Mathematical Analysis of Earth Air Heat Exchanger (EAHE) for Storage system

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ABSTRACT
The temperature of earth at below ground level around 2 to 5m, is almost remain constant through out of year. This temperature called as Earth Undisturbed temperature EUT. This EUT is higher than atmospherics temperature in winter season. While in reverse condition can find in summer season. In summer season, EUT is always lower than atmospherics outside temperature. The heat exchange is set up at below ground approximately 2 to 5m. The heat exchanger is device exchange heat and gives satisfied utilization of EUT. In summer, the ambient is air pass through this below ground heat exchanger and provide cooling effect to any domestic and industrial building with the help of EUT. While opposite in Winter season the ambient is air pass through this below ground heat exchanger and provide cooling effect to any domestic and industrial building with the help of EUT. In both seasons like in summer and winter; heat exchanger gives efficient result of cooling and heating result respectively. It was found that our aim of designing made us to face designing and analyzing of it by implanting various types of basic fundamentals related to the concepts of Heat Exchanger.

Keywords: *Air Heat Exchanger (EAHE), Earth Undisturbed temperature (EUT), Coefficient of Performance (COP), storage system Introduction*

1. INTRODUCTION

Geothermal Energy is renewable resource like biomass energy and solar energy. So, with the use of geothermal energy, Heating Ventilation and Air-Conditioning HVAC application can be satisfied. In summer season, Earth Air Heat exchanger (EAHE) is converting the hot atmospherics air into cool and in winter, cool atmospherics heat into hot. sometimes comprises loop(s) of pipe buried possible two set up can be possible. First is vertical and second is horizontal. Temperature regime at this depth and on the far side is stable [1].

Concept Of Earth-Air Heat Exchangers (EAHE): Geothermal energy as renewable, free of cost, availability during year days & eco-friendly in nature being popular for domestic and commercial applications

Geothermal energy as renewable, free of cost, availability during year days & eco-friendly in nature being popular for domestic and commercial applications [1]

Working Principal of Earth-Air Heat Exchangers (EAHE):

The working principle of Earth Air Heat Exchanger (EAHE)is utilized for summer and winter season is not new concept.

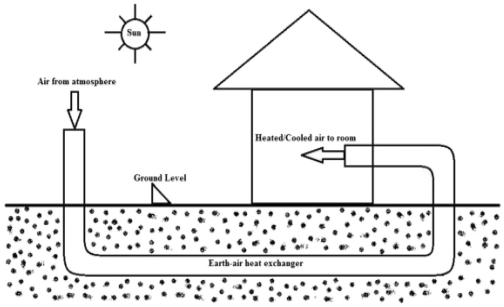


Fig 1 Earth Air Heat Exchanger [3]

It consists of a ground buried pipe. During summer season, Air inside the buried pipe is utilized for cooling of outside building or storage system. But opposite in winter season, Air inside the buried pipe is utilized for heating of outside room.

The geometric parameters of an EAHE are

D= Diameter of buried Pipe

L= Length of Pipe

Np= Number of pipes

Coefficient of Performance (COP) [9].

Coefficient of performance as per ASHRAE 1985

C.O.P =Qout/Win

Where, Qout = MPCP(Ti- To)

Win= Rate of energy input (energy supplied to blower)

Cp = Capacity heat energy of air (J / KgoK)

Qout= Rate at that heat is changed between hot air and cooler soil

Mp= Mass flow rate of air (Kg/s)

Ti= Temperature of air inside the tube (ok)

To =Temperature of air at outlet (ok)

2. METHODS

1 Miroslaw Zukowski et al. He suggested results of from simulation data and experimental data investigations of thermal C.O.P. of earth air heat exchanger (EAHE). This natural energy-based system will reduce heating masses. The temperature difference between the two locations for three different materials—polyvinyl chlorine(PVC), polycarbonate (PC), and polyethylene (PE). The temperature difference was lowest in the PC case and highest in the PE case, though these differences were not significant. The authors have used – Energyplus (energy simulation computer code) to calculate the capacity of earth air heat

exchanger in domestic's buildings. For simulations, author has observed parameter like EUT, and other temperature related to soil and pipe was calculated by CalcSoilSurfTemp.

