

# A REVIEW ON COMPARATIVE 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°C-12.6°C in hot weather and temperature rising of 6°C-10°C 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 earth's 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

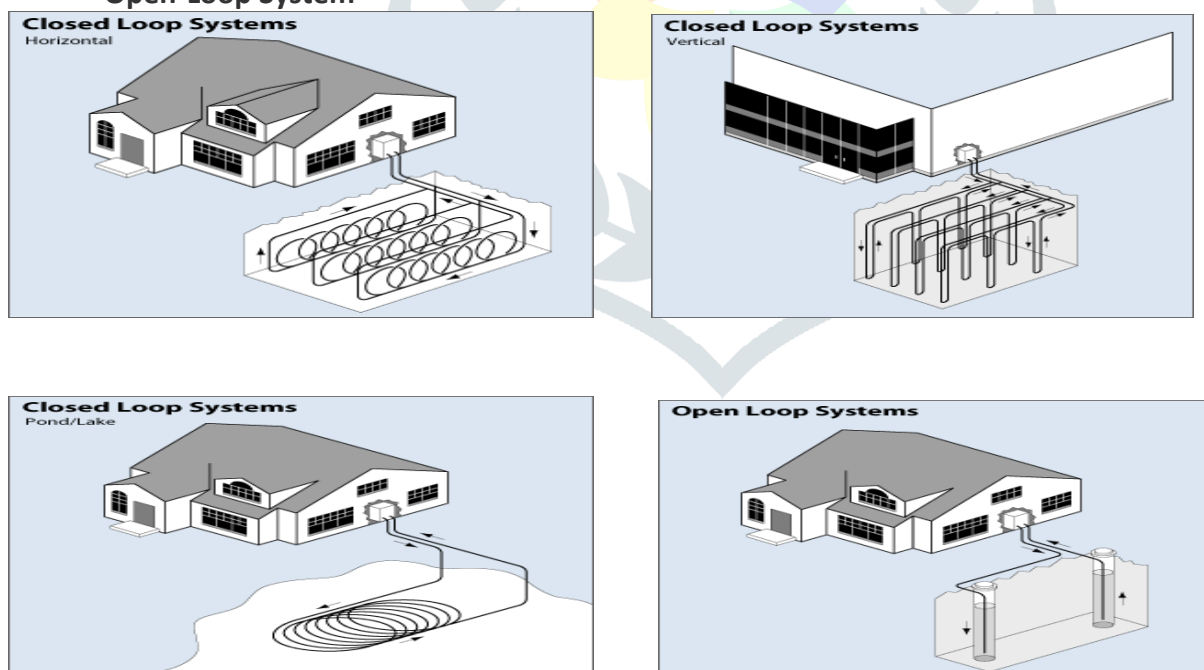


Fig No.1: Earth tube Heat Exchanger install in house

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

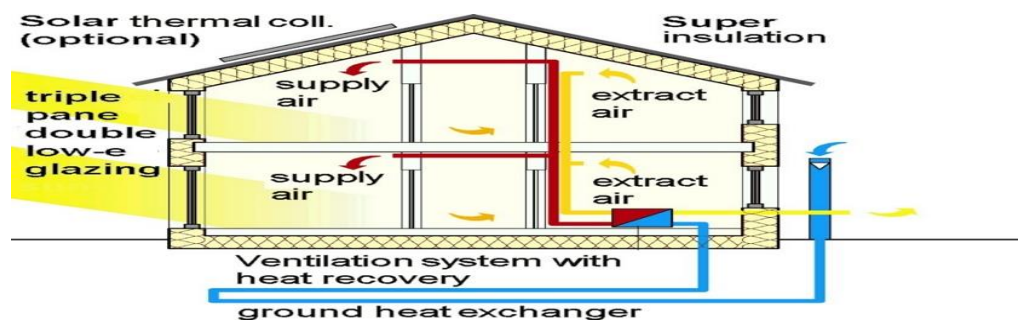


Fig No.2: Earth tube Heat Exchanger install in house

## 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 thermistors 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 m<sup>3</sup>/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

**Arvind Chel et al [10]** 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 thermal comfort.
- The total annual energy saving potential of adobe house for three conditions:
  - (i) before renovation,
  - (ii) after renovation and
  - (iii) with EAHE for six rooms for renovated adobe house was calculated as 4182kWh/year, 4946kWh/year and 10321kWh/year respectively.

