

# International Journal of Innovative Research in Science, Engineering and Technology

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## Design and Development of Earth Air Tunnel Heat Exchanger

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**ABSTRACT:** The Earth Air Tunnel Heat Exchanger (EATHE) is a hybrid passive way of cooling. The hybrid way suggests that it involves an active agent fan for the flow of air, but the cooling and heating of air is done with the help of a passive agent ground soil. In this pipes are buried underground and air is flown through it to cool or heat according to the season since the temperature of soil underground remains constant and at near human comfort level. EATHE can be used and in some places it still in use cool homes, buildings and other systems. There is a need to make a shift from high energy consuming active user to low energy consuming techniques. And EATHE is one of those techniques. There has been a lot of research done over it with the development of algorithms to design the heat exchanger, CFD analysis etc. This paper aims to contribute for further development of EATHE. We had developed an algorithm in which we assumes a maximum load in a room and with this input factor we design a heat exchanger, in which we find out the required diameter and length of the pipe to cool the load in the room. We assume some required factors like required temperature in the room, maximum outside temperature, velocity of air. This paper aims to bring ground source cooling into use and research. We acknowledge the limitations of EATHE systems over AC systems and hope this paper would help others to work over it.

**KEYWORDS:** Earth, Air, Heat Exchanger, Sustainable Energy, Ground source.

### I. INTRODUCTION

Energy has been a most important factor for human beings since Stone Age. The use of energy in active cooling systems especially for HVACs in homes building and other recreations has been tremendous. Energy demand for space cooling is growing rapidly with time in India and so as along the world, driven by rising income, lowering cost of technology and natural preference of ambient human comfort level temperature. Air conditioners are among the most prevalent purchases for the growing middle class, with its sales increasing by 20 percent in the recent times. In US now almost 87% owns air conditioners, says the latest data from EIA's residential energy consumption survey. A base case estimates a consumption of 42 terawatt-hour in 2010 for air conditioners. All that air conditioning does is to throwing the indoor heat out, warming up the outdoors, increasing the green house effect. Dependency of air conditioners on CFCs, HCFCs and others has increased the effect of global warming too by depleting the ozone layer. All these facts lead to changing the source of cooling and most importantly the energy. Earth air tunnel heat exchanger (EATHE) is one such solution to all of the problems mentioned against air conditioners. EATHE as the name suggests is a pipe matrix arrangement led underground, in which ambient air is passed. The temperature of soil being lesser than the air in summer cools down and vice versa happens in winter. This cooled air in summer or hot air in winter is then directed in the houses or buildings. The temperature of the soil remains constant throughout the year after a certain depth, mostly after 2.5-3 meters depending upon the geological areas, climatic conditions and soil type

### II. RELATED WORK

The heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental investigations. Girja Sharan and Ratan Jadhav installed a single pass earth-tube heat exchanger (ETHE) to study its performance in cooling and heating mode. 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. A 400 w blower pumps ambient air through it. Air velocity in the pipe is 11 m/s. ETHE was able to reduce the temperature of hot ambient air by as much as 14°C in May.

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The basic soil temperature in May was 26.6°C. It was able to warm up the cold ambient air by a similar amount in the nights of January. The coefficient of performance (COP) in cooling mode averaged to 3.3. Fabrizio Ascione, Laura Bellia and Francesco Minichiello the energy performances achievable using an earth-to-air heat exchanger for an air-conditioned building have been evaluated for both winter and summer. By means of dynamic building energy performance simulation codes, the energy requirements of the systems have been analyzed for different Italian climates, as a function of the main boundary conditions. Trilok Singh Bisoniya has developed a one-dimensional model of the EAHE systems using a set of simplified design equations and discovered the factors that affected the performance.

## III. METHODOLOGY

There are mainly two commonly methods used to design a heat exchanger depending upon the input factors. It can be done either by using the logarithmic mean temperature difference (LMTD) method or the effectiveness and number of transfer units (NTU) method. LMTD method is used to design the heat exchanger when the inlet and outlet temperatures, the flow rate and overall heat transfer coefficient are given and the heat exchanger's diameter and length are designed accordingly. The Number of Transfer Units (NTU) Method is used to calculate the rate of heat transfer in heat exchangers (especially counter current exchangers) when there is insufficient information to calculate the Logarithmic Mean Temperature Difference (LMTD). In this method, the fluid inlet and outlet temperatures are specified or can be determined by simple energy balance. In this paper the LMTD method is used.

