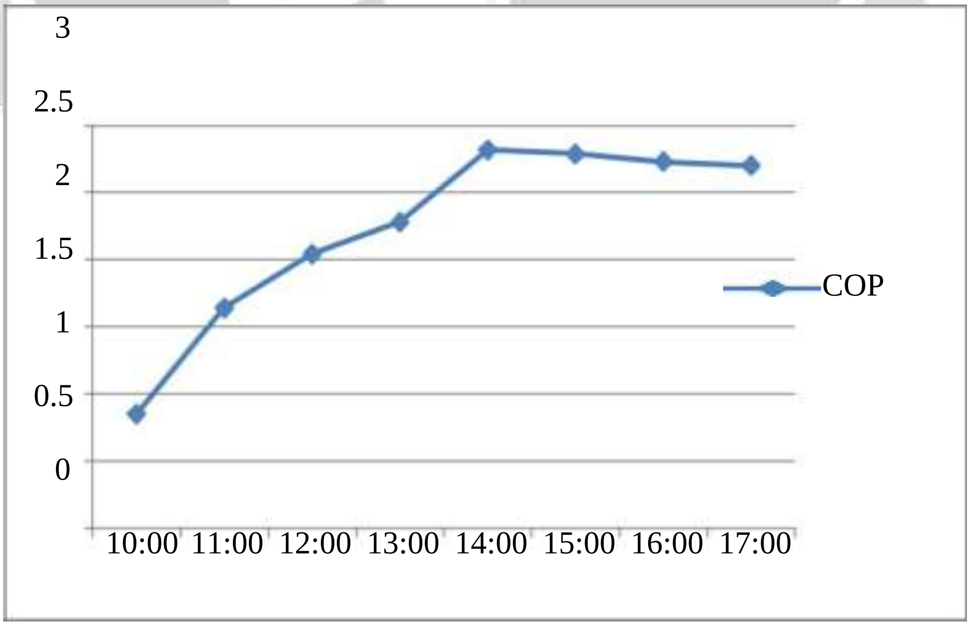

Fig. No. 5.3 Variation of COP with Time

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

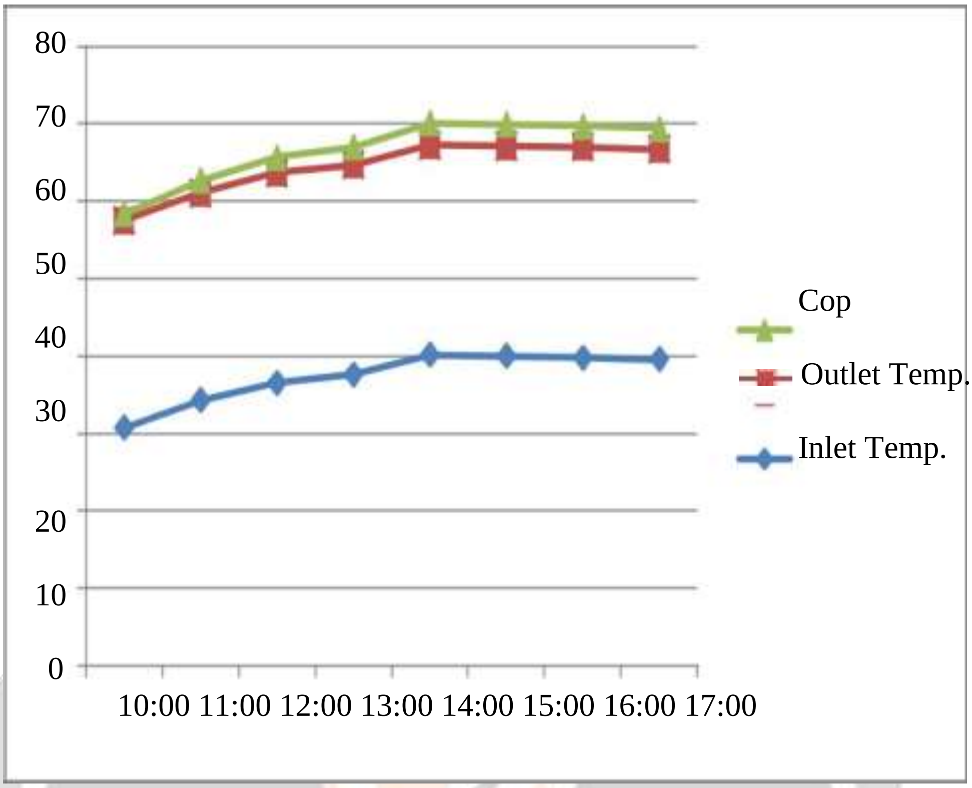

Fig. No. 5.4 Variation of Inlet, Outlet Temp. & COP with Time

5.2 (a) HEATING MODEL TEST(GI PIPE):

Heating mode test tests were carried out for three Day of Jan.2019 (06, 7&8th) The system was turned on at 10am and operated for 8 hours continuously, till 5 pm that day. Temperature readings were noted at hourly interval. Here also the conditions on the three consecutive days were similar and therefore the results combined.. The ambient temperature started at 21oC (10 AM), increasing the highest value 30.05oC at 5 p.m. Temperature of the air at the outlet varying from 27.53oC to 40.36oC. ETHE was able to raise the ambient air temperature at 5 PM from 21.00oC to 30.30 oC.

Inlet Temp, Middle And Outlet Temp. Of ETHE(JAN-2019)

Date	06.1.2019			7.1.2019			8.1.2019		
Time	T_a	Tm	To	Ta	Tm	To	Ta	Tm	To
10:00	21.00	25.4	27.5	21.02	25.42	27.6	21.00	25.46	27.5
11:00	22.00	25.5	28.4	22.5	25.53	28.7	21.9	25.6	28.8
12:00	24.4	25.5	31.2	24.5	25.54	31.6	24.1	25.83	31.5
13:00	26.5	27.7	34.2	26.7	27.72	34.9	26.4	27.93	34.6
14:00	27.4	28.6	36.3	27.3	28.68	36.5	27.2	28.10	36.7
15:00	27.6	28.9	36.5	27.01	28.92	36.6	27.2	28.96	36.9