2 Girja Sharan et al. Girja Sharan et al. ETHE consists of Diameter 10centimeter, and length was 50 m and material of Pipe is Mild Steel pipe with wall thickness of 3 mm. Especially made fins have been installed on the outer surface of the pipe, all along the 50m length. Fins are made of thin GI strip spirally wound over the pipe and then spot-welded at several points. There are 40 fins per meter length. As per his observation write-up describes the event and a few applications of earth tube heat exchangers in Gujarat. Work made public here was delivered as Nanubhai Amin Memorial Lecture at Electrical analysis and Development Association, Vadodara as a part of a part of, eleven could 2004. Cummins Foundation-IIMA Laboratory for Environmental Technology in Arid Areas has been engaged in development of ETHE within the recent years. As stated, this was impelled by ought to realize ways that to chill greenhouses in hot-arid tannin, with borderline or no use of water. smart quality water is inveterately scarce there.

3 Girja Sharan et al. He has suggested that an outsized a part of Gujarat within the North-west region of Asian nation is semi-arid. For better air circulation of air, for highest thermal conductivity and low specific heat, best material was Steel material used for pipe and as a result, it transfers heat from air to earth. The lands are less fitted to agriculture. farming is thus common. Productivity of oxen is but additionally low thanks to issues of feed and thanks to climatically stresses, especially heat. Environmental management of farm buildings - animal homes, greenhouses- in semi-arid areas may be a special challenge. there's widespread shortage of water; rural grid is vulnerable to interruptions many times daily. oxen homeowners don't provide importance to animal comfort as a method to boost productivity.

4 L. Chandra, Praveen Garg, Rohit V. Maitri et al. The potential exists for considerably increasing the performance of shallow ponds used as supplemental heat rejecters in GSHP systems. any analysis is usually recommended within the following areas: improvement of the planning procedure and management strategy. Hybrid ground supply apparatus systems have several degrees of freedom; there are trade-offs between the reduction in size of the bottom loop device, the dimensions of the pool, and also the management strategy. To additional totally perceive this, further analysis victimization the simulation techniques developed during this paper is required. This analysis would additionally take into consideration the economic prices and edges, that we've got not investigated. further validation of the model, victimization information from an operating system, would be helpful. Extension of the model to hide deep pools for things wherever associate existing pond or lake is offered.

5 Upamanyu Bangale Samir Deshmukh et al. India is largest producer of fruit and vegetable in world state of affairs however handiness of fruit and vegetable per capita is considerably low thanks to post-harvest loses that is concerning twenty fifth to half-hour of production that the demand of refrigeration and air-con has been increased. Building or cluster of buildings with thermal insulation and cooling system during which biodegradable food or product will be hold on for numerous lengths of your time to cut down deterioration with necessary temperature and humidness is named as cold storage. In cold storage cooling system brings down the temperature ab initio throughout start off however thermal insulation maintains the temperature soon ceaselessly. during this read, the easy methodology is given to calculate heat transfer by analytical method conjointly try has been created to attenuate the energy consumption by substitution a hundred and fifty metric linear unit enlarged phenyl ethylene (EPS) by a hundred-metric linear unit Poly ester foam (PUF) insulation. The methodology is valid against actual knowledge obtained from sphenisciform cold storage settled in Pune, India.

6 Stuart J. Self, Bale V. Reddy, brandy A et al. They had investigated that geothermic heat pumps square measure extremely economical heating technologies that yield reductions in dioxide emissions, the potential rejection of fuel usage and economic blessings. Heat pumps utilize considerably less energy to heat a building than different heating systems. several variations of geothermic systems for heating exist, with

totally different configurations appropriate in several things and most locations round the world. decide among heating choices, it's vital to see the advantages for various ground setup choices, usually in terms of potency, emissions and social science.

