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STUDY ON GEOTHERMAL REFRIGARATION

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ABSTRACT

Geothermal heat can be used for different purposes, depending the operating temperature of the source. Usually, in case of low and medium-enthalpy sources, geothermal energy is used directly, for space heating, domestic hot water, agricultural uses, etc. Conversely, in case of high-enthalpy geothermal resources, heat is more profitably converted in to electricity or in more complex cascade cycles. Low or medium temperature geothermal energy can be converted in to electric power only when innovative and expensive system layouts are considered. Unfortunately, at are as on able depth only low-enthalpy geothermal energy is usually available; only in some specific locations in the world, high-enthalpy geothermal resources are available even using low- depth wells.

1. INTRODUCTION

The majority of the studies regarding space heating and cooling systems driven by geothermal energy focus on Geothermal Heat Pumps (GHPs), able to exploit low enthalpy geothermal resources, available all over the world. Such systems are going to become more and more profitable in the next future, also due to a favorable regulatory framework. GHPs energy and economic performance significantly depends on climatic conditions. In fact, Morrone showed that in mild climates, where GHPs are mainly used as heat pumps, the annual average temperature of the ground around the energy piles can increase up to about 10 °C after a few years of operation, causing a deterioration in the performance of the system; conversely, in cold climates such increase is negligible. Medium and low temperature geothermal resources are mainly used for space heating purposes by geothermal district heating systems. In case of space cooling, another reference geothermal system is represented by medium and low-enthalpy geothermal sources coupled with absorption chillers. In fact, many geothermally driven absorption chillers are installed all over the world and many studies are available regarding this topic. Wang et al. used the hot aquifers (70–100°C at a 3 km depth) in Perth to design a largescale geothermal cooling district for an university campus. The Pay-Back Period ranged between 11 and 13 years. Typically, AHUs based on Desiccant Wheels (DW) meet latent loads through air dehumidification provided by the desiccant material and sensible loads through an evaporative cooler. Such device operates according to an open cycle known as the ventilation cycle or Pennington cycle. The system includes a number of heat exchangers and thermodynamic processes. As a consequence, an exergy optimization is crucial in order to reduce irreversibility within the system. Typically, the exergy efficiency of this device is around 30–35%. Several studies also showed that the regeneration temperature dramatically affects the overall exergy performance. Obviously, the performance of desiccant cooling systems dramatically depends on the weather conditions. In desiccant-based AHUs, the thermal energy needed for regeneration purpose can be provided by geothermal resources, in order to save fossil fuels and reduce greenhouse emissions. However, such opportunity has been scarcely investigated in literature. In the majority of the available studies, only schemes based on the use of solar energy are considered. The possibility of using the heat produced by a Concentrating Photovoltaic Thermal (CPVT) collector to drive the regeneration process in a desiccant-based AHU was investigated.[1]

2. THEORETICAL ANDEXPERIMENTAL STUDIES

Studies performedonlowandmediumenthalpy geothermal wellsshowedthattheuse ofDownhole Heat Exchangers(DHHE)is moreprofitable thantheextraction of geothermalbrine,sincethistechniqueallowsonetoavoidpumpin g costs.However,in order tomaintaina stable welltemperature,acertainamountof geothermalfluidmust becontinuouslyextracted.Usually,suchextractedfluidisusedfo rpurposesotherthan spacecooling(domestichotwater,spaceheating, thermalbaths,etc.Inthisframework, themotivationofthepresentworkisbasedonthepossibilityofusi ngallthegeothermal heat(by thedownholeheatexchangerandby theextractedfluid,simultaneously)for spacecooling purposes,inordertomaximizethe energyandeconomicperformanceof the system.Tothisscope,a novellayoutwasproposed,inwhichtheheatof the Downholeheatexchangerisusedtodrivetheregenerationproces sin adesiccantbased AHU,whereastheextractedgeothermalfluidisusedtodrive asinglestageabsorption chiller,producing coldwater for thecooling coilof theAHU.Geothermalfluid extraction is also usedinorder toallow onetoachieveastableoutlet temperatureform Downholeheatexchanger,preventing wellcooling.Finally,theexceedinggeothermal heatisusedtoproduceDomesticHotWater.Thisnovelarrangeme nt,neveranalyzedin literature,allowsoneto design afully-renewablegeothermalheatingandcoolingsystem,exceptforthe electricenergyconsumedbytheauxiliarycomponents.Thisnove l systemisexpectedtosignificantly improvetheenergy efficiency andtheeconomic profitability ofthesystem,duetoanenhancedutilizationofthegeothermalsour ces, withrespecttoa conventionalsystembasedonageothermalwellanda single-stage absorption chiller.