16:00	29.00	29.3	39.3	29.2	29.34	39.5	29.1	29.5	39.7

17:00	30.05	32.3	40.2	30.06	32.35	40.4	30.2	32.6	40.5

Table-5.2(a) Inlet Temp, Middle and Outlet Temp. Of ETHE (JAN-2019)

FOR WINTER SEASON (Jan-2019)

Area = π x $d^2/4$= π x 0.05x0.05/4=0.00196 m2
Density of air = 1.225 kg/m3
Specific heat capacity of air,

Cp= 1007 J/kg K
Total heating, Qh= mCp(Toutlet– Tinlet)

Mass flow rate, m = density x area x velocity=0.0269
Power Input = 125 W

Coefficient of Performance, COP = = mCp(T outlet – T inlet)/Power Input

1.Time:10:00
Inlet temperature, T inlet: 21.000C
Outlet temperature, T outlet: 27.530C
Velocity at outlet: 11 m/s

Qc = 176.88W
COP = 1.41

2.Time:11:00
Inlet temperature, T inlet: 22.330C

Outlet temperature, T outlet: 28.630C
Velocity at outlet: 11 m/s
Qc = 176.074 W
COP = 1.40

3.Time:12:00
Inlet temperature, T inlet: 24.330C
Outlet temperature, T outlet: 31.430C
Velocity at outlet: 11 m/s

Qc = 192.326 W
COP = 1.53

4.Time:13:00
Inlet temperature, T inlet: 26.530C

Outlet temperature, T outlet: 34.560C
Velocity at outlet: 11 m/s
Qc = 217.519 W
COP = 1.74

5Time:14:00
Inlet temperature, T inlet: 27.300C
Outlet temperature, T outlet: 36.500C
Velocity at outlet: 11 m/s
Qc = 249.212W

COP = 1.99

6.Time:15:00
Inlet temperature, Tinlet:27.27 0C
Outlet temperature, T outlet: 36.660C