7 Raluca Teodosiu, Lidia Nicult et al. They addressed earth-air device (EAHX) implementation for Romanian dwellings. the target is to assess the potential of this resolution for ventilation energy savings and greenhouse emission emissions reductions. Numerical transient coupled model (single-pipe EAHX – ventilation – building) is developed exploitation Trnsys as simulation tool. The simulations square measure administered for typical Romanian single-family detached home, taken under consideration 3 totally different climate regions. for every case, careful results square measure conferred regarding EAHX thermal behavior and its edges in terms of energy savings and anti-pollution effects for recent air pre-heating and pre-cooling inside mechanical ventilation of the house.

8 Amanda Pertzborn, Gregory Nellis et al as per their observation, a summary of the work being conducted on GSHPs at the University of Wisconsin – Madison has been conferred. The work to this point has found that styles supported TMY weather information could under-predict the specified part sizes because of the particular year-to-year weather variation is neglected. Initial validation of the part wants to simulate the GHX (the DST model) has shown that the model will predict the outlet temperature of the GHX for brief term simulations, however extra validation is needed. extra validation of the DST model is performed as information is collected from the location in Madison similarly as from extra sites in city, NV. the warmth pump part model will be valid.

9 Trilok Singh Bisoniya et al. The Earth air heat exchanger (EAHE) will be recent or new advancement which might be effectively for the heating and cooling load calculation. several authors observed equations, models and procedures about EAHE. The model EAHE utilized for a observations of equations and main objective is that to find out the earth's undisturbed temperature (EUT) The model also help to calculate Reynold number Re, Nusselt Number Ne, and others parameters for pipe and soil. The prepared equations are used to change in design to calculate Co-efficient of heat and other performance parameters.

10 Rakesh Kumar, A.R. Sinha et al. They addressed that new improvement methodology supported GA is applied as a generative and search procedure to optimize the look of earth-to-air device. The GA is employed to come up with doable style solutions, that square measure evaluated in terms of passive heating and cooling of building, employing a careful thermal analysis of non-air-condition building setting the results from the simulations square measure afterward accustomed more guide the GA search to seek out the high-energy solutions for optimized style parameters. the drawback self-addressed during this study is that the size of earth-to-air device in a very non-air-conditioned residential building.

11 SujataNayak and G.N. Tiwari (2009) investigated the theoretical performance of earth heat exchanger concern with greenhouse exploitation energy and exergy analysis ways. The utilization of solar energy through the electrical phenomenon system and EAHE for heating and cooling of greenhouse. Calculations are in dire straits the four varieties of weather conditions (a. b, c and d types) in Indian capital, India. The paper was compares with greenhouse air temperatures once it's operated with photovoltaic/thermal throughout day time including the planet air tunnel heat exchanger in the dark, with the air temperatures, The results conclude that air temperature within greenhouse may be magnified by 7-80C throughout the winter season, once system is operated with the electrical phenomenon, coupled with earth air tunnel device in the dark. From the results it's seen that hourly helpful thermal energy generated, throughout the daytime and already dark, when system is operated with electrical phenomenon including the planet air tunnel heat exchanger, is 33MJ and 24.5 MJ.

11 ArvindChel and G.N. Tiwari (2010) Investigated the complete electrical phenomenon integrated with EAHE for area heating and cooling of a house in Delhi-India. this paper deals with the experimental outside

annual performance analysis of the 2.32 kWp electrical phenomenon (PV) grid situated at Delhi – solar energy park. electrical load nearly about ten-kilowatt h/day that is compare with the electrical air blower of associate earth air tunnel heat exchanger used for cooling/heating of the soddy, ceiling fan, fluorescent tube-light, computer, submersible pump, etc. The outside efficiencies, power generated and lost in PV system elements were determined exploitation hourly experimental measured knowledge for one year on typical clear day in monthly.