3. GROUND-SOURCE HEAT PUMPS TECHNOLOGIES

Inthissection,a briefdescription of the presentGSHPtechnologiesisdeveloped. The designandtherelativecostofthesystemisaffected by thegeologicalproperties,the subsurface temperatures,the thermalandthehydrologicalpropertiesofthe site. Consequently, systemperformancedependsontheuncertainty indesigninput parameters,withparticular regards tothe temperature andthermalpropertiesofthe source. TheGSHPsystems general scheme is represented inFig. 1.

It is composed by,

1.The loadsidewithanair-waterorawater-waterloopinrelationtotheapplication considered;
2. Therefrigerant loop ofthe watersourceheat pump;
3. Theground loop in which waterexchanges heat with the refrigerantand the earth.

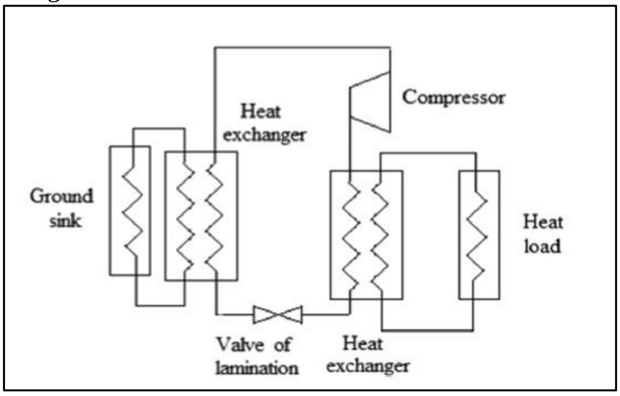

Fig.1.GeneralDesignofGSHP

Thesystemabsorbsheatatalowtemperaturelevelandrejectsitt oahighertemperature level.TheGSHPsusethethermalenergystoredintheearththrou ghtwomain different geometriesof thecircuits,verticalor horizontalheatexchange systemsburiedinthe ground,asrepresentedinFig.2.The systemcanworkbothasarefrigeratorandasa heatingsystem,withthepossibility ofobtainingdual-modeGSHPsystemsby usinga reversing valvetoswitchbetweenheatingandcoolingmodes,by reversingthe refrigerantflowdirection.Inrelationtothetechnologyused,the GSHPsystemscanbe classified in fourcategories:

3.1. GWHP, ground-water heat pump systems

Itisalsoknownasopen-loopsystems,are theoriginaltypeofGSHPsystem, firstinstalledinthelate1940s.TheyareverticalGWHPsystems ,whichinvolve wellsandwellpumpsinordertosupplygroundwatertoaheatpu mpordirectly totheapplications.Theusedgroundwaterisdischargedtoa suitable receptor. Designing isbasedontheknowledgeofsomeconditionsrelatedtothegrou nd-wateravailabilityanditschemicalquality.Theyareinterestings ystemsfortheir lowcost,simplicity inrealizationandsmallamountofgroundareanecessary. Disadvantagesandproblemsarerelatedtothepossiblelimiteda vailability and poor chemical qualityand to groundwaterwithdrawaland re-injection;

