ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Analysis of Geothermal Heating System for Buildings

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Abstract

One-third of the world energy utilization is for space heating and cooling. Steady increase in the prices of sources of energy and electricity has resulted in more and more use of alternate sources of energy such as geothermal energy for heating and cooling. Maximum heat loss from the building and water flow rate are for the month of January. The value of maximum heat loss is 3.41 kW and that for water flow rate is 0.84 m3/h respectively. The maximum savings in terms of value and energy by using the geothermal heating system are again for the month of January in terms of energy 1038 units of electricity and in terms of value Rs. 5191 respectively. Total savings for the winter season in terms of energy are 2983 units of electricity and in terms of value are Rs. 14915.

Keywords: Geothermal energy, Reynolds's number, heating load.

Introduction

Almost 30% of total world energy consumption is utilized for space heating and cooling [1]. Steady escalation in the prices of conventional fuels and electricity has resulted in search for renewable forms of energy. Geothermal energy is one such form of renewable energy which can be used for heating the buildings and energy can be saved. Geothermal form of energy comes from the heat retained in the earth since the original creation of the planet, radioactive decay of minerals, and solar energy captivated at the surface. Every day and yearly temperature variations go into the earth to depths of about 1, 20 m respectively [3, 4], earth temperature remains almost constant about 10°C to 16°C underneath a depth of 6 ft. [1]. This information is used for space heating such as residential buildings or offices. Big underground heat exchanger can be utilized for adding heat to the buildings. Geothermal form of energy contributes merely a fraction of the electricity production in the United States and estimates are that increase will be marginal by 2035 [5]. About 270 PJ of geothermal form of energy was utilized for direct heating in 2004 by about seventy countries [2]. High thermal efficiency is obtainable in geothermal heating as no energy conversion is required. Payback time is less than five years and at times less than two years. Low CO_2 emission leads to lowest amount of greenhouse warming impact. Design of geothermal heating unit needs the familiarity with heat transfer, place geology and availability of land area is too one of the factors [6]. Winters are very cold in India and especially in Punjab. So heating of the buildings is a necessity. The minimum temperature in Punjab reaches 4°C in winters.

The present work is the analysis of the geothermal heating unit for a home situated in Punjab and to approximate the savings in terms of value and energy. The temperature of the atmosphere and room temperature were measured and various other parameters like flow rate of water, savings in terms of energy and savings in terms of value were computed.

Geothermal Heating Systems

A sketch of the geothermal heating unit for the home is shown in Fig. 1. The sketch comprises of GI pipes implanted in the roof of the home, water pump and linked to the building by a distribution unit and the unit exchanges heat with the ground. Underground heat exchanger made of GI pipes is used for exchanging heat.