12 Xamána et al. he has used 3 cities of Mexico for his Experimental set up of Earth Air Heat Exchanger. So, different atmospherics climate condition found during his work and COP were different at 3 cities of Mexico. He has used 2 experimental setups for EAHE. One EAHE having thermal Polystyrene insulation. While other EAHE having there is no insulation. So, Material of Polystyrene affect thermal performance of EAHE. He has calculated Reynold Number was 1500 at 3 different Maxico Cities. He has used Ciudad Jaurez which is city of maxico, thermal insulation used in EAHE during winter season only. While other 2 cities of maxico and merida, used thermal insulation in summer conditions.

13 Viaka Bansal and Misra et al. they observed that the utilization of material like PVC for the cooling capacity. This aim of the planning of the duct system. The practical works was created as an example EAHE model. This paper applicable of small residential. For this application, suitable steel material and non-ferrous material like brass material can be possible. So thermal conductivities of Ferrous & non-ferrous materials are different. The Coefficient of performance also depend on materials of tube or pipe. So, useable energy is less as compared to conventional system. They have used lower cost of steel material or steel graded material used. The COP of EAHE depend on Mass flow rate of air. The COP also depends on Materials of Pipe.

14 Trilok Bisoniya et al. They have prepared EAHE model for calculating parameter like pipe length, radius, and depth of buried pipe. An Authors prepared 1D and 2D of EAHE for Find out earth undisturbed temperature at different depth level. As well as 3D model is developed for performance analysis of Earth Air Heat Exchanger. The CFD is used for a heat transfer analysis of 3D model. Even also they concluded that CFX, CFD200, FLUENT and ADINA can be used for complicated fluid flow analysis of Earth air heat exchanger. The energy equation can be given efficient analysis of EAHE

15 Jakhar et al. The Author has used TRYNSYS 17.0 used for analysis of Earth Air Heat Exchanger The experimental setup was established in Ajmer location of India. The results were calculated as per thermal climates conditions of Ajmer. There was a galvanized iron duct used for star air heating purpose. So, it's also known as Star Air Heating Duct (SAHD). They have found that variable in air conditions affect the performance of EAHE. But the other parameters like thermal conductivity of duct, soil diffusivity and design of EAHE also can be improved coupled with other system.

16 Ahmed et al. The author used Rockhampton – Australia for experimental set up for EAHE. They used two shipping containers. Vertical EAHE and Horizontal EAHE are set up in two containers. So, Materials of Container play use role in this set up. Air blower is used for sucked atmospheric air and blow inside set up. There are 20 PVC pipes are used experimental work. The researchers had also prepared CFD Model based Experimental set up. the soil temperature also calculated in summer days at different depth levels. From the CFD analysis results show the common temperature for HEAHE was larger than VEAHE. Thus, concluded that VEAHE provides a lot of reduction in temperature drop than the HEAHE. Thus, VEAHE is preferred to use for Australian weather

17 Dubey et al. as per suggested of researcher, he has used open loop type EAHE used. In the experimental work consist of three pipes. These pipes arranged in Vertical direction with parallel. In the summer, good cooling rate calculated based on steel graded material. Also suggested that PVC material can be used but

thermal conductivity less as compared to steel graded materials. The mass flow rate of air and speed pf air increased, in result temperature decrease but COP is slightly decrease as per their expected.

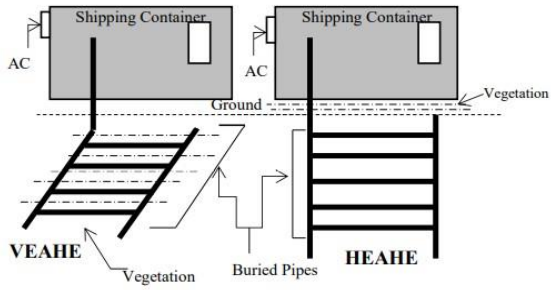


Figure 2: Vertical EAHE & Horizontal EAHE [12]