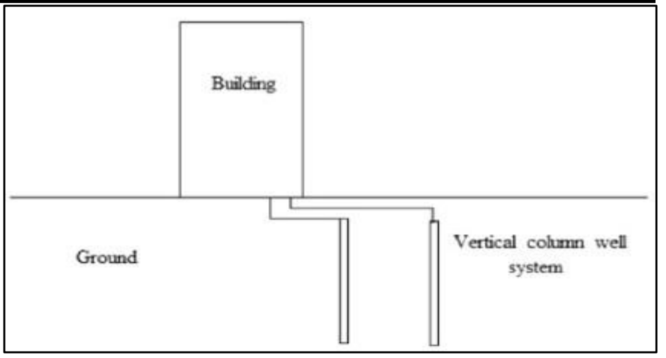

Fig.2. Vertical boreholes GSHP

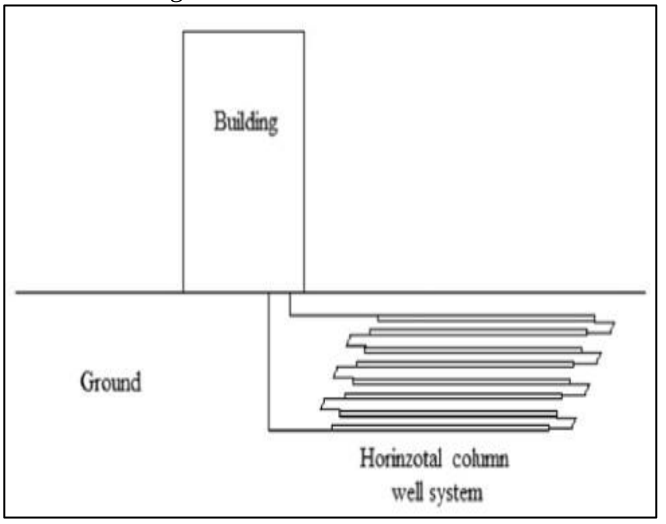

Fig.3.Horizontal trenchesGSHP

3.2 GCHP, Ground-Coupled Peat Pumpsystem

Itknownasclosed-loopGSHPsystems.They weredevelopedduringthe1970 swiththeadvantageofovertaking theproblemsrelatedtotheground water quality andavailability.Moreover,they use lesspumpingenergythanthe previoussystemsbecauseof the lesselevationrequired.Inthese systems,heat rejectionandextractionareobtainedbyahigh-density polyethylenepipeheat exchanger buriedinverticalboreholes (Fig.3) orhorizontaltrenches (Fig.3). Thisfluidusedcanbe water or anantifreeze solution.Inthecase of vertical boreholeGCHPsystems, thegroundheatexchangercanbe composedof (30.5-120m)deepand(76–127mm)-diameterboreholes,backfilled witha material thatpreventscontaminationofgroundwater,andwitha (19–38mm)-diameter U-shapedpipethroughwhichtheheatexchangefluidflows.One ofthe difficultiesintheverticalGCHPdesignconsists intheappropriatesizing the depth of borehole.In horizontal GCHPsystems,groundheatexchangeris composedof aseriesof (19–38mm)-diameterand(121.9–182.9m)-length parallelpipe,pertonofheating andcoolingcapacity,inhorizontal(0.91–1.83 m)-deepboreholes.Thissuperficialsoillayerhasanampletemperat ure swing: duringfallseasonitisatahighertemperaturethenthedeepersoil (＞10mdepth),because of thesummer solar irradiation;attheendof thewinteritis typically atalowertemperature,duetothegroundsurfaceheatlosses.Fort his reason,a drawbackof thissystemisa lessstable heatsource temperature anda variable COPduringtheheatingseason.

3.3 SWHP, Surface Water Heat Pumpsystem

It is of two different configurations:

The closed-loopin which heatrejection-extraction circulating system is positionedatanoptimizeddepthwithina lake,pond,reservoir,or,ingeneral, openchannel.The thermal systemsusepipesof(19-38mm)diameters anda (30.5-91.4 m)length perton of heatingor cooling capacity;
Theopen-looptype,inwhichscreenedintakeareaisusedtoextractwaterfrom the surface-waterbody.Then, the water is discharged toareceptor;
At the present, this technologyis stillin developing;

3.4 SCW, Standing Column Well system

Inthissystem(Fig.4), waterispumpedoutandinastanding columninadeep wellbore.Theborehole,whichallowstheheatexchangefluidto be indirect contactwiththeearth,hasdiametersofabout15.2cmwitha depthof457.2m. Theyhaveverysignificant installationcosts.