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Impact Factor: 1.852

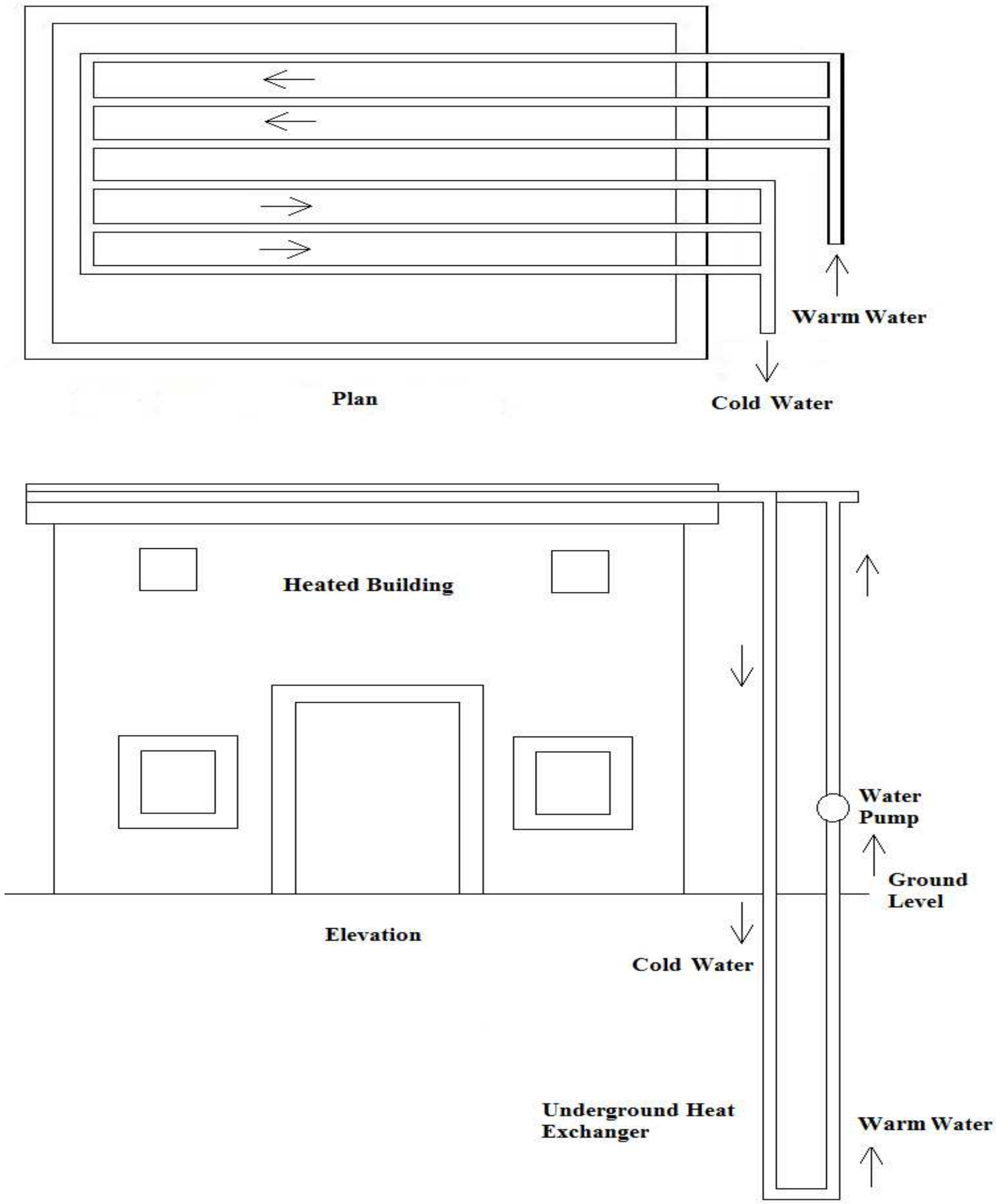

Fig. 1. Schematics of winter heated building using geothermal unit

Specifications of the single storey home (Table 1.) analyzed for heating and the properties of Galvanized Iron pipe and water (Table 2.) are given below: -

Table 1. Specification of the home

Length (m)	6.70
Breadth(m)	4.57
Height (m)	3.35
Roof area(m^2)	30.62

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Table 2. Material and working fluid properties

Density of water (kg/m^3)	1000
Specific heat of water (MJ/m^{3}K)	4.1813
Pipe material	GI
Thermal conductivity of pipe (W/m-k)	75.31
Internal diameter of pipe (in)	1

In winters when the ambient temperature of the building falls below that of the ground the heating water takes heat from the earth and transfers it to the building through pipes with the help of water pump and an underground heat exchanger positioned at a depth where the seasonal effect goes.

Methodology

Main source of heat loss from a home in winters is the roof. Therefore an arrangement of GI pipes can be used in the roof. The heat will be provided through roof by heating water circulated in GI pipes arrangement. Water flow can be maintained with the help of a water pump. Various parameters are calculated using the formulae given below: -

Sensible heat loss	(Q_s)	$= (T_r - T_o)/(R_t * 10^6)$	MJ/s
Heat added by water	(Q_w)	$= c_{pw} * (T_c - T_w) * \varepsilon_r * \varepsilon_g$	MJ/m^3
Flow rate of water	(Q_f)	$= (Q_s * 3600)/Q_w$	m^3/h
Darcy friction factor	(f)	$1/\sqrt{f} = -1.8 \log_{10}((\varepsilon/D)/3.7)^{1.1} + 6.9/Re$	
Head loss due to friction	(h_f)	$= f * L * V^2/(D*2g)$	m
Head	(h)	$= p_w/(\rho_w * g) + V^2/2g + Z + h_f$	m
Power input	(P)	$= Q_w * \rho_w * g * h/(3.6*10^6 * \eta_{pump})$	kW
Electric energy input/day	(E)	$= P * n$	kWh

Results and Discussions

Maximum heat loss by the building is in the month of January (Fig. 2.) as the minimum atmospheric temperature is for the month of January. The maximum water flow rate (Fig. 3.) through the pipes is also for the month of January as the maximum heat loss rate is for January. The utilization of electricity (Fig.4) increased from November to January and then decreased for both geothermal and vapour compression system as heat loss by the building increased upto January and then decreased. The comparison tells that the energy utilized in case of geothermal cooling unit is much less because it utilizes water as working substance. The water can transfer more heat because of higher heat capacity. The savings in terms of value and in terms of energy for geothermal cooling system are shown in Fig. 5 & Fig. 6. The savings in terms of money and in terms of energy are highest for the month of January as maximum heating load is for the said month; therefore more energy is consumed in vapour compression unit. A pipe of 3 m length underneath ground where the seasonal effect goes is sufficient for transferring the heat to the ground for all months.