This results in mitigation of CO<sub>2</sub> emissions nearly equal to 7 tons/year, 8 tons/year and 16 tons/year respectively. Hence, annual carbon credits that can be earned by the adobe house for three conditions are €140/year, €160/year and €320/year respectively.

**G.Colangelo et al [11]** 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 winter conditions.

**Akio Miyara et al [12]** 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.

### 3.3 Tube 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)**

Mild steel is untreated and usually hot or cold rolled or in the case of pipe extruded while molten. Low carbon content and rusts in humid weather and can be bent easier than other steel. It's not black pipe used for gas, it's not case hardened with cyanide, it's not galvanized with zinc plating, it's not blued like used for guns, it's not cast like fore cast iron furniture. It's the most affordable type of steel.

Mild steel pipe refers to the content of less than 0.25% carbon steel because of its low strength, low hardness and soft. It includes most of the part of ordinary carbon steel and high-quality carbon structural steel, mostly without heat treatment used in engineering structures, some carburizing heat treatment and other mechanical parts required for wear.

- **Copper**

Copper is usually the best choice for designing materials for heat transfer. The various advantages of using copper for such systems are mainly because of its high thermal conductivity. It is also resistant to corrosion by liquids. But one key disadvantage of using copper for our system was its high price. Moreover, it is generally not suitable for applications where high forces are applied on these pipes as these pipes are prone to bending.

- **Aluminium**

Aluminium is known for its high thermal conductivity and thus was actively considered for use in our system. It is found freely in the earth's crust but never found free. It is a good conductor of heat and electricity. But as in case of copper, the cost of aluminium is very high and makes it unsuitable for our system where we are concerning ourselves with cost effectiveness of the overall set-up.

- **Concrete**

Concrete-mix pipes are obtained by mixing cement with concrete in adequate proportions and using reinforcements of steel wire or steel bars. These pipes are of high strength and are resistant to corrosion from various environmental factors.

But they have an inherent property of porosity that will induce losses for our system. Because of porosity, although they will be better able to transfer heat but a lot of fluid will be lost to diffusion through the walls of the concrete pipe. Thus, these pipes might not prove to be efficient.

- **Poly-vinyl Chloride (PVC)**

Poly-vinyl chloride or PVC pipes have started being used widely in home applications and transfer of highly reactive chemical substances in various industrial plants. Their non-reactivity with a wide range of chemicals and environmental agents has made them increasingly popular with a wide range of applications. Their other advantages include the ease of handling because of their light weight. Moreover they have good ageing properties. But at temperatures higher than 80°C these pipes tend to become soft. They have high coefficient of thermal expansion. But since we will require our system to cool environment air only, we will not encounter such high temperatures. The main factor for considering PVC pipe was its durability and cost.

## 4. EXPERIMENTAL SET UP

### 4.1 Description of Set-Up

For the experimental work we used MS pipe of 5 cm diameter and was buried at a depth of 3 meters. 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 .