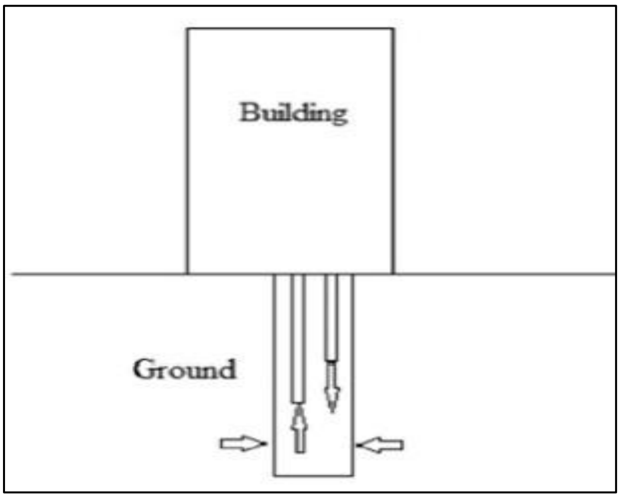

Fig.4. Standing column well system

Initially,ground-coupledheatpumpswere introducedinrural,residentialapplications, whiletheirimprovementsforhighlevelofcomfortandlowoperating costshave allowedthemarkettobeexpandedtourbanandcommercialapplications.Forexample, inUSA,in1985,theGSHPsinstalledinresidentialandcommercialapplicationswere14,000,in1990around100,000,in1999about400,000:betweentheyears 2000and theirannualenergyusegrewatarateof30.3%,whiletheirinstalled capacitiesincreased by23.8%. [1]
Theircoefficientofperformance(COP)isusually intherange3-3.8becausethese systemsworkusing thesinkearthtemperature whichcanbeconsideredconstant(the geothermalgradientisaround30°Ckm−1)atits workingdepth(6-100m).Moreover, they usewaterasaheattransfermediumwhichhasahighheatcapacity. Theusual methodofgroundcouplingconsistsinburyingthermallyfusedplasticpipeinhorizontal orverticalaccommodation,using a circulatorpumpfor water orantifreeze solutionas thermalworking fluidinheatexchangersuchthatnowaterentersthesystemfromthe ground.Theusualmethodofgroundcouplingconsistsinburyingthermallyfusedplastic pipeinhorizontalorverticalaccommodation, using acirculatorpumpforwateror antifreezesolutionasthermalworkingfluidinheatexchangersuchthatnowaterenters thesystemfromtheground.Alessusedsystemconsistsinadirectexpansionsuchthat a refrigerantline isburiedinthe ground andtheintermediate heatexchanger andfluid areeliminated.Anotherrarely appliedsystem,forverticalapplicationonly,usesheat pipesfilledwithphase changing CO_2.Theprincipaldifficultytorapidimplementation oftheGSHPisrepresentedbothbythetechnologyinvolvedand bytheircosts,evenif someprogresseshave beenmade intheiruse forsystemintegration,withtheresultof reducing thecostofthegroundheatexchanger(GHE),ofimprovingcollector configuration and their control systems. [2]

4. SYSTEM LAYOUT

Thelayoutofthe systemisshown inFig.5,inwhichtwomajorsubsystemscanbe observed:theAHUandthegeothermalequipment.The AHUincludedinthismodelis representativeofthetestfacilitylocatedatUniversity ofSannio(Benevento,Southern Italy),which consistsoffivemaincomponents:
(1) DirectEvaporativeCooler(EV); (2)The crossflow air-to-airheat exchanger(HE3);(3)TheCoolingCoil(CC)witha capacity of7.5kW;(4)TheHeatingCoil(HC)witha capacity of12kW;(5)TheDesiccant Wheel (DW), thathasarotorofdiameterof0.7m,thicknessof0.2m,nominalrotationalspeed of12revolutionperhour;60%ofitsactiveareaiscrossedby theprocessair,40%by theregenerationair.Duringsummer,theAHUinteractswiththreeairstreams,eachone drawn from outside andwith nominal flow rate of800 m3/h, Fig.6:
Regeneration air is heated bytheHeatingCoil, HC, (1–5) to regenerate the DW(5–6); then itis exhausted to outside;
Coolingairiscooledandhumidifiedinan EV(1–7)andthenflowsthrougha cross-flowheatexchanger (HE3) toprecooltheprocessair(7–8); thenitis exhausted to outside;
Processairisdehumidified by DW,whichreducesspecificmoistureandraises itstemperature (1–2);toensurethermoshygrometriccomfortconditionsinthe ConditionedSpace(CS), theairflowisthencooledin thecross-flowheat exchanger, HE3, (2–3) and in theCoolingCoil, CC, (3–4). [2]

Obviously,during the wintersomemodificationshavebeenintroduced,becausethe systemwasdesignedtooperateinthecooling periodonly.Inparticular,asshownin Fig.7,theDWisbypassed;twoductsoftheAHUareemployed,onefortheprocessair andthesecondonefortherecovery air;thislatterisdrawnfromthebuildingandin summer flowsthroughthe ductof thecoolingair.Inaddition,insuchperiodthe regenerationairfan andtheEVinthecoolingairductofFig.1areswitchedoff,and an EV and aheating coil(HC2) areadded in theprocess airduct. Inthiscase,theprocessesofthetwoairstreams,ataratedflowrateof800 m3/h,areas follows:
Therecoveryairisdrawnfromthe CS,thenitflowsthroughtheHE3topre-heat the process air (6–7);
Theprocessairispre-heatedinthecross-flowheatexchanger,HE3,(1–2)and inthefirstheatingcoil,HC1,(2–3),humidified(3–4)andthenpost-heated(4–5) and fed to theCS. [4]

