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Experimental Performance Analysis of Earth Air Heat Exchanger

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Abstract—*One of the Most Challenging Problems is the Global Warming and Ozone Depletion in the World. This Engineering Technique is used to reduce this Problem. Ground Earth Air Heat Exchanger(GEAHE) are the Emerging Technique Which Reduce the cooling and Heating Load of Buildings in Summer and Winter Season and Thus Reduce the Overall Energy Consumption in Building. Geo-thermal Energy is a Renewable eco -friendly and freely available Energy Resource on earth. So with the help of this energy we avoid the Increasing use of Refrigerants, Which are used in the Air-Conditioning and also reduced the Global Warming and Ozone Depletion. the performance analysis of Earth Air Pipe Heat Exchanger(EAPHE) Done by varying the various parameters like air velocity, mass flow rate, Depth of the pipes and material of the pipes etc. The Results Obtained Revealed that the temperature inside the earth can be increased by 8-10°C During winter Season and can be Decreased by 12°C -13°C During Summer Season Compare to the air atmospheric temperature.*

Keywords: *Earth pipe air heat Exchanger Energy Efficiency, Heating Ventilation and Air-Conditioning (HVAC).*

1. INTRODUCTION

In Recent years, there is a Global Consensus for Exploration and Utilization of Different Renewable Energy Sources to meet the Energy Demand of a Rapidly Growing world Population, driven Primarily by Increasing Prices and limited Energy Resources of Conventional or Fossil Fuels. The new Option Should is Eco-Friendly as well as Abundant in Nature. The Various Options may be Nuclear, wind, bio mass, Solar and Geo-Thermal Energy etc.

Geo-Thermal Energy is a Renewable Eco Friendly and Freely Available Energy Resources on Earth. Its Use will ensure the Conservation of Conventional Energy Sources. It also Help in Avoiding the Increasing Use of Refrigerants Used in Air-Conditioning. Thus it helps in Avoiding the Ozone Depletion. In General Most People feel Comfortable when the Temperature is between 20°C and 26°C and Relative Humidity is within the Range of 40% to 60%. Air-Conditioning System is Widely Employed for Comfort Occupant as well as the Industrial Production it can be Achieved Effectively by Vapor Compression Machine. But Due to the Depletion of Ozone Layer and Global Warming by Using Chlorofluorocarbons and the Need to Minimize the High Grade Energy Consumption Various Passive Technique are now a day's Introduced, One Such Method is Earth Air Heat Exchanger (EAHE). The Performance of an Earth Air Heat Exchanger System Depends upon the Temperature and Moisture Distribution in the Ground, as well as on the Surface Conditions.

Greenhouse gases Includes Water Vapor, Carbon dioxide, Methane, Nitrous oxide, the Chlorofluorocarbons (CFCs), Hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and Sulfur hexafluoride (SF6). In Refrigeration Application, there are two Causes of Global Warming - Indirect Release of Carbon dioxide (CO2) into the Atmosphere as a Result of Energy Use, and Direct Release of Harmful Refrigerant Gases to the Atmosphere from leakage, Breakdowns or Poor Servicing Practices. The Combination of these two Effects is Often Referred to as the **"total Equivalent Warming Impact"**(TEWI). So Earth air heat Exchanger (EAHE) is one of the Engineering techniques to reduce the Refrigerants and Greenhouse gases.

Soil temperature, at a depth of about 10 feet or more, stay fairly constant throughout the year, and is approximately equal to average annual ambient air temperature. The ground can, therefore be used as a heat sink for cooling in the summer and as a heat source for heating in the winter.

An open loop, underground air tunnel system cools or heats the ambient air passing through it. Thus air is then introduced directly into the conditioned space of a building. In order to reduce the required tunnel length, a closed loop system may be used. In this system the air from the conditioned space, with some ventilation air, is recalculated through the underground tunnel.

This can improve the C.O.P. of the heat pump and increase its capacity for heating and cooling. The systems described above have the potential to give very high C.O.P. and therefore high energy savings, C.O.P. is a taken used in refrigeration and air-conditioning to describe the performance of a system. Normally, heating and airconditioning systems have average year round C.O.P. of about 2.0. However the C.O.P. of the systems utilizing underground air-tunnels is much higher. For open and closed loop systems, the C.O.P. can be as high as 10.