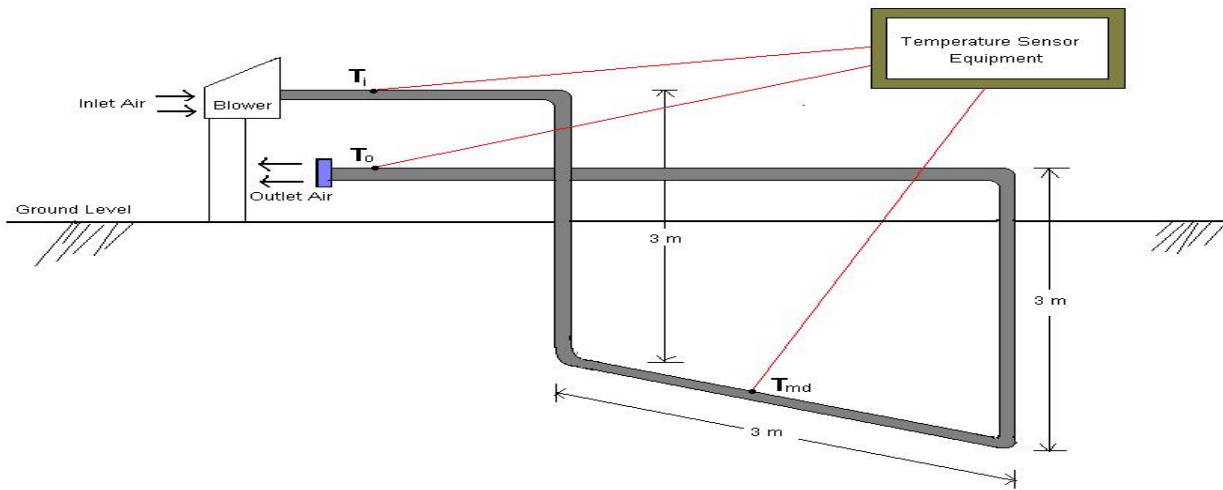


Figure 4.1: Schematic Representation of Experimental Set up

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

$$Q_c = mC_p(T_{inlet} - T_{outlet})$$

For winter climate

$$Q_c = mC_p(T_{\text{outlet}} - T_{\text{inlet}})$$

Where  $m$ = mass flow rate of air through the pipe

$C_p$ = specific heat capacity of air

$T_{\text{inlet}}$ = inlet temperature of air

$T_{\text{outlet}}$ = outlet temperature of air.

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

For Summer Climate

$$\text{COP} = mC_p(T_{\text{inlet}} - T_{\text{outlet}}) / \text{Power Input} \quad (1)$$

For winter climate

$$\text{COP} = mC_p(T_{\text{outlet}} - T_{\text{inlet}}) / \text{Power Input} \quad (2)$$

#### 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 m<sup>3</sup>/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  $\pm 0.2\% + 0.1$  m/s.

- **Temperature Auto Scanner**

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



Figure 4.4: Temperature Auto Scanner

**Specifications:**

Table 4.1: Specifications of Temperature Auto Scanner

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

- Blower



Figure 4.6: Blower

**Specifications:**

Table 4.2: Specifications of Blower

Input Voltage	220 – 240 V
Wattage	125W
Motor	Class B (Blower type Motor)
RPM	1800

**5. EXPERIMENTAL RESULT FOR SUMMER & WINTER SEASON****5.1(b) Cooling Model Test (COPPER 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 x 29.2 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 m<sup>3</sup>/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 Table-1(b) 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). The table also shows the COP values. The maximum COP Achieved at 2pm i.e. 2.702

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

Table-5.1(b) Inlet Temp, Middle And Outlet Temp. Of ETHE(May-2019)									
Date	29.06.2019			30.06.2019			31.06.2019		
Time	T <sub>a</sub>	T <sub>m</sub>	To	T <sub>a</sub>	T <sub>m</sub>	To	T <sub>a</sub>	T <sub>m</sub>	To
10:00	30.5	27.1	23.8	30.7	27.1	23.6	31.0	27.0	23.5
11:00	33.7	27.2	23.8	33.8	27.2	23.7	33.5	27.1	23.6
12:00	36.4	27.5	23.2	36.6	27.4	23.1	36.7	27.3	23.1
13:00	37.8	27.5	23.0	37.7	27.4	23.0	37.4	27.4	23.0
14:00	40.8	27.7	23.1	39.9	27.6	23.1	39.7	27.6	23.2
15:00	40.4	27.7	23.2	39.8	27.5	23.1	39.8	27.5	23.1
16:00	39.8	27.8	23.1	39.8	27.7	23.0	39.9	27.7	23.2
17.00	39.6	27.9	23.2	39.5	27.9	23.2	39.7	27.8	23.1