### Assumptions

1. The soil surrounding the pipe is isotropic, with homogenous thermal conductivity in all ground strata.
2. The thermal resistance of the pipe material is negligible (thickness of the pipe is very small).
3. The surface temperature of the ground can be approximated to the ambient air temperature, which equals the inlet air temperature.
4. The pipe is of uniform circular cross-section.
5. The soil temperature near the pipe is not influenced by the pipe, so the surface temperature of the pipe is uniform in the axial direction.
6. Thermo-physical properties (density, viscosity, thermal conductivity and specific heat capacity etc.) of air and soil are constant.

A general equation for the rate of heat transfer is given by,

$$Q = \dot{m} \times c_p \times \Delta T$$

Where,

- $Q$  = maximum cooling load in the room (system) (Joule/sec). Since the main aim of this paper is to replace AC with an EATHE system giving equivalent output, hence the maximum cooling load is the maximum cooling capacity of AC that meant to be replaced.
- $\dot{m}$  = mass flow rate of air into the room (kg/sec). This is to be found out from the above equation.
- $c_p$  = specific heat of air at an average temperature of air (J/kg/K).
- $\Delta T$  = temperature difference of air at the inlet i.e. ambient temperature  $T_a$  and at the outlet of the pipe i.e. room temperature  $T_r$  (Kelvin). For this data the inlet and outlet temperature needs to be fixed according to the maximum surrounding temperature and the required temperature of the room respectively. The inlet temperature would be the maximum outdoor temperature since we are designing the system for an extreme condition. And the outlet of pipe or the room temperature would be the required room temperature needed.

From the above equation the mass flow rate for the required cooling load and the temperature difference is found out.

Since,

$$\text{discharge (volume flow rate of air), } q = \frac{\text{mass flow (m)}}{\text{density of air at average temperature } (\rho)}$$

Diameter (d) of the duct of the heat exchanger can be calculated using the continuity equation,  $q = AV$ .

Hence,

$$q = V \times \frac{(\pi \times d^2)}{4}$$

The velocity of air between 2-15 m/s is economical.

Now to find the length of the heat exchanger LMTD method is used which is govern by the equation,

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$$Q = h_a \times A \times T_{lm}$$

Where,

- $Q$  = is the cooling load.
- $h_a$  = is the heat transfer coefficient.
- $A$  = surface area of heat exchanger from where heat will be exchanged between the pipe and the soil.
- $T_{lm}$  = logarithmic mean temperature difference.

The calculations process for the above parameters takes place as follows

i. Calculation of heat transfer coefficient.

Since for forced convection heat transfer coefficient is given by,

$$h_a = \frac{Nu \times k}{d}$$

Where,

- $Nu$  = Nusselt no.
- $k$  = Conductivity of air.
- $D$  = diameter of air.

For Nusselt no. Renolds no.(Re) need to be found out, which is given by

$$Re = \frac{V \times d}{\nu}$$

Where,

- $V$  = velocity of air.
- $d$  = diameter of pipe.
- $\nu$  = dynamic viscosity of air. It is constant at constant temperature

If  $Re < 10000$ , it would be laminar flow

If  $Re > 10000$ , hence it is a turbulent flow

For most of the cases  $Re > 10000$ . So for turbulent flow in circular tube Nusselt no. is given by Petukhov equation i.e,

$$Nu = \frac{(f/8) \times (Re - 1000) \times Pr}{1 - 12.7 \times \sqrt{f/8} \times (Pr^{2/3} - 1)}$$

Where,  $f$  is friction coefficient =  $\frac{1}{\sqrt{(0.79 \times \ln Re - 1.64)}}$

Hence putting the values  $Nu$  can be found out.

Hence, now the heat transfer coefficient can be found out using,

$$h_a = \frac{Nu \times k}{d}$$

ii. Calculation of logarithmic mean temperature difference,  $T_{lm}$ .

Given by,

$$T_{lm} = \frac{(\theta_1 - \theta_2)}{\ln(\theta_1 / \theta_2)}$$

Where,

$$\theta_1 = T_a - T_s$$

$$\theta_2 = T_r - T_s$$

There would be two conditions between the room temperature  $T_r$  and soil temperature  $T_s$ .