The main components of the geothermal system are:
GW:GeothermalWell,equippedwithanU-shapedDHHE,modelledastwo heatexchangers linked througha pipeanda submergedgeothermalfluidpump (P1).
ACH: asingle-effect 30kWfLiBr-H2Oabsorption chiller.
DHHE: DownholeHeat exchanger.
HE1: plate fin heatexchanger supplying geothermal heat to the ACH.
AHU: desiccant-based Air Handling Unit.
DHW: plate fin heat exchanger producingDomesticHot Water(DHW).
HE2: plate fin heatexchanger supplying cooling energyto theACH.
P1: geothermalfluid pump forwellExtraction.
P2: variablespeed pumps forthe DHHE.
P3: constant speed waterpumps fortheCoolingCoilCC (not activein winter).
P4:constantspeedpumpsforabsorptionchillercooling(primary circuitofHE2– notactivein thewinteroperation mode).
P5:constantspeedpumpsforabsorptionchillercooling(HE2– notactiveinthe winteroperation mode).
M: Mixer.
D: Diverter.
ThemainloopsmadeupfromcouplingbetweenAHUandgeothermalsystemare follows:
HWA:Hot WaterAbsorption,hotwaterflowing betweentheabsorptionchiller(ACH) and the heat exchanger HE1, supplied bygeothermal fluid.
CSW:CoolingSeaWater,seawatercoolingtheabsorberandthecondenserof the ACH cooling (bymeans of theHE2).
HWHE: Hot fluid,flowing intothe Downhole HeatExchanger (DHHE), consistingof hot water supplyingthe HC.
HWHE: Hot fluid,flowing intothe Downhole Heat Exchanger (DHHE), consistingof hot water supplyingthe HC.
ACW:AbsorptionChilled Water, consistingofwaterfromtheACH,usedto feed the CC inthe summeroperation mode.
AHPW:AbsorptionHeat Pump Water, consistingof coolingwaterflowing from absorber to the cooling coil.

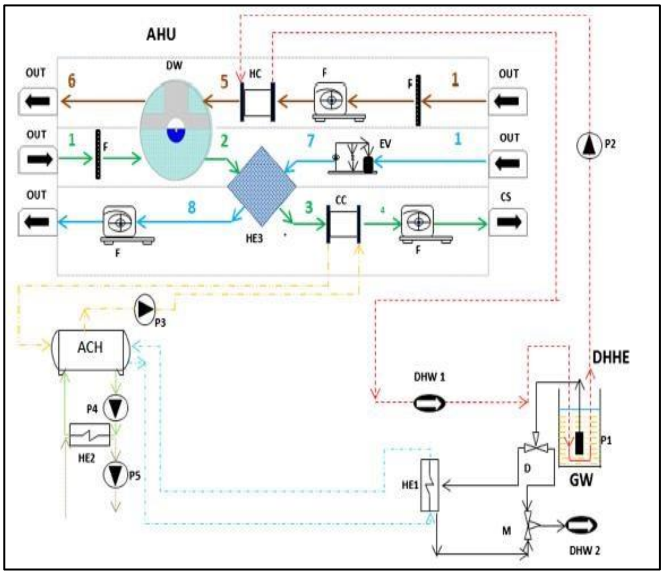

Fig.5. System layout duringsummerperiod.

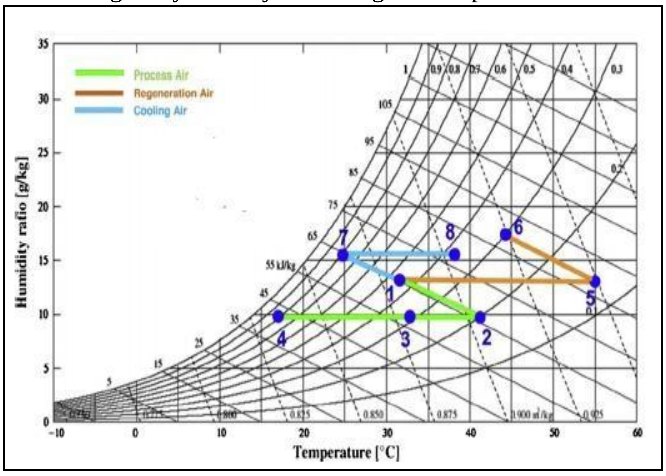

Fig.6. Psychrometric chart.