**FOR SUMMER SEASON (MAY-2019)**

$$\text{Area} = \pi \times d^2/4 = \pi \times 0.05 \times 0.05/4 = 0.00196 \text{ m}^2$$

$$\text{Density of air} = 1.225 \text{ kg/m}^3$$

$$\text{Specific heat capacity of air,}$$

$$C_p = 1007 \text{ J/kg K}$$

$$\text{Total cooling, } Q_c = m C_p (T_{\text{inlet}} - T_{\text{outlet}})$$

$$\text{Coefficient of Performance, COP} = \frac{m C_p (T_{\text{inlet}} - T_{\text{outlet}})}{\text{Power}}$$

Input

[24]

$$\text{Mass flow rate, } m = \text{density} \times \text{area} \times \text{velocity} = 0.0269$$

[25]

$$\text{Power Input} = 125 \text{ W}$$

**1.Time:10:00**

$$\text{Inlet temperature, } T_{\text{inlet}}: 30.730\text{C}$$

$$\text{Outlet temperature, } T_{\text{outlet}}: 23.630\text{C}$$

$$\text{Velocity at outlet: } 11 \text{ m/s}$$

$$Q_c = 192.32.45\text{W}$$

$$\text{COP} = 1.53$$

**2.Time:11:00**

$$\text{Inlet temperature, } T_{\text{inlet}}: 34.33.20\text{C}$$

$$\text{Outlet temperature, } T_{\text{outlet}}: 23.070\text{C}$$

$$\text{Velocity at outlet: } 11 \text{ m/s}$$

$$Q_c = 305.01 \text{ W}$$

$$\text{COP} = 2.44$$

**3.Time:12:00**

Inlet temperature,  $T_{inlet}$ : 36.560C

Outlet temperature,  $T_{outlet}$ : 23.130C

Velocity at outlet: 11 m/s

$Q_c = 363.79$  W

COP = 2.91

**4.Time:13:00**

Inlet temperature,  $T_{inlet}$ : 37.630C

Outlet temperature,  $T_{outlet}$ : 23.000C

Velocity at outlet: 11 m/s

$Q_c = 396.29$  W

COP = 3.17

**5Time:14:00**

Inlet temperature,  $T_{inlet}$ : 40.130C

Outlet temperature,  $T_{outlet}$ : 23.130C

Velocity at outlet: 11 m/s

$Q_c = 460.49$  W

COP = 3.68

**6.Time:15:00**

Inlet temperature,  $T_{inlet}$ : 40.0C

Outlet temperature,  $T_{outlet}$ : 23.130C

Velocity at outlet: 11 m/s

$Q_c = 456.17$  W

COP = 3.65

**7.Time:16:00**

Inlet temperature,  $T_{inlet}$ : 39.80C

Outlet temperature,  $T_{outlet}$ : 23.010C