There are many different Configurations that can be used to make a Ground Coupled Heat exchanger System.

These Systems Can use Open and Closed loops, different fluids, or any Combination in the System all to Optimize Ground Coupled Heat exchangers. The Ground loops can be arranged in a Vertical, Horizontal, Slinky Ground loop, or Pond loop.

- A Vertical Ground loop is used where there is little yard Space, when Surface Rocks make Digging Impractical, or when you want to Disrupt the landscape as a little as Possible. Vertical Holes are bored in the Ground, 150 to 450 feet deep, and a Single loop of Pipe with a U-bend at the bottom is inserted before the Hole is backfilled. Each Vertical Pipe is then connected to a Horizontal Underground Pipe that carries the air or fluid Inside.
- A Horizontal Ground loop is usually the most Cost Effective when Trenches are easy to Dig and the Size of the yard is Adequate. Trenches are Dug below the Ground in which a Series of Pipes are laid. Then, the air or fluid runs through the Pipe to be Heated or Cooled.
- A Slinky Ground loop is a Variation on the Horizontal loop. The Horizontal Slinky layout Consists of Piping Unrolled in Overlapping Circular loops that are laid flat in Trenches of Approximately the Same width as the Coil Diameters. In the Vertical Slinky layout, Coils Stand Upright in Narrow Trenches that are Deep Enough to Accommodate the Coil Diameter and a Sufficient Overburden So that the tops of the Coils do not Experience Overall, Slinky Systems Require three to five times less land area than Straight Horizontal loop Systems.
- A Pond loop Design may be the most Economical when a home is near a body of water. Such as a Shallow Pond or lake. The air or fluid Circulates Underwater through Piping, Just as it does through Ground loops. The Pipes may be coiled in a Slinky Shape to fit more of it into a given amount of Space. Since the air or fluid does not directly interact with the Pond, It Results in no Adverse Impacts on the Aquatic System.
- A Closed loop Ground Coupled Heat exchanger draws the already Heated/Cooled air from inside the building and through a Series of Underground Pipes to be Heated/Cooled before Re- entering the building.
- An Open loop Ground Coupled Heat exchanger Draws Outside air, through a Series of Underground Pipes, into the building trying to be Heated/Cooled. An Open loop system uses the "near constant" temperature of the Earth to Heat/Cool the Outside air Prior to it being Admitted into building. An Open loop System is naturally less efficient, in Extreme Climates then a Closed loop System due to the need to Heat/Cool the air further before it reaches the required temperature. A Combination of both Open and Closed loop Ground Coupled heat Exchanger can be utilized to optimize a Heating and Cooling System and circulate more air.

Generally, air is not circulated through the Underground Pipes in a Ground Coupled Heat exchanger. This is Due to the Potential for mold and bacteria Growth Caused by Condensate formation in the Pipes as a Result of the heat transfer Process. Typically, Ethylene Glycol (or Other Similar fluid) is used in the Underground Portion of a Ground Coupled heat exchanger and it is then passed through a Secondary heat exchanger where air is drawn in to be Heated or Cooled to the desired temperature by Ethylene Glycol.

Geo-thermal energy reduces heating and cooling costs

At 5 to 7 ft (1.5 to 2m) below the Earth Surface, Ground Temperature Remain relatively constant throughout the year. As Incoming air Passes Throughout the underground Pipes, It is Pre-warmed with Ground heat in winter and Pre-cooled with Cooler Ground Temperature in summer. For Example, in mid-latitude where Ground Temperature Range from 45F-54F (7°C -12°C), It is Possible to Reduce the Intake air Temperature by up to 29F (16°C) in summer and to Raise the Intake air temperature by up to 16F (9°C) in winter.

By Narrowing the Gap between Outdoor Temperature and Comfortable Indoor Temperature, a Ground-air heat Exchange System Significantly Reduce the Amount of Additional Energy Required to heat or cool the building. The System Requires only a Small amount of Electrical Power to operate an air Intake fan and Provides Significant Energy Cost Saving, Especially when used in Conjunction with heat or Energy Recovery Ventilators (HRV or ERV).