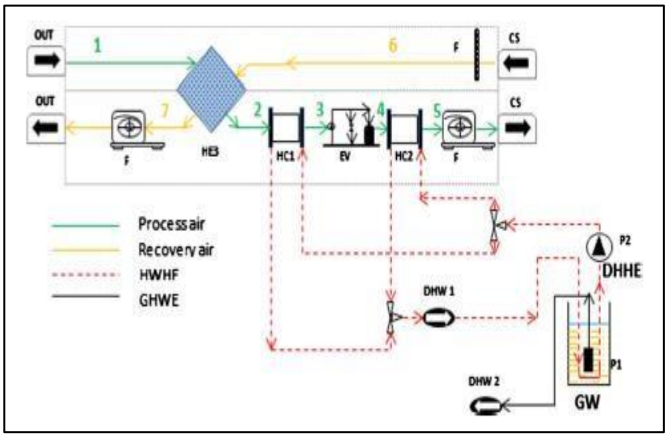

Fig.7. System layout duringwinterperiod.

Thecontrolstrategiescanbesummarizedasfollows.Inbothsummerandwinter periods,waterfromtheDHHEisusedforsupplyingHCforheatingtheregeneration air, and the remainingthermal energysupplied byDHHEis used to produceDomestic HotWater(DHW1)onthereturnlineoftheHC.Obviously,duringthewinter,DWis notnecessary because theprocess airhasto be humidified and consequentlytheoperation of

GWHEisslightlydifferentin the two periods. Indeed, as can beseen inFigs.5 and7,diverterDdivertsthe geothermal fluidtoHE1forthe ACH activationduring cooling periodorto mixer M during heating period. Theoutlet geothermal fluid fromHE1(summer) andfrom geothermal well (winter)is collected by mixerMfor producingDomesticHot Water(DHW2). [1]
Theoperationofsubmergedgeothermalfluidpumpisnotstrictly requiredforheating purposesinthewinter period.However,a certain amountofgeothermalfluidmustbe continuously extracted inordertocontrol welltemperature.Therefore, GHWE is managed by afeedback controllerwhichturnsontheGHWEpump(P1)ifthe geothermalwelltemperatureis lower thanthe setpointvalue (80°C).

5. EXPERIMENTAL STUDIES

Several researchers have usedtheground heatexchangerasasource or sink.The parameterslike pipe material,lengthof pipe,diameter of pipe,spacingbetweenpipes, numberofpipes,soiltype,depthofburialandairflowratearemainly consideredfor properdesigningof effectivethissystem. Thissystemmainlyfindstheir applicationsin green-houses,livestockhouses,commercialandresidentialbuildings ,andfor space conditioning.
Goswamiconstructedhisexperimentalstudy attheUniversity ofFlorida.The experimentalsetupconsistedofa30.5mlong PVCpipeburiedatadepth2.75mand havingadiameterof300mm.A2000Wblowerisusedfor transportingtheairinan openloopsystem.Fromthisstudyitwassuggestedthat30mmdiameterforsinglepipe and200–250mmdiameterformultiplepipescouldbesuitableforachieving optimum performance.Also,itwasobservedthatpipeshaving smallerdiameterprovidedhigher temperaturedrop, but consumption offan power is higher.
Dubeypresentedtheearthairheatexchangersystem'sresultwithpipesinparallelatBhopal,India.Experimentalsetupconsistsofthreenumbersof GIpipeseachoflength3mandhaving 0.064mminternaldiameter,allthreepipesareconnectedinparallelto commonintake andexhaust.Authorspredictsthatthe temperature difference ofairat theinletandoutletsectionofthesystemvariedfrom8.6to4.18°C,whentheairvelocityvariesfrom4.1–11.6m/s and COPvariesfrom6.4 to 3.6.Thus, it wasobservedthatat lower air velocitiesresults higher temperaturedrop and COP.[1]

Studies conductedbyvarious researchers thatmaterial ofpipedid notaffect the performanceofsystem.BansalconductedhisexperimentatAjmerinIndia, the experimentalsetupconsistsoftwohorizontalcylindricalpipes eachof150mmdiameter andhavingaburiedlengthanddepthof23.42mand2.7m.Onecylindricalpipeismade upofpolyvinylchloride(PVC)whiletheotherismade upofgalvanizedsteel.The experimentalresultsshowthattheperformanceofthe systemwasnotaffected by the materialoftheburiedpipeforsummerandwinterasshowninTable1.However,thecost of the project was higher by20-25%ifgalvanized steel is used.