Velocity at outlet: 11 m/s

$Q_c = 454.80$  W

COP = 3.63

**8.Time:17:00**

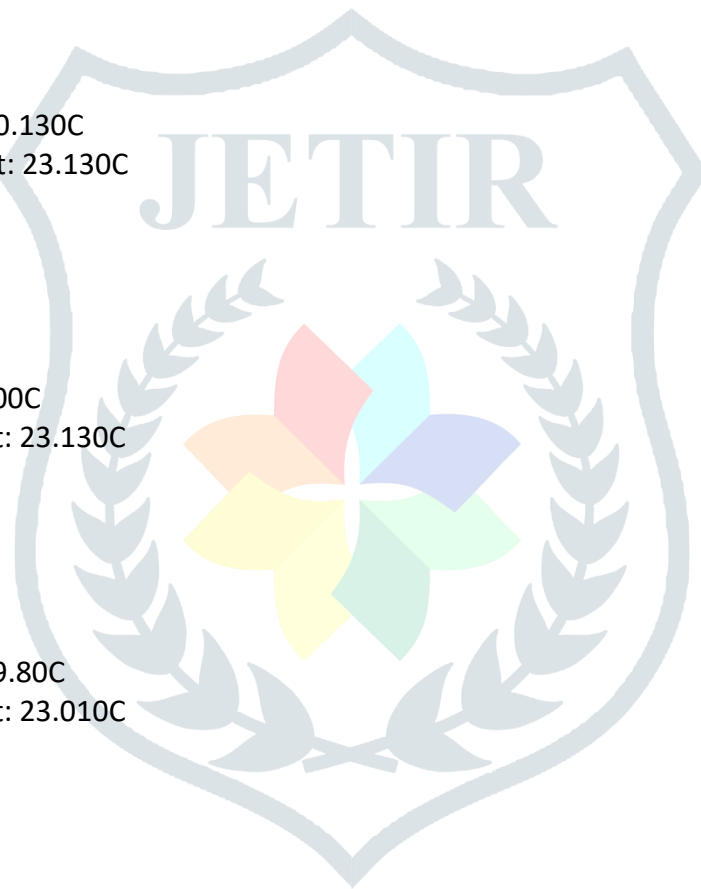
Inlet temperature,  $T_{inlet}$ : 39.60C

Outlet temperature,  $T_{outlet}$ : 23.160C

Velocity at outlet: 11 m/s

$Q_c = 445.32$  W

COP = 3.56



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

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

	<b>Time</b>	<b>Ta=Ti</b>	<b>Tmid</b>	<b>To</b>	<b>COP</b>
	10:00	30.73	27.06	23.63	1.53
	11:00	34.33	27.16	23.07	2.44
	12:00	36.56	27.04	23.13	2.91
	13:00	37.63	27.04	23.00	3.17
	14:00	40.13	27.06	23.13	3.68
	15:00	40.00	27.05	23.13	3.65
	16:00	39.8	27.07	23.01	3.63
	17:00	39.6	27.08	23.16	3.56

**5.2(b) HEATING MODEL TEST (COPPER PIPE):**

Heating mode test tests were carried out for three Day of Jan.2018 (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. Table 5.2(a) shows the measured data, and Table 5.2(b) which is the mean of three test runs. The ambient temperature started at 21oC (10 AM), increasing the highest value 30.30oC at 5 pM. Basic soil temperature at 3 m depth was constant at 24.2oC.

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

<b>Inlet Temp, Middle And Outlet Temp. Of ETHE (JAN-2019)</b>									
<b>Date</b>	<b>06.1.2019</b>			<b>7.1.2019</b>			<b>8.1.2019</b>		
<b>Time</b>	<b>T<sub>a</sub></b>	<b>T<sub>m</sub></b>	<b>To</b>	<b>T<sub>a</sub></b>	<b>T<sub>m</sub></b>	<b>To</b>	<b>T<sub>a</sub></b>	<b>T<sub>m</sub></b>	<b>To</b>
10:00	21.00	29.4	30.5	21.02	29.5	30.7	21.00	29.8	30.7
11:00	22.00	30.5	31.4	22.5	30.6	31.8	21.9	30.6	31.8
12:00	24.4	30.5	32.2	24.5	30.6	32.3	24.1	30.5	32.8
13:00	26.5	30.7	36.2	26.7	30.8	36.4	26.4	30.8	36.9
14:00	27.4	32.6	36.3	27.3	32.7	36.4	27.2	32.7	36.7

15:00	27.6	32.9	35.5	27.01	32.8	35.6	27.2	32.9	35.8
16:00	26.00	31.3	36.3	26.00	31.4	36.4	26.00	31.5	36.5
17:00	25.05	30.3	35.2	25.05	30.4	35.3	25.05	30.5	35.4