Description of Earth to air Heat Exchanger

An earth to air heat exchanger is a plastic, co creates, ceramics or metallic pipes buried at a certain depth in the ground. Given the very high thermal inertia of the ground, the conductivity of the pipe is of minor importance. In order to improve the thermal contact between the pipes and the ground 5cm of sand are typically placed below and above the pipes.

The Increased Need for Cooling

The use of air-conditioning is the Cause of different Problems. Apart from the Serious Increased of the Absolute Energy Consumption of buildings, Other Important Impacts Include:

- The Increase of the Peak Electricity load.
- Environmental Problems Associated with Ozone Depletion and Global Warming.

- Indoor air Quality Problems.

Motivation

The greenhouse technology is being used in Several Regions of the world but the Problem Associated with is to Maintain the favorable Environment all the time and use of Several Electrical devices Require Power to Operate.

The Electricity demands increasing day by day. HVAC Systems Consume Maximum Portion of the Electricity. Hence it has been felt to work in this area which is very much related to the Existing Research on Energy Efficient Greenhouse technology. In Recent years, there is Global Consensus for Exploration and Utilization of different Renewable energy Sources to meet the energy demand of a Rapidly Growing world Population, driven Primarily by Increasing Prices and limited energy Resources of Conventional or fossil fuels. The new option should be ecofriendly as well as Abundant in nature. The various options may be nuclear; wind, bio-mass, Solar and geo-thermal energy etc. geo-thermal energy is a Renewable eco-friendly and freely available energy on Earth. Its use will ensure the Conservation of Conventional Energy Sources. It's also helps in avoiding the increasing use of refrigerants used in air-conditioning, thus it helps in avoiding the ozone depletion. The Cost of the System is as low as that of Conventional air-conditioning Systems. Thus we can say that, Here it is a great of Implementing and Improving these Kinds of techniques for better future.

Material and Method
Material with Specification
Dimension of set-up and components:

Area of Dogged Section : 12×3 ft_2

Depth of Section : 9 ft

Polyethylene Pipe:

Diameter of Pipe : 0.016 m

Length of Pipe : 100 m

Blower unit:

Voltage : 165-250 Volt

Freq : 50 Hz

Power : 500 W

16,000 rpm.

Cooling jacket:

Radius of jacket : 2.5 inches

Cylindrical

Depth of the jacket : 5 feet

Small Cooling tower

Anemometer

Temperature Sensors

No. of thermocouple 2 Pieces of least Count. 1°C

Water Pump:

Nomenclature	
t	temperature (°C)
N	speed (RPM)
c	Specific heat capacity (J/kgK)
K	thermal conductivity (W/mK)
ρ	Density (kg/m^3)
v	velocity (m/s)
d	Diameter of pipe (m)
l	length of the pipe (m)
n	No. of thermocouple
r	Radius of jacket cylindrical jacket
EAPHE	earth air pipe heat exchanger
PVC	polyvinyl chloride
COP	Coefficient of Performance
m	mass flow rate of air through the pipe

Voltage : 165-250 Volts

Maximum height : 8.5 feet

Output : 20001t/hr

Experimental set-up and location:

Location of the experimental site:

It is located in navgaon, Dehradun 10 km milestone from Premnagar, Dehradun.

Venue

Dev Bhoomi Institute of Technology, Dehradun.