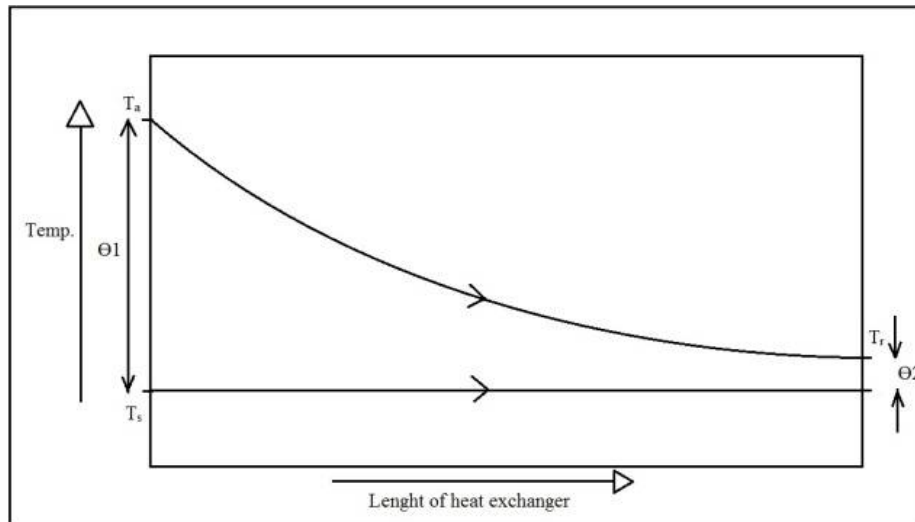
- When  $T_r \geq T_s$ , this happens during summer,

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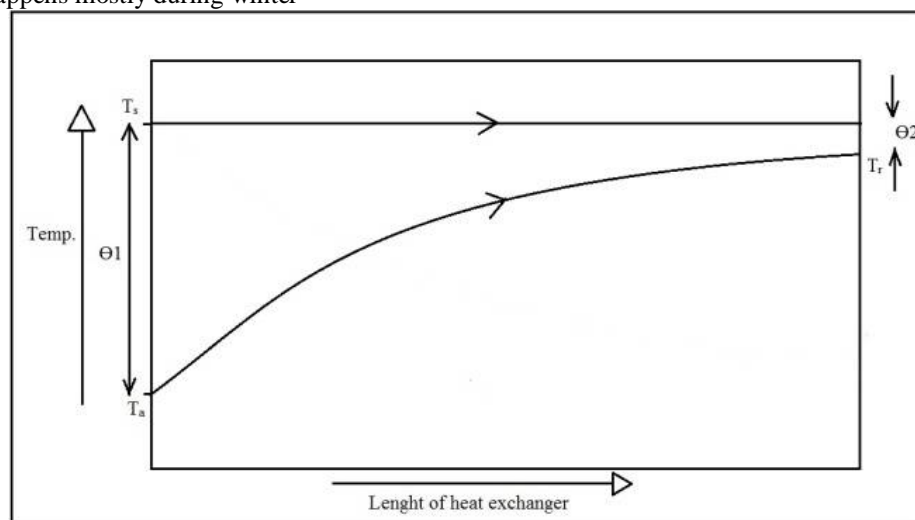
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- $T_r \leq T_s$ , this happens mostly during winter



The temperatures are needed to be fixed as we are using LMTD method and so we are designing the heat exchanger according to the inlet and outlet temperatures as an input. This can be fixed according to our needs and environmental datas. The temperature of the soil is different in different geographical areas. This temperature is found out experimentally. The temperature of the room is fixed to a human comfort temperature that lies between 22-27 deg C. The temperature of the environment is variable naturally. It changes with time. And so we need to take the max temperature that can be predicted as we are designing for an extreme condition.