### FOR WINTER SEASON (Jan-2019)

Area =  $\pi \times d^2/4 = \pi \times 0.05 \times 0.05/4 = 0.00196 \text{ m}^2$

Density of air =  $1.225 \text{ kg/m}^3$

Specific heat capacity of air,

$C_p = 1007 \text{ J/kg K}$

Total heating,  $Q_h = m C_p (T_{\text{outlet}} - T_{\text{inlet}})$

Mass flow rate,  $m = \text{density} \times \text{area} \times \text{velocity} = 0.0269$  Power Input =  $125 \text{ W}$

Coefficient of Performance,  $\text{COP} = m C_p (T_{\text{outlet}} - T_{\text{inlet}}) / \text{Power Input}$

#### 1.Time:10:00

Inlet temperature,  $T_{\text{inlet}}: 21.000\text{C}$

Outlet temperature,  $T_{\text{outlet}}: 30.630\text{C}$

Velocity at outlet:  $11 \text{ m/s}$

$Q_c = 260.33\text{W}$

$\text{COP} = 2.08$

#### 2.Time:11:00

Inlet temperature,  $T_{\text{inlet}}: 22.130\text{C}$

Outlet temperature,  $T_{\text{outlet}}: 31.630\text{C}$

Velocity at outlet:  $11 \text{ m/s}$

$Q_c = 257.33 \text{ W}$

$\text{COP} = 2.05$

#### 3.Time:12:00

Inlet temperature,  $T_{\text{inlet}}: 24.330\text{C}$

Outlet temperature,  $T_{\text{outlet}}: 32.430\text{C}$

Velocity at outlet:  $11 \text{ m/s}$

$Q_c = 219.412 \text{ W}$

$\text{COP} = 1.755$

#### 4.Time:13:00

Inlet temperature,  $T_{\text{inlet}}: 26.530\text{C}$

Outlet temperature,  $T_{\text{outlet}}: 36.540\text{C}$

Velocity at outlet:  $11 \text{ m/s}$

$Q_c = 271.150 \text{ W}$

$\text{COP} = 2.16$

**5Time:14:00**Inlet temperature,  $T_{inlet}$ : 27.300COutlet temperature,  $T_{outlet}$ : 36.440C

Velocity at outlet: 11 m/s

 $Q_c = 247.58W$ 

COP = 1.98

**6.Time:15:00**Inlet temperature,  $T_{inlet}$ :27.27 0COutlet temperature,  $T_{outlet}$ : 36.660C

Velocity at outlet: 11 m/s

 $Q_c = 254.359W$ 

COP = 2.03

**7.Time:16:00**Inlet temperature,  $T_{inlet}$ : 26.000COutlet temperature,  $T_{outlet}$ : 37.040C

Velocity at outlet: 11 m/s

 $Q_c = 299.96W$ 

COP = 2.392

**8.Time:17:00**Inlet temperature,  $T_{inlet}$ : 25.050COutlet temperature,  $T_{outlet}$ : 35.030C

Velocity at outlet: 11 m/s

 $Q_c = 270.338W$ 

COP = 2.162

In Copper Pipe Temperature of the air at the outlet varying from 30.63oC to 37.04oC. ETHE was able to raise the ambient air temperature at 10AM To 5 PM from 21.00oC to 27.30oC.The table also shows the COP values. The maximum COP Achieved at 5pm i.e2.39

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

Average Inlet Temp, Middle And Outlet Temp. of ETHE (Jan2019)				
Time	$T_a=T_i$	$T_{mid}$	$T_o$	COP
10:00	21.00	29.52	30.63	2.08
11:00	22.13	30.54	31.63	2.05
12:00	24.33	3050	32.43	1.75
13:00	26.53	30.76	36.56	2.16
14:00	27.3	32.62	36.44	1.98
15:00	27.27	32.82	36.66	2.03