Sr. no.	Air flow velocity (m/s)	Temperature (k)	Winter heating(k)		Summer cooling(k)	
			PVC pipe	Galvanized steel	PVC pipe	Galvanized steel
1	2	Tin	293.6	293.6	316.3	316.7
		Tout	298.1	298.4	306.1	304
		Tin-Tout	4.8	4.8	10.2	12.4
2	3	Tin	293.6	293.6	315.5	316.5
		Tout	297.7	298.1	306.1	305
		Tin-Tout	4.1	4.5	9.3	11.5
3	4	Tin	293.6	293.6	315.3	316.1
		Tout	297.3	297.9	306.5	305.5
		Tin-Tout	3.7	4.3	8.8	10.6
4	5	Tin	293.6	293.6	315.2	316.6
		Tout	297.2	297.7	307.2	306.7
		Tin-Tout	3.6	4.1	8	9.9

Table 1. Comparison ofgalvanized steel and PVC pipe.

InthehotanddryconditionsofNewDelhi,thesystemcooledthe roomby276K.While duringcoldclimaticconditions,thesystemheatedtheroomby279.5Kmoreincomparisonwithnormalconditions.However,the roomwithcrossventilationgave significantlylower temperaturethan untreated rooms inthe absenceof sunshine during summerorpeaksunshineduringwinter.Thus,propermodificationlikecrossventilation, wallconfiguration, earth's surface etc.enhancetheperformanceofsystem.
Sodhaconductedtheexperimentaleffectsofvariousearthsurfacetreatmentsonthermal performanceof EATHEsystemfora coupledroominIndia. Earth'ssurfacetreatment wasconducted by shadingandwetting.Itwaspredictedthatearthsurfacetreatments couldconserve hugeamountofenergy.WhileLietal.testedhisexperimentalsetupat China. Itwasfoundthat geographicalandclimaticconditions affecttheperformanceof earth to air heat exchanger.

6. ANALYTICAL STUDIES OFMODELS

Alotofresearchhasbeendonetodevelopanalyticalandnumericalmodelsforanalysis ofsystemmodels.Anumberofcomputersmodellingtoolsarecommercially available. Energy PlusandTRNSYShavesystemmodulesthatworkwell;however,theseare analysistoolsandarenotquickly usedfordesign.Presently,computationalfluid dynamics(CFD)isverypopularamongresearchersformodelling andperformance analysisofsystemsbecausetheCFDemploysaverysimplerule ofdiscretizationofthe wholesysteminsmallgridsandgoverningequationsappliedon thesediscreteelements togetnumericalsolutionsconcerning lowparameters,pressuredistributionand temperature gradientsinlesstime andatreasonable costbecause of reducedrequired experimental work.

7. DESIGNPARAMETERS

a. Pipedepth

Inearthairheatexchanger,thedepthofthetubesisan important considerationandtubesareplacedata distancewheretemperatureof soilis undistributed.Asperthereseresearchesthetemperatureofearthfluctuateswithtime, buttheamplitudeoffluctuationdiminisheswhilewemovedownwardtheearth's surface.Itwasstudiedthattubesshouldbeburiedatleast1.5mbelowthegrade, butmorethan3.5mdepthdoesnotvarytheearth'stemperature. Thetubedepthisalsoinfluencedbythesurfaceconditionsofsoil whetherthesurfaceisexposed to sunlight or covered with trees andgrass.

b. Pipe length,diameterandair flowrate

Theimportantfactorfor overall heating/cooling ofearthairheatexchangerisitstotalsurfaceareaandthis parametercan beincreased by eitherincreasingthediameterofpipe or by increasing thelengthofpipe.However,theincreaseindiameterreducesthe air speedandlongerlengthincreasesthepressure drop.Thus,foroptimizeddesign of earthairheatexchanger setof parallelpipeshasbeenusedfor itsbest performance.Optimumdiameterforanearthairheatexchanger varieswithpipe length,pipecost,flowvelocityandvolumeofpipe.Generally,diameterbetween150mm-450 mmare thebestandmostappropriatefortheoptimumdesign. Diameterofearthairheatexchanger'spipeshouldbeselectedthatitcanbalance the thermal and economical factor for thebest performance at the low cost.

c. Pipematerial

Themajorconsiderationforselectinganearthairheatexchanger isselecting thematerialofpipe,pipecost,corrosionresistanceanddurability. Pipesmade ofconcrete,metal,plasticetc.andsimulationsinpreviousstudies indicatesthatpipematerialhaslittleinfluence ontheperformanceofearthair heatexchanger.Astudy ontwo earthpipes;oneisPVCpipeandotherismetal pipeby AbramsandBojicetal.They investigatethatPVCpipeperformssame assteelpipefor samedimensions,thus theuseof PVCis morebeneficial becausethesepipesareeasy toinstall,cheapaswellasmorecorrosion resistance.