Chaturvedi et al. he has done his Experimental set up of EAHE in Bhopal region. The EAHE consist of Multiple pipes in parallel direction in summer climates. It found that there was impact on output due changing material like PVC and Steel or other ferrous materials. But diameter, length and arrangement of pipe affect COP of EAHE. The COP of EAHE depends on Materials of pipe, but also depend on soil diffusivity and performance parameters. The conclusion as per his suggestion that material of pipe is not play used role in COP of EAHE. 19 Rahul Rathee& Dr Atul Lanjewar investigated that after learning the views of authors. evokes of all this attempt we have a tendency could proceed that The technology of cooling system with ground coupled condenser reduces energy consumption, fuel price and heating and cooling system seems to be flexible, multi-functional, and also the overall constant of performance of the device may be abundant improved. The conventional air-conditioner may be a massive shopper of power while in cooling system with ground coupled condenser cut back power consumption. During this system the seasonal thermal storage ability of the soil, that encompasses a temperature delay compared to the outside temperature. This temperature difference between the outside temperature and also the soil temperature permits a cooling result of the new summer air.

Sansui et al. he has suggested soil material and pipe material are very useful for performance of EAHE. As well as during simulation of EAHE, he has found different soil temperature at 5meter depth or below ground level. He has done his research work in Islamic university in Asian condition. Also, he has experienced that soil having grass coated. The soil is sandy type. Pipe material might not be affecting the performance of EAHE. As well as types of EAHE also not supported parameter for COP EAHE. The air velocity slightly affects the COP of EAHE.

3. RESULTS AND DISCUSSION

1. As per the Literature review Earth air device utilize for various analysis like physics analysis, theoretical analysis, and performance analysis, and simulation purpose, optimization of parameter or criteria for warmth energy.

2. EAHE is best device for heating and cooling application with good performance and efficiency. EAHE systems square measure usually used city or country throughout the year, either as an entire system for small level of cooling for storage system or domestics building to use with normal HVAC systems.
3. EAHE to boot already applied to collecting, Artificial Neural Network, dwellings, Greenhouse and totally different agriculture purpose. but as per the literature review, EAHE never used in cold storage purpose.
4. Cold storage is used for storage of Wheat, food and fruit preservation what is more as totally different storage. Temperature of cold storage is match with the temperature of Earth ground. So, EAEH focuses on the thermal performance of cold storage for cooling purpose

As per the Literature review, Earth air heat exchanger utilize for various analysis like thermodynamics analysis, theoretical analysis, and performance analysis, and simulation purpose, optimization of parameter or criteria etc. for dwellings, Greenhouse, and other agriculture purpose for geothermal energy as HVAC Application.

- But as per the literature review, EAHE never use in storage purpose.
- Storage system is used for storage of wheat, grain food and fruit preservation as well as other storage. Temperature of storage is match with the temperature of Earth ground.
- So, EAHE focuses on the thermal performance of storage for cooling and heating purpose.
- EAEH is the largest single category of geothermal energy use in the world, with well-developed markets in for HVAC purpose.
- Design EAHE of a given capacity or capability analysis
- To measure the temperature distribution with respect to depth of ground surface.
- Compare design predicted work with experimental work
- To study and investigate the effects of various parameter of heat exchanger like material, Inlet and outlet temperature, pipe diameter, thermal conductivity of pipe, fluid, COP of an EAHE etc. even also to investigate the effect of ground related criteria like soil material, properties, moisture, thermal conductivity, water movement etc.
- To develop an economical and energy efficient CFD model which can be used for versatile applications or to reduce the size of existing set up. The motto of this project is to be helpful for commercialization of the application as well as correction of limitations for future development.
- To develop an economical and energy efficient CFD model this can be used for versatile applications or to reduce the size of existing set up.
- The motto of this project is to be helpful for cold storage system as well as correction of limitations for future development.
- To make for recommendation of selective application.Citations

Analysis of EAHE

Boundary Conditions

The following parameters for boundary conditions were utilised in the one-dimensional model of the EAHE system.