Velocity at outlet: 11 m/s
Qc = 254.359W
COP = 2.03

7.Time:16:00
Inlet temperature, T inlet: 29.100C
Outlet temperature, T outlet: 39.500C
Velocity at outlet: 11 m/s
Qc = 281.718W
COP = 2.22

8.Time:17:00
Inlet temperature, T inlet: 30.100C
Outlet temperature, T outlet: 40.360C
Velocity at outlet: 11 m/s

Qc = 277.926W
COP = 2.25

Temperature of the air at the outlet varying from 27.53oC to 40.36oC. ETHE was able to raise the ambient air temperature at 5 PM from 21.00oC to 30.30oC.The table also shows the COP values. The maximum COP Achieved at 5pm i.e2.25

Average Inlet Temp, Middle And Outlet Temp. of ETHE(Jan2019)

Time	Ta=Ti	Tmid	To	COP
10:00	21.00	25.42	27.53	1.41
11:00	22.13	25.54	28.63	1.40
12:00	24.33	25.62	31.43	1.53
13:00	26.53	27.78	34.56	1.74
14:00	27.3	28.46	36.5	1.99
15:00	27.27	28.92	36.66	2.03
16:00	29.1	29.38	39.5	2.22
17:00	30.10	32.41	40.36	2.25

Table-5.2 (b) Inlet Temp, Middle & Outlet Temp. Of ETHE (JAN-2019)

5.2 (a) TIME & INLET TEMP (JAN-2019)

