# To Experimental Study of Earth Tube Heat Exchanger Cooling And Heating of Air

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***Abstract - Earth tube heat exchanger systems can be used to cool the building in summer climate(March to May 2016) and heat the buildings in winter climate(Jun to Feb2016). 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 bexchanger are 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 riseing 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.***

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## 1. INTRODUCTION

Saving 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 fueled systems. Geothermal energy is the heat from within the earth. Geothermal energy is generated in the earth's core and core is made up of very hot magma (melted rock) surrounding a solid iron center. 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.

### Ground heat transfer mechanism

The temperature field in the ground is influenced by different quantities Absorption of the solar radiation depends on the ground cover and color, while the long wave radiant loss depends on soil surface temperature [3].

The net radiant balance between solar gain and long wave loss is usually positive in summer and negative in winter. This causes heat to flow down from the surface into the ground in the summer and upward to the surface during the winter. The net radiant balance also determines the relationships between the averages of the earth surface and the ambient air temperatures. By shading the soil in summer while partially exposing it to the sky in winter, for example, with trees, it is possible to lower the ground temperature in summer to a greater extent while possibly increase the ground temperature in winter somehow. The performance of ground coupled air heat exchanger is directly related to the thermal properties of the ground. The ground has thermal properties that give it a high thermal inertia. The heat transfer mechanisms in soils are, in order of importance: conduction, convection and radiation. The temperature field in the ground depends on the soil type and the moisture contained respectively.

### 1.6 Types Of Ground Coupled Heat Exchangers

There are two general types of ground heat exchangers: open and closed. In an open system, the ground may be used directly to heat or cool a medium that may itself be used for space heating or cooling. Also, the ground may be used indirectly with the aid of a heat carrier medium that is circulated in a closed system.

#### 1.6.1 Open systems:

In open systems, ambient air passes through tubes buried in the ground for preheating or pre-cooling and fresh fluid is circulated through the ground loop heat exchanger. This system provides ventilation while hopefully cooling or heating the building's interior.

#### 1.6.2 Closed Systems:

In closed systems, both the ends of the pipe are kept inside the control environment, which can be a room in case of air and a tank in case of water, the system is said to be closed loop because the same fluid is passed continuously over and over through the loop.

Closed type ground heat exchangers can be either in horizontal, vertical or oblique position and a heat carrier medium is circulated within the heat exchanger.

#### 1.6.3 Vertical loops system:

Vertical loops are generally more expensive to install, but require less piping than horizontal loops because the earth deeper down is cooler in summer and warmer in winter, compared to ambient temperature. Vertical type borehole heat exchangers can be classified into two basic types: (a) A pair of straight pipes having U-turn at the bottom side. (b) Coaxial or concentric pipe configuration in which one pipe is placed inside the pipe with bigger diameter.

### 1.7 Advantages and Disadvantages of Ground Heat Exchanger

#### 1.7.1 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.

#### 1.7.2 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 a expert installer which increases the cost of the system

## Literature review

A literature has been reviewed on the earth tube heat exchanger technology.it has been observed that the research in this field mainly took place in the following area:

•Design of earth tube heat exchanger

•Working

•Energy seving

**Girja saran and rattan jadhav[7]** has conducted experiment on singal pass earth tube heat exchanger.they conducted experiment in ahmedabad gujrat (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. And the result conclude that:

• **Tempreture:**

ETHE was able to reduce the temperature of hot ambient air by as much as 14oC in May. The basic soil temperature in May was 26.6oC. It was able to warm up the cold ambient air by a similar amount in the nights of January. The basic soil temperature in January was 24.2oC.

**• The coefficient of performance (COP):**

Coefficient of performance is one of the measures of heat exchanger efficiency. It is defined :

$$COP = Q/Win$$

$$Q = m_a \, Cp \, (T_i - T_o)$$

$c_p$ = Specific heat of air ( J / kg $^oC$ )

$Q_{out}$ = Rate at which heat is exchanged between hot air and cooler soil

$W_i$ = Rate of energy input into the heat exchanger( energy used by blower )

$m_a$ = Mass flow rate of ( kg / s )

$T_i$ = Temperature of air entering the tube ( oC )

$T_o$ =Temprature of air at the outlet ( oC)

In cooling mode averaged to 3.3. Cooling tests were of 7 hour continuous duration during the day.

In heating mode it averaged to 3.8. Heating tests were of 14 hour continuous duration through the night.

**Fabrizio Ascione et al [8]:** 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 [9]** 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 4.1-4.80C for 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 velocity 2.0 m/s for (a) steel pipe (b) PVC pipe shows Fig 2.1

## DESIGN PARAMETERS

### 3.1 Tube 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 [22]:

• 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 remain 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 [23]. After a depth of 3-4 m in the ground, temperature remains nearly constant [5].

### 3.2 Tube 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 9 m, 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. Its not black pipe used for gas, its not case hardened with cyanide, its not galvanized with zinc plating, its not blued like used for guns, its not cast like for cast iron furniture. Its 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.

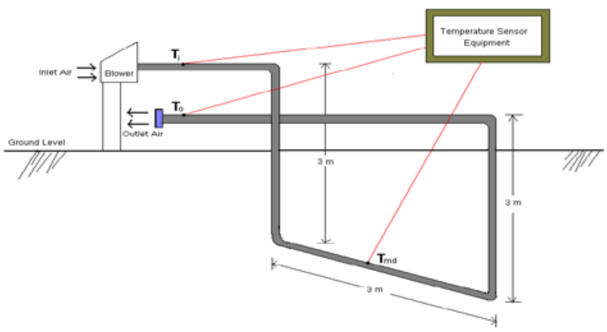
**• Poly-vinyl Chloride (PVC)**

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 800C 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.

### Experimental Set Up

### Description Of The 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 Temp. sensor.




Schematic Representation of Experimental Set up

The experimental set-up in the figure 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.

## 3. PREVIOUS WORK

Till date the work done on this topic only taken by researcher concrete pipe and find system COP.

## 4. PROPOSED METHODOLOGY

My work is basically based on only used mild steel pipe and find COP of system.

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