Input boundary conditions

At the water conditions of the EAHE pipe, air flow speed in m/s and static temperature of air in (°C) at water were to be outlined. The density and heat energy capacity of air and thermal conductivity of air were to be considered at static temperature of air at water.

Output boundary conditions

For slow speed flow regime, the relative pressure at the outlet of the EAHE pipe was consider or outlined as adequate zero atmospherics.

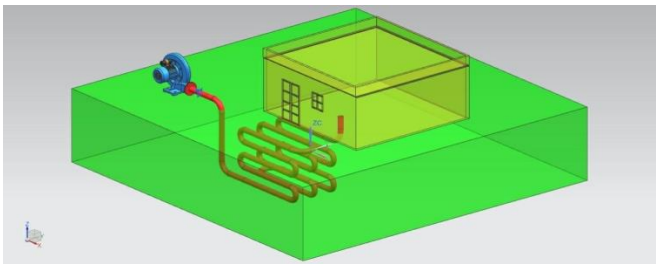


Fig 4 Diagram of Earth Air Heat Exchanger

Wall Parameter/Properties

P= air fan Blower in Watt.

C_p = heat energy or capacity of air J/kg K

D= Diameter of pipe in m.

f = Co-efficient of Fluid friction factor

hc = Convective heat transfer Co-efficient from air to tube wall in W/m2–K

K_t = Thermal Physical phenomenon for tube in W/m–K

K = Thermal Physical phenomenon for air in W/m– K

m= Mass flow rate of air in kg/s

NTU = range of warmth transfer unit

n= Number of Pipes

Δp= Pressure Drop or lossin Pascal

Re = Reynold Number

Nu = Nusselt Number

r_i and r_o = inner and outer radius of tube in meter respectively.

Ut = Overall Heat Transfer Co-Efficient in W/m2–K

ρ = Density of air in kg/m^3

v = Speed of air in m/s

V = Volume of air in m^3/s

ε = Effectiveness of EAHE

μ = Dynamics body in Pa. s

1. **Earth's undisturbed temperature**

The earth's undisturbed temperature (EUT) is a vital parameterfor designing of Earth Air heat Exchanger assumption is that Diffusivity of soil is constant as a consideration homogeneous. the temperature of air at depth z and time t can be obtained by

$$T_G = T_m + A_s \exp^{-z\sqrt{\frac{\pi}{365a_s}}} \sin\frac{(2\pi(t - t_{ag})}{365} - z\sqrt{\frac{\pi}{365a_s}}$$

Tm = 28^0C = Mean Annual Surface temp of Rajkot (Taken from Research paper)

As =11.4^{0}C = Amplitude of soil surface variation (Taken from ASHRAE district cooling – Fundamental)

T_{lag}= 115.9 days (Taken from ASHRAE district cooling – Fundamental)

Z = 2m = Depth in Meter

K_p= Thermal Conductivity of Pipe PVC material = 0.19 (Taken from Research paper)

Ks = Soil Conductivity = 0.52 (Taken from Research paper)

a_s= Soil thermal diffusivity (m^2/day)

$$T_G = 28 + 11.4\exp^{-2\sqrt{\frac{\pi}{365a_s}}} \sin\frac{(2\pi(t-115.4)}{365} - z\sqrt{\frac{\pi}{365a_s}}$$

$$T_G = 28 + 11.4\exp^{-2\sqrt{\frac{\pi}{365a_s}}} \sin\frac{(2\pi(365-115.4)}{365} - z\sqrt{\frac{\pi}{365a_s}}$$

TG = 22.34ºC

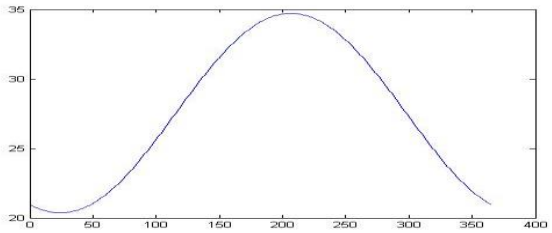
$a_s = 0.161$ for PVC Pipe.