### iii. Calculation of Length of heat exchanger.

Since the area of the heat exchanger where the heat is going to be exchanged is just the curved surface area of the duct and since we are using cylindrical pipe and assuming heat exchange in any other area to be zero,  
Hence

$$A = 2\pi rL.$$

Hence putting this equation in equation,

$$Q = h_a \times A \times T_m,$$

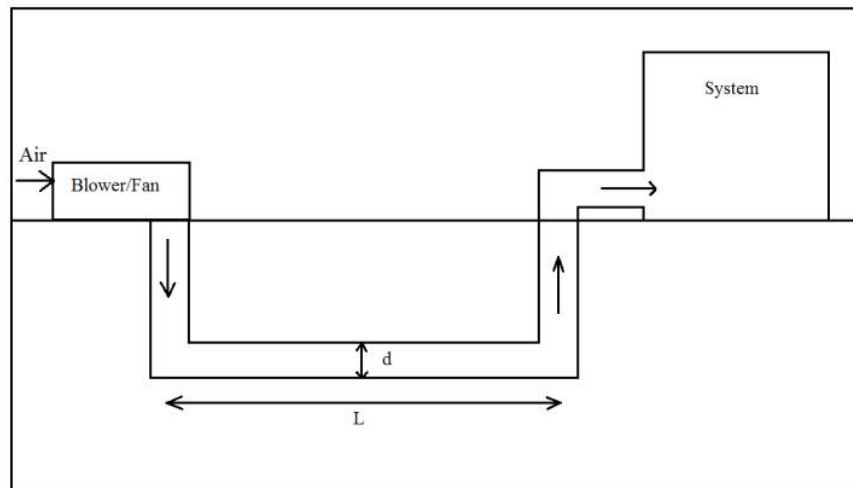
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length of the pipe can be discovered. Hence design of the heat exchanger is complete. Below is a schematic diagram of EATHE.



Since now our design is fixed hence effectiveness of heat exchanger is also fixed because of the factors it depends upon. Effectiveness is given by,

$$\epsilon = 1 - e^{-UA/C_p}$$

The only parameter that will vary will be the ambient environment temperature. And ambient temperature and room temperature in relation with fixed design is given by,

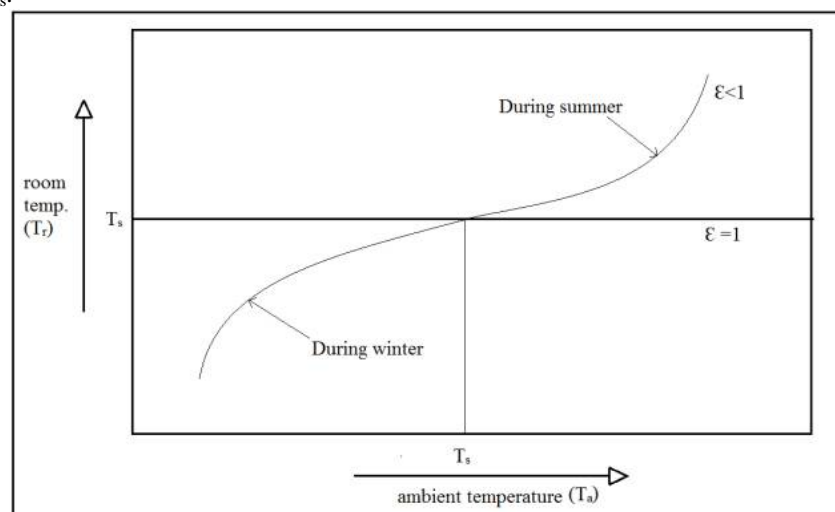
$$T_r = T_a - (T_a - T_s) \times \epsilon$$

The behaviour of room temperature  $T_r$  with respect to  $T_a$  can be seen in the graph for two cases.

- When  $\epsilon = 1$ .
- And when  $\epsilon < 1$ .

The graph also acknowledges the relationship between  $T_r$  and  $T_s$  in summer and winter i.e.

- When  $T_r \geq T_s$ .
- And when  $T_r \leq T_s$ .



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## IV. RESULTS

The output of EATHE depends upon the effectiveness of the heat exchanger, as can be seen from the graph. As  $\varepsilon$  tend to 1 and  $T_r$  tend to  $T_s$  and so the change of  $T_r$  with respect to  $T_a$  is less. This can be only be achieved when the fabrication of EATHE is just done according to the design and assumptions. The more effectiveness  $\varepsilon$  tends to 1, the better the performance.

## V. CONCLUSION

Earth air tunnel heat exchanger is a very reliable way to cool homes and buildings. Besides having all the advantages of a passive cooling technique, it is a long term plan. Its life span is 3-4 times that of an AC systems. EATHE can also be used to reduce load on AC reducing energy consumption. EATHE can also be used in winter to heat and ventilate the atmospheric.

There is a need of shift of technology from a non-renewable source to a renewable one. And this method helps to make that shift. The design model helps to develop EATHE for any required cooling load.

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