d. Pipearrangement

Pipearrangementisalsothe crucialparametertomeetthe heating/cooling demandsofabuilding.Sinceairthroughonepipeisnot enoughtomeettheloadrequirementthusoneormorethanonepipesaretobe buriedinthegroundtomeetthebuildingloadrequirements.Topreventeffect of neighboringpipes distancebetween the pipes shouldbe1 meter.

e. Moisture

Astudyonthepossibility ofwaterbycondensationinsidethepipes isinvestigated by Abrams.Ifthetemperature ofinner wallofthepipeislower thantheDPT ofairthencondensationwilloccur,furthermore it dependson humidity andtemperatureofair.AssuggestedbyGoswamicondensation will observedathighDBTandlowairflow rate. Since the earthairheatexchanger maynotabletoremovethemoisturefromtheairthusitmay beusedin combination with desiccant or an air conditioner.

f. Indoorairquality

Thecomfortofhumanbodyisdeterminedbytheindoorair qualityandrelativehumidity.Moistureinsidethepipescanbeasourceofmould aswellascanaffecttheindoorairquality andresponsibleforallergicreactions or respiratoryproblemsforhumanbeings.Good constructionandproperdrainagecouldeliminatecondensation.Toavoidwateraccumulatinginthepipes undergroundpipesaretilted at an angle of1°.

g. Insectsorbirds

Insectsorbirdsmay enterthepipesofanopenloopearthair heat exchanger, toavoid thisgrill and bird screento be installed at pipeinlet.

8. OTHERFACTORS AFFECTINGGEOTHERMAL SYSTEM

Fordesigningofearthairheatexchangersystempositiveandnegativeaspectsthat influencethe performanceof EATHEsystemare:

The soil temperature is governed by the climatic conditions throughout the year.During summer surface temperature can be reduced by adopting processes like shading, wetted surface with spray water or by growing grass over the surface etc.

Soil composition also plays avital roleto enhance the performancethe earth air heat. Vegetation for heating but is lower for cooling. Soil must be packed densely around the tube to increase the heat exchange rate, generally compacted clay or sand is recommended.

Position of pipes beneath the earth's surface also plays an important role to analyses the performance of EATHE. An increase in soil depth above the tube surface enhances the system's heating/cooling potential. However, it is concluded that optimum depth is 3 m for earth air heat exchanger.

Parameters like tube length, diameter and spacing between the tubes also plays the key role for earth air heat exchanger performance enhancement. Generally optimum value for length of tube is 70 m, typical diameter for tubes is 0.1-0.3 m and spacing between the tubes beneath thesoil surfaceis 1m. Tube material has a very little impact on the performance of EATHE system.Differentthermalconductivitiesofmaterialhardlyinfluencetheheatexchange rate.

Numberofpipesdepends ontheamountofairflowrequirement.Anincreasein air flow in thetube tendsto a slight decreasein outlet air temperature.Seasonalimpactslikesummer,monsoonand winterarekeyparameters forheat exchange rate. And itisconcludedthatheatexchange isabout1.3times higher on summerthan winter.Also,executionofearthairheatexchangerinWesternHimalayanregionhasa positiveimpactforspace heating.IfweexecuteEATHEinthisregionthen definitelytherewillbe performanceenhance.

9. CONCLUSION

The resultsofthesimulationsshowthattheproposednovelgeothermalheatingand coolingsystemcanbeextremely profitableintermsofenergyandeconomic performance. Theperformanceofthesystemisgreatlyaffectedbythecapacity ofthegeothermalwell (i.e.:thenominalflowrateextractedfromthewell).Conversely, intherange90–100°C, the variation ofthetemperatureof thegeothermalfluid does not significantlyaffectthe performanceof the system.Obviously,whenthe temperature ofthe wellisevenlower than90°C,theproposed systemmay beunfeasible,sincegeothermaltemperaturewill benothighenoughtoeffectively drivetheabsorptionchiller.Finally,thesensitivity analysisshowedthatsystemprofitabilityisdramaticallyaffectedbythevalueofnatural gascost.Thisparameterismuchmoreimportantthanthecostofelectricity.Obviously, systemeconomicprofitability improvesincaseofhighernaturalgasandelectricity costs. Futuredevelopmentsofthisworkwillincludeadetailedtransientexergyanalysisofthe system.Inparticular,detailedunsteadyexergy balanceswillbeconsideredinorderto calculatethemagnitudeofirreversibilitywithinthecomponentsandtoevaluatepossible strategiesinordertoreducethem.Then,theresultsprovidedbytheexergyanalysiswill becoupledwiththeeconomicones,in order toperformamulti-criteriaoptimization in whichtheminimizationofirreversibility andthemaximizationoftheeconomic profitabilityof thesystem will be considered.

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