Similarly, t = 1 to 365, value of T_G is given…

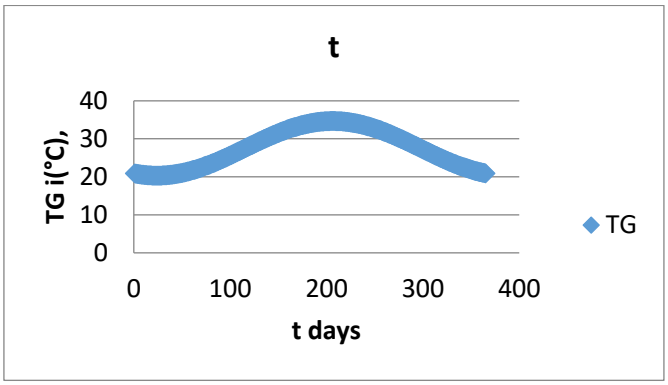
Where Tg is the ground temperature at time t in second and depth z is in m,

Tm is the average or mean soil surface temperature (°C),

As is the amplitude of soil surface variance in°C, αs is thermal diffusivity for the soil in m2/s; m2/day, t is elapsed time from beginning of the calendar year in day, and to is the phase constant of soil surface in days. It is very difficult to find out accurately the value of earth's undisturbed temperature (EUT) because the soil parameters are often unknown.



Graph 1 between Temperature vs. Days. It's calculated using with help of MATLAB.



Air flow:

The parameters of an EAHE Consist of tube diameter (D), tube length (L) and number of tube(n) in the heat exchanger. Now, we select an arbitrary size diameter (D) of tube and then with the help of the known value of volume flow rate (V), the number of tubes, in parallel and mass flow rate are calculated. For a tube radius ri, air density, air flow velocity, numbers of parallel pipe etc. are to be considered during mathematical study of earth air heat exchanger. Now, mean or average velocity of the air of the heat exchanger v will be:

$v= V/(n\pi r_i^2)$

and

$m=\rho v\pi r_i^2$

n = no. of parallel tube = 5

D= do = diameter of pipe = 50mm =0.050m

Di = inside diameter of Pipe =0.044m and ri= 0.022m

For one room volume is 10x10x10 = 1000 m3/hr. = 5.5x10-3 m3/s.

Air change is taken from ASHRAE handbook & it will be 16.6

$v= V/(n\pi r_i^2) =$ (16.6x5.5x10-3)/5x3.14x0.0222x0.022 = 12.013m/s

Put all value in equation of v and it is 12m3/s

ρ = density of air for Rajkot = 1.261 kg/m3

m = mass flow rate in one tube

=1.2x12.016x3.14x (0.022)2 = 0.0219kg or kg/s

Heat Transfer:

If the Dimensions of EAEH are known values, then calculation of the heat transfer rate can be easily calculated with the help of using log mean temperature Difference (LMTD) method. Calculation of the heat transfer rate can be calculated by ε- NTU method too. The output temperature of air was calculated by using effectiveness of EAHE which is function of NTU.

The equation is selected from book ASHRAE Fundamentals 2013 OR BS EN 15241:2007. The overall heat transfers co-efficient Ut is

U_t=1/((1/h_c +1/(2πk_t) ln r_o/r_i)) = 1/((1/h_c +1/(2π (0.19)) ln 0.050/0.044))

Here unknown value h_c also can be given by…..

h_c=(Nu k)/D = (Nu 0.542)/0.050

Where K = Thermal Conductivity of air (W/m–k) = 0.027

For this work, we calculate Nu using book of ASHRAE 2013 fundamental – heat exchanger forced convection co relation which is .