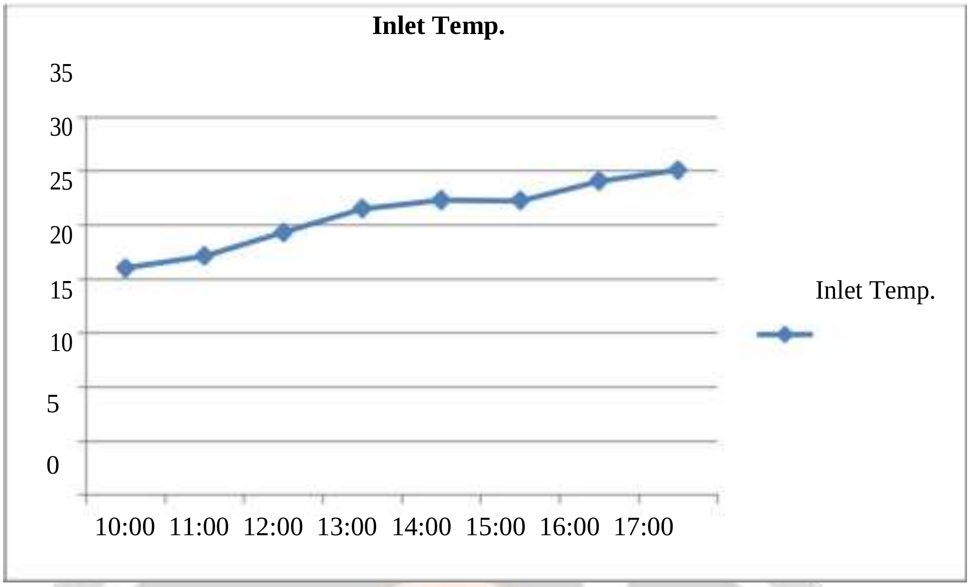

Fig.No. 5.9 Variation of Inlet Temp with Tim

6. TIME & OUTLET TEMP (JAN-2019)

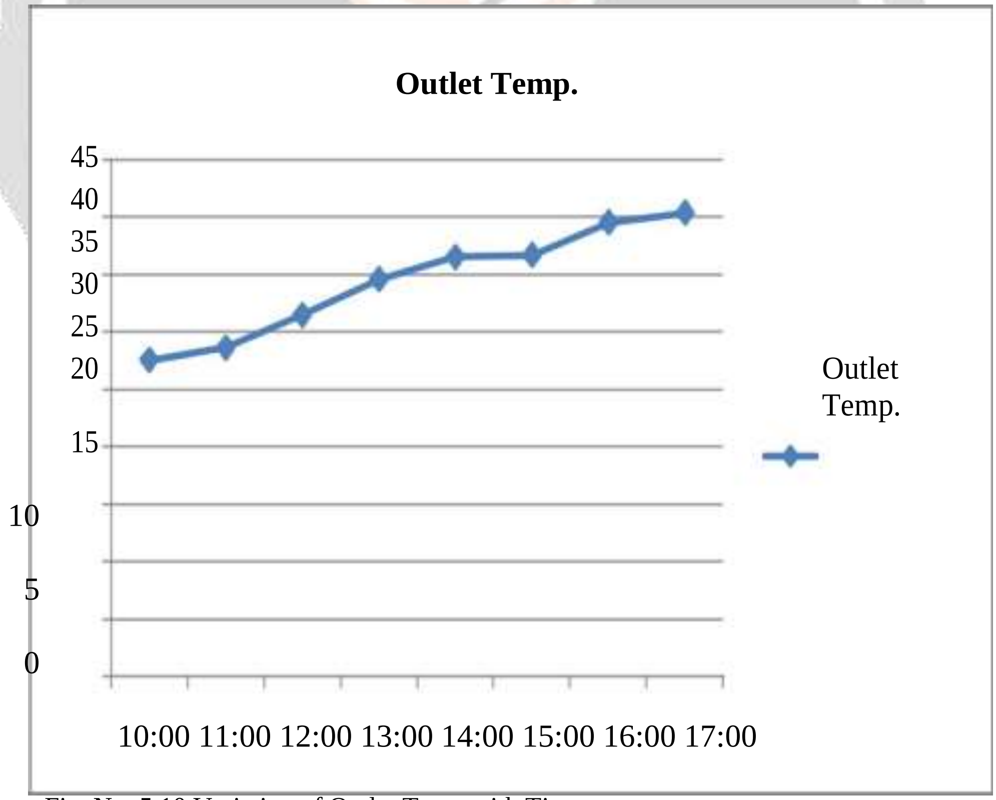

Fig. No. 5.10 Variation of Outlet Temp with Time

7. TIME & COP (JAN-2019)

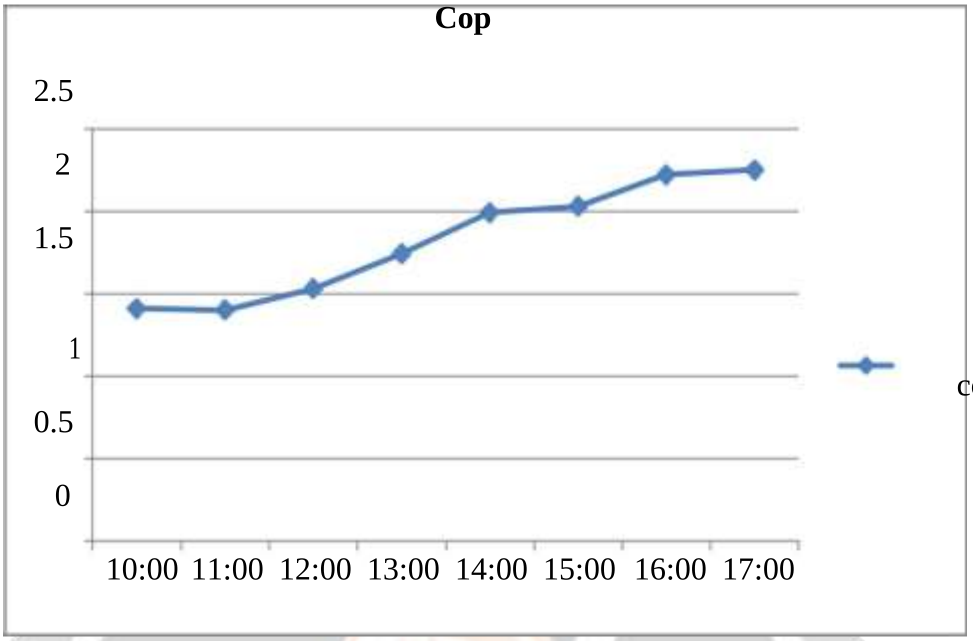

Fig. No. 5.11 Variation of COP with Time

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

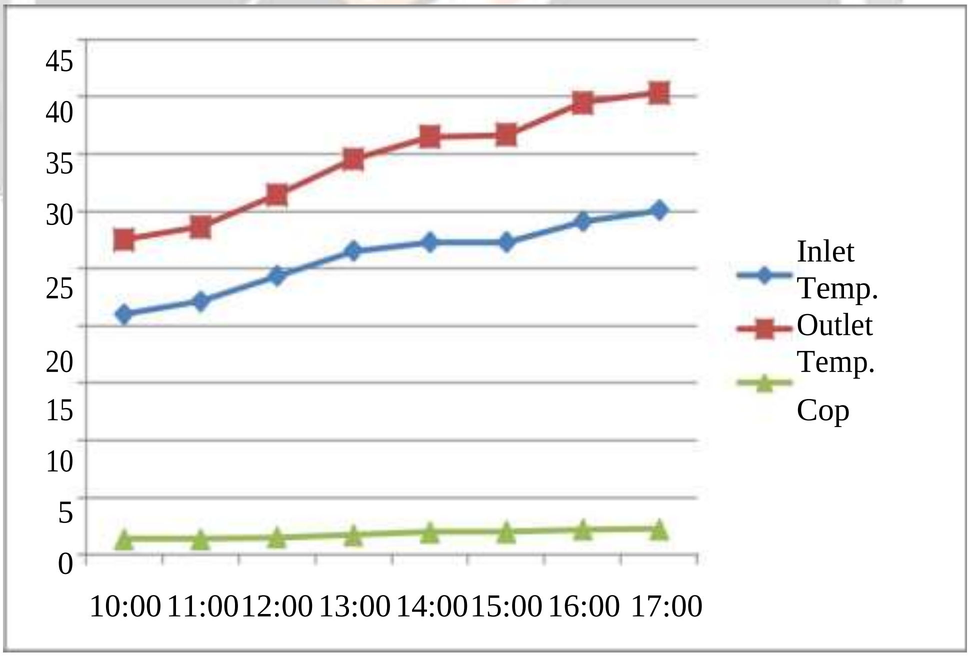

Fig. No. 5.12 Variation of Inlet, Outlet Temp. & COP with Time

6.CONCLUSION

6.1 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:

• IN GI Pipe For the pipe of 9 m length and 0.05 m diameter, temperature rise of 3.230C-6.10C has been observed for the outlet flow velocity 11m/s

• IN COPPER Pipe For the pipe of 9 m length and 0.05 m diameter, temperature rise of 8.330C-10.10C has been observed for the outlet flow velocity 11m/s
• IN GI Pipe The maximum COP obtained in summer season is 2.817 at time 14:00 and the maximum COP obtained in winter season is 2.25 at time 17:00
• IN COPPER Pipe The maximum COP obtained in summer Season is 3.68 at time 14:00 and the maximum COP obtained in winter Season is 2.39 at time 17:00 m/s. ow velocity 11m/s
• IN GI Pipe The COP of the system varies from 0.85 – 2.70 in summer season and 1.41-2.25 in winter season in outlet velocity 11m/s.
• IN COPPER The COP of the system varies from 1.53 – 3.68 in summer Season and 1.75-2.39 in winter Season in outlet velocity 11
• The results also show that conduction plays very important role in the cooling of air, it is evident from the fact that temperature remains constant where the insulation is done.
•If the blower speed is high and the length of pipe is less than the temperature difference inlet and outlet is very small.

This work can be used as a design tool for the design of such systems depending upon the requirements and environmental variables. The work can aid in designing of such systems with flexibility to choose different types of pipes, different dimensions of pipes, different materials and for different ambient conditions. So this provides option of analysing wide range of combinations before finally deciding upon the best alternative in terms of the dimension of the pipe, material of the pipe, type of fluid to be used.

7.FUTURE SCOPE

• The blower with variable running speed should be used.
• Theoretical model should be developed to predict the temperature of soil per meter depth of soil and effect of moisture content in the soil.
• This system will be tested for different length and different diameter pipe.
• For further study humidity control mechanism should be incorporated for winter and summer season.
• The fluid dynamics studies should be conducted to minimize the flow losses in the pipe and effect of moisture to be studied.

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