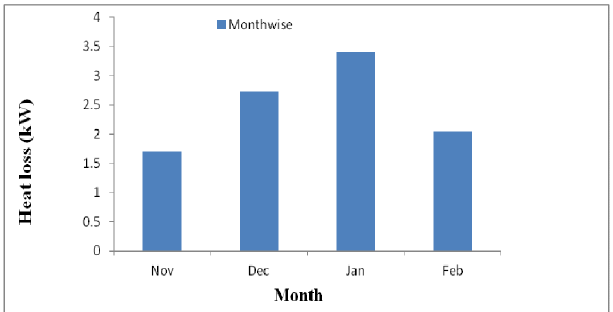

Fig. 2 Monthwise heat loss rate from the building

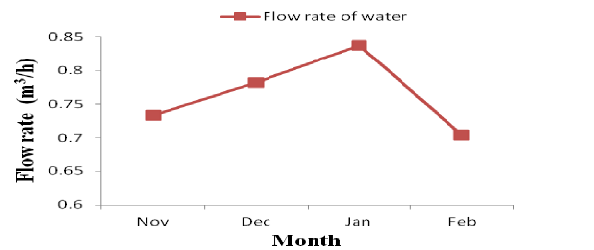

Fig. 3 Flow rate of water in geothermal unit

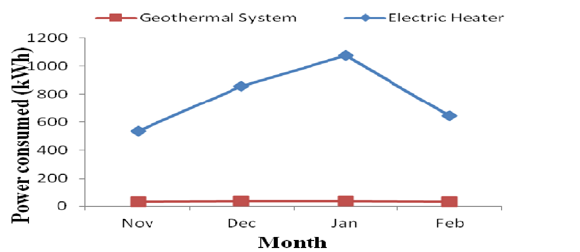

Fig. 4 Monthwise electricity consumption

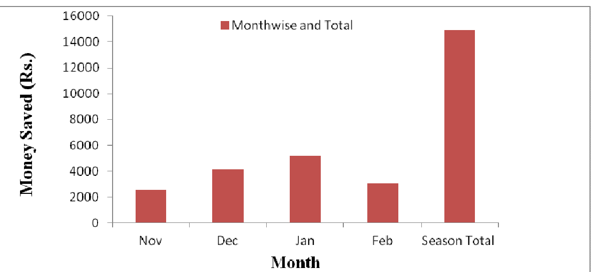

Fig. 5 Monthwise and total money saved

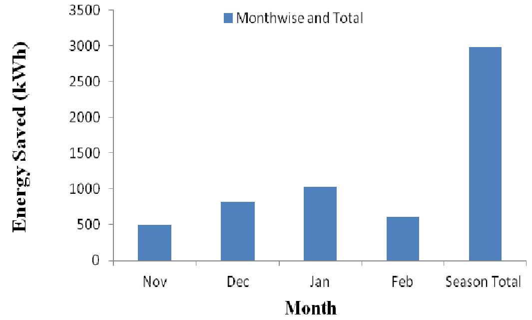

Fig. 6 Monthwise and total energy saved

Conclusions

Geothermal heating unit is very efficient and inexpensive method of heating the buildings. Maximum heat loss from the buildings and the maximum water flow rate in the pipe are in the month of January. The power consumption is less in case of geothermal heating system. Maximum savings are in the month of January in terms of value and energy. In terms of value and energy the maximum savings are Rs. 5191 and 1038 kWh respectively. Total savings for the winter season in terms of energy are 2983 units of electricity and in terms of value are Rs. 14915.

Abbreviations

T_r	=	Room temperature
T_o	=	Outside atmospheric temperature
R_t	=	Total resistance of brick and concrete roof
C_{pw}	=	Specific heat of water
D	=	Internal diameter of the pipe
I	=	Insolation
L	=	Length of the pipe
n	=	Number of hours.
η_{pump}	=	Pump efficiency
p_w	=	Pressure of water
Re	=	Reynolds number
T_c (roof/wall)	=	Temperature of the concrete
T_w	=	Temperature of the water
V	=	Velocity of water
Z	=	Datum head.
ε/D	=	Relative roughness
ε_g	=	Heat exchanger efficiency in the ground
ε_r	=	Heat exchanger efficiency at roof
ρ_w	=	Density of water

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