Nu=((fs/8(Re-1000)Pr)/(1+√(12.7&f/8)(Pr^(2/3)-1)))

For Laminar flow, Nusselt Number Nu= 3.66 for Re<2300

For Turbulent flow, Reynolds Number Re>2300.

Where Reis Reynolds Number

Pr = Prandlt number

f = is the friction factor.

The friction factor f we used here is the newly developed correlation of Ghanbari et.al which give as below.

f=(-1.52log(((ϵ⁄D)/7.12)^1.042+(2.731/Re)^0.9152))^(-2.619)

ϵ = roughness factor which can be significant as f, Nu and hc can be changed by factor if the design changes from smooth PVC to rough concrete pipe.

The Re is calculated by using diameter of the tube and average air flow velocity.

Re= ρvD/μ=1.261X12.16x0.050/μ

and

$\mu = 1.966 \times 10\text{-}5$

Re = 3853

The Prandlt number is defined as:

Pr= (μC_p)/K =(1.966 x 10-5 X 1006.9)/0.027 = 0.7331

Where Cp is the specific heat of air.

Nusselt Number also can be calculated as

Nu = 0.023xRe0.8xPr0.3 (this equation also can be used)

= 0.023x(3853)0.8x (0.7331)0.3

= 15.48

hc=(Nu k)/D = (15.48 X 0.542)/0.050=167.80 W/m 2K

Now Ut is to be calculate

U_t=1/((1/h_c +1/(2πk_t) ln r_o/r_i)) = 1/((1/167.80+1/(2π (0.19)) ln 0.050/0.044))=1/((0.0059+0.84(0.127)))=8.87 W/m 2K

Once Ut is calculated, output temperature of air leaving of system EAHE s can be estimated as function of tube wall temperature and inlet air temperatureusing equation.

Tin = 35ºC and TG = 21.023ºC

T_L=T_G+(T_in-T_G) e^(-hA/(mC_p))=21.02+(35-22.34) e^(-18.6/(0.021*1006.9))

T_L=21.03ºC

Now, the instantaneous rate of heat transfer from the ground to air in each tube, Qt is then given as:

Q_t=mC_p (T_in-T_L) = 0.021 x 1006.9 (35-21.03)

= 33.75 W

NTU is defined as

NTU= (h_c A)/(mC_p)= (167.8X 2 X 3.14 X 0.022 X 25.92)/(0.021 X 1006.9)=530.7

Where A=2πr_i L = (2 x 3.14 x 0.044 x 25)

The efficiency of EAHE is defined as:

ε= (T_L-T_in)/(T_G-T_in)=(22.34-35)/(21.34-35)=0.901=1-e^(-NTU)

Now f + Friction factor is to be obtained in its

f= 0.0238

Now, the pressure dropsΔp at the end of tube will be.

Δp=ρf v^2/(4r_i) L=1.261*0.0238* 〖12〗^2/4x0.022 25.92=1272.93 Pa

Design Equation:

Design equations are derived from the above relations. For estimate the length of tube and Δp.we know value of total volume flow rate, size of tube, depth at which tubes are placed and no. of tube parallel tube.

NTU=-ln(1-e)

The effectiveness of heat exchanger is determined by NTU. the effect of NTU on effectiveness is given graph. NTU increase the effectiveness though the rapid flatness, after NTU>3, relative gain is small.

The required length of tube can be determined from the derived value of NTU using the relations:

L= (mC_p)/(2πr_i U_t)= (0.021 x 900)/2πx0.022x8.93 = 25.92m

The fan power required is calculated as:

P=VΔp = 16.6x5.5x10-3 x1272.93= 0.116Kw

4. CONCLUSION

An outcome is given follow:

1. Earth's undisturbed temperature or Earth's ground temperature is calculated as TG = 22.34ºC which suitable for Cold Storage Purpose
2. The fan power needed to maneuver V volume of air across the overall pressure drop is calculated as 116kW
3. The specified length of tube calculated as 25.92m.

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