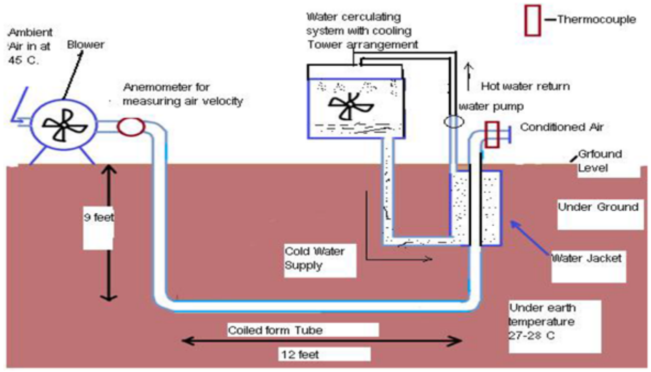

Figure-1: Experimental set up of Earth air pipe heat exchanger

Method

Description: The Earth pipe air heat exchanger(EPAHE) as shown in figure comprise of air blower through which outside air supply at 45°C passes through PVC tube in coiled form. Subsequently air passes through the anemometer to measure the velocity of air. Air flowing in the coiled pipe along the horizontal length of 12 ft. As we know that the average temperature at stratum is 27°C to 28°C. The soil provides a good Inertia to climate change during summer and winter season as the depth Increases. When the supply air passes through tube then heat transfer take place between air and cold soil temperature under ground level. Due to which air get cooled, after words the air passes through the indirect type heat exchanger. In which air flowing through pipe and the cold water circulating from induced type cooling tower, due to which heat transfer between air and cold water takes place and the air get recoiled by virtue of coldness of water. Cold water gets heated by heat exchanging to the warm air and recalculated back to the cooling tower with the help of water circulating pump. In such a way the temperature of supplied air will be decreases up to 10°C - 15°C. The conditioned air supply to various air handling units.

Observations and calculations:

Observation:

Table no-1 Physical and thermal parameters used in system.

Material	Density (kg/m^3)	Specific heat capacity (J/kgk)	Thermal Conductivity (w/mk)
Air	1.225	1006	0.0242
Soil	2050	1840	0.52
PVC	1380	1200	0.16
PE	950	2000	0.43

Table no-2 Comparison of temperature without water jacket at different velocities of air-

Section	Air Velocity=1.7m/s	Air Velocity=1.5m/s	Air Velocity=1.2m/s	Air Velocity=0.7m/s
$T_{(inlet)}$(in C)	44.7	44.8	45.0	45.3
$T_{(outlet)}$(in C)	31.3	31.7	32.5	33.3

Table no-3 Comparison of temperature of air with water jacket at Different velocities of air-

Section	Air velocity=1.7m/s	Air velocity=1.5m/s	Air velocity=1.2m/s	Air velocity=0.7m/s
$T_{(inlet)}$(in C)	46.0	46.3	46.6	46.7
$T_{(outlet)}$(in C)	25.4	26.1	26.2	26.9

Calculations

Sample calculation

Change in temperature without jacket:

Inlet temperature of pipe : 44.5

Outlet temperature of pipe : 31.3

Change in temperature : 13.2

Change in temperature with jacket:

Inlet temperature of pipe : 46.0

Outlet temperature of pipe : 25.4

Change in temperature : 20.6

Running Cost Analysis:

Flow rate for the output at maximum speed: 0.02 m3/min.

No. of power operated components

Blower unit- 500 W

Water Pump- 100 W

Consider that it is operated for 8 hr. a day then

Total power Consumption for a day : (0.8+4) units

Power consumed in a month : 4.8×30 units

Cost of 1 unit is considered as : 4 Rs.

Total bill on running of equipment : 576 Rs.

Coefficient of Performance (C.O.P):

We know that

$$COP = \frac{Refrigeration\ effect}{work\ done}$$

$$COP = \frac{0.02 \times 2000 \times 20.6}{600}$$

$$COP = 1.4$$

Results

Maximum Temperature difference attained by EAPHX System without implementing the water jacket is 14.0°C. Maximum Temperature difference attained by EAPHX System with the implementation of the water jacket is 21°C.

Table 4; Comparison of results without water jacket and water jacket at different velocities of air:

Section	Air Velocity=1.2m/s		Air Velocity=1.5m/s		Air Velocity=1.7m/s	
	Without water jacket temperature	With water jacket temperature	Without water jacket temperature	With water jacket temperature	Without water jacket temperature	With water jacket temperature
$T_{(inlet)}$(in °C)	45.0	46.6	44.8	46.3	44.7	46.0
$T_{(outlet)}$(in °C)	32.5	26.2	31.7	26.1	31.3	25.4

Conclusions

At a sufficient depth, the ground temperature is lower than the outside temperature in summer and higher in winter. When ambient air is drawn thought buried pipes, the air is cooled in summer and heated in winter. The main advantages of the system are its simplicity, high cooling and pre-heating potential, low operational and maintenance costs, saving of fossil fuels and related emissions.

Due to the Refrigerants that which we are using in the Refrigeration or air-conditioning, the depletion of the ozone layer and global warming is increasing day by day. So earth air Pipe heat exchanger is the best solution of this problem.

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