16:00	26.00	32..36	37.04	2.39
17:00	25.05	30.04	35.03	2.16

3.2(b) TIME & INLET TEMP (JAN-2019)

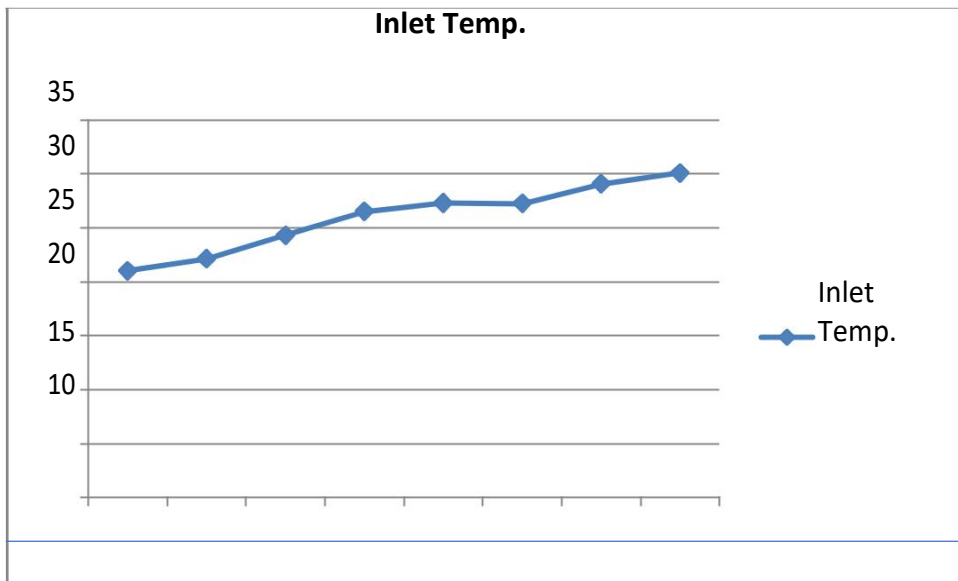


Fig.No. 5.13 Variation of Inlet Temp with Time

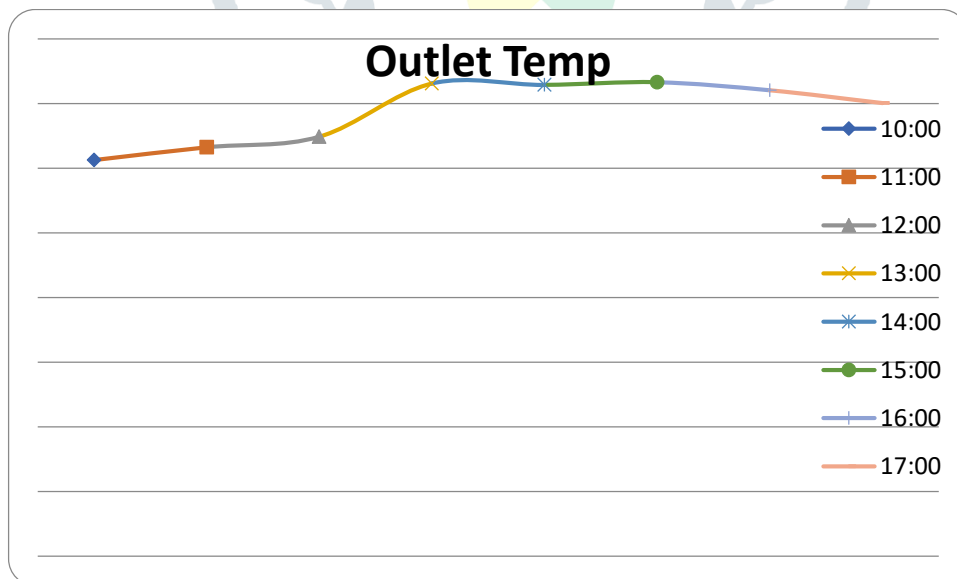


Fig.No. 5.14 Variation of Outlet Temp with Time



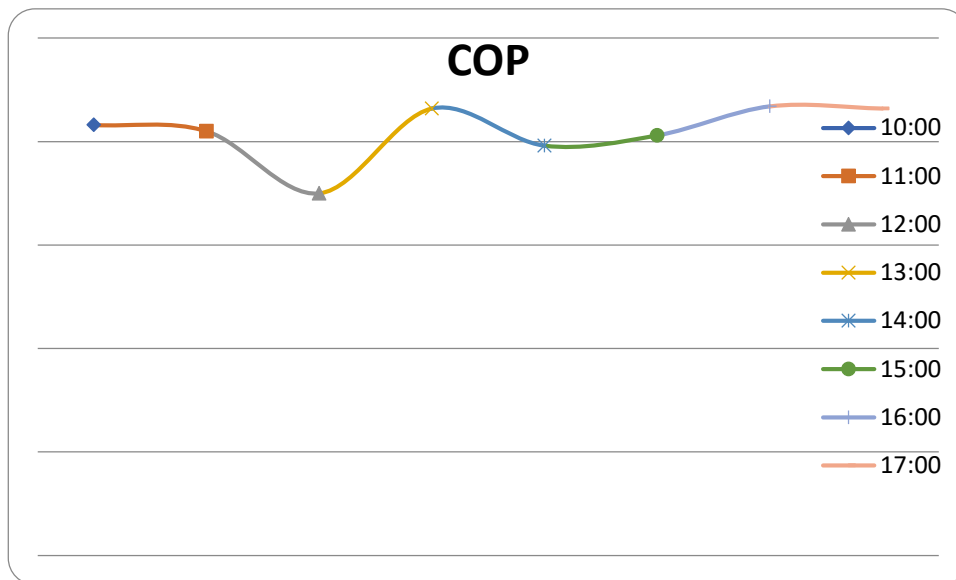


Fig. No. 5.15 Variation of COP with Time

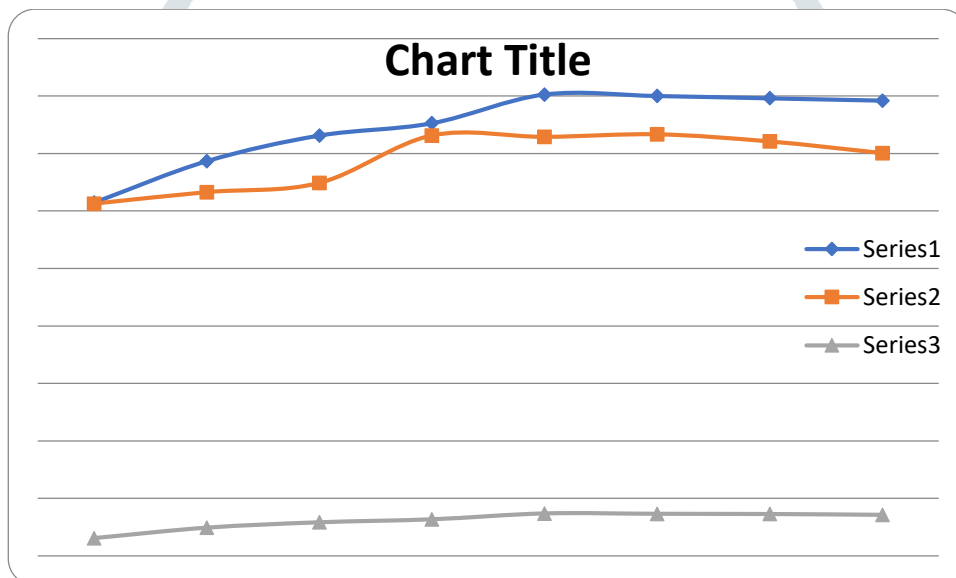


Fig. No. 5.16 Variation of Inlet, Outlet Temp. &amp; COP with Time

## 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 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 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 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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