IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Analysis of Geothermal Cooling System For Buildings.

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Abstract

Energy used for space heating and cooling accounts for almost one-third of world energy consumption. Escalation in the prices of fuels and electricity cost has led to the use of alternate energy sources like geothermal energy to be used for heating and cooling. Maximum heat gain and flow rate of water is for the month of May. Maximum heat gain and flow rate of water are 17.88 kJ/s and 3.62 m^3/h respectively. The maximum savings in terms of energy and value by using the geothermal cooling system are again for the month of May, in terms of energy 692 units of electricity and in terms of value Rs. 3742 respectively.

Keywords: Geothermal energy, Insolation, Reynolds's number, cooling load.

Introduction

Around 30% of total energy consumption of the world is used for space heating and cooling [1]. Escalation in the prices of electricity and conventional fuels has led to the search for non conventional forms of renewable energy.

Geothermal energy is one such option which can be used for cooling the buildings for saving energy. Geothermal energy originates from the heat retained within the earth since the original formation of the planet, from radioactive decay of minerals, and from solar energy absorbed at the surface. Daily and annual temperature variations penetrate into the ground to depths of approximately 1, 20 m respectively [2, 3], soil temperature remains nearly constant around 10°C to 16°C below a depth of 6 ft. [1]. This fact can be used for space heating or cooling such as offices or residential houses. Large underground heat exchanger can be used for removing heat from the building. Geothermal energy contributes only a fraction of the electricity generation in the United States and projections are that it will increase marginally by 2035 [7]. Approximately 270 PJ of geothermal energy was used for direct heating in 2004 by around seventy countries [4]. Thermal efficiency is high in geothermal heating since no energy conversion is needed. Paybacks period is less than five years or sometimes less than two years. The low CO_2 emissions lead to minimum greenhouse warming impact. The design of geothermal cooling system requires the knowledge of heat transfer, the geology of the place and availability of space is also one of the factors [5]. Summers are very hot in India and especially in Punjab. So cooling of the buildings is a necessity. Average insolation in Punjab for the months of May, June, July, August and September is 7, 6.6, 6.3, 5.5, 5.3 kWh/m^2/day respectively [6].

The present work is to analyze the geothermal cooling unit for a house situated in Punjab and to estimate the savings in terms of energy and value. Insolation for each month was taken from literature available [6]. The various other parameters like flow rate of water, savings in terms of energy and savings in terms of value were computed.

Geothermal Cooling Systems

The schematic sketch of the geothermal cooling system for a house is shown in Fig. 1. It consists of GI pipes embedded in the roof of the house, hydraulic pump and connected to the building by a distribution system and the system exchanges heat with the earth with the help of an underground heat exchanger made of GI pipes.

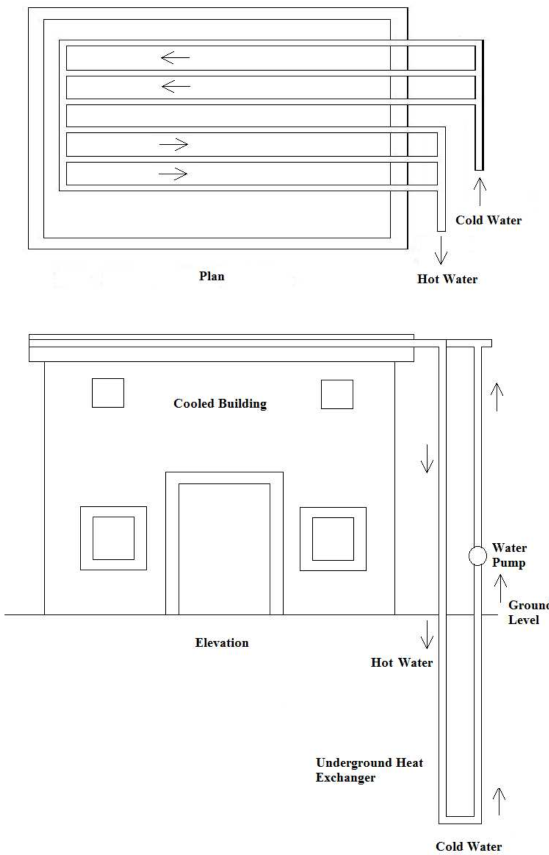

Fig.1 Schematics of summer cooled building using geothermal unit

The specifications of the single storey house (Table 1.) analyzed for cooling and the properties of GI pipe and water (Table 2.) are given below: -

Table 1. Specification of the house

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

Table 2. Properties of the material and working fluid

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

In summers when the ambient temperature of the building exceeds that of the ground the cooling water takes heat from the building and transfers it to the ground through narrow pipes with the help of liquid pumps and the heat is dissipated in the earth with the help of underground heat exchanger placed at a depth where the seasonal effect goes.

Methodology

Main source of heat inflow to a house in summers is the roof. So a network of GI pipes can be provided in the roof. The heat from the roof will be taken away by cooling water circulated in GI pipes network. Water circulation can be maintained by means of a hydraulic pump. The formulae for calculating various parameters are given below: -

Sensible heat gain	(Q_s)	$= I * (A_w * 2 + A_r) / (24 * 1000)$	MJ/s
Heat removed 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

 ISSN: 2277-9655

Results and Discussions

Maximum heat gain by the building is in the month of May (Fig. 2.) and decreases each month because the insolation is maximum for the month of May. The flow rate of water (Fig. 3.) circulated through the pipes decreased from May to September as the cooling load decreases every month. The electricity consumption (Fig.4) decreased from May to September for both geothermal and vapour compression unit as heat gain by the building decreased each month. The comparison shows that the energy consumed is much less in case of geothermal cooling because it uses water as working substance which can transfer more heat due to higher heat capacity. The savings for geothermal cooling unit in terms of energy and in terms of value are shown in Fig. 5 & Fig. 6. The savings in terms of energy and in terms of money are maximum for the month of May because cooling load is maximum for this month so more energy is consumed which accounts for higher value in case of vapour compression unit. 3 m length of the pipe below ground where the seasonal variations go is sufficient to transfer the heat to the ground for all months.

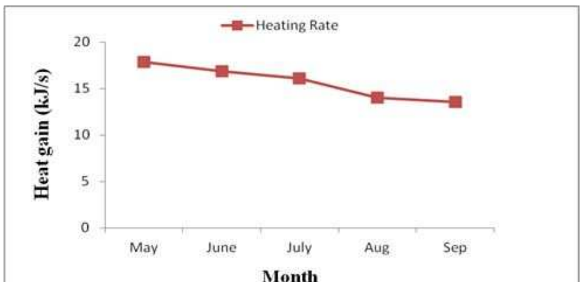

Fig. 2. Heat gain by the building

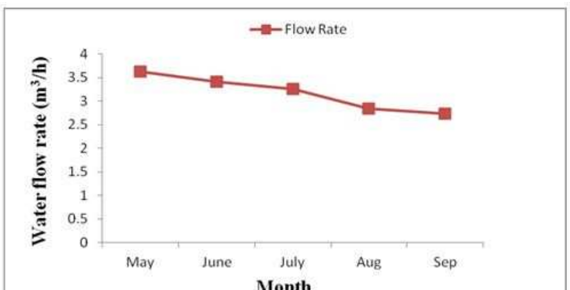

Fig. 3. Flow rate in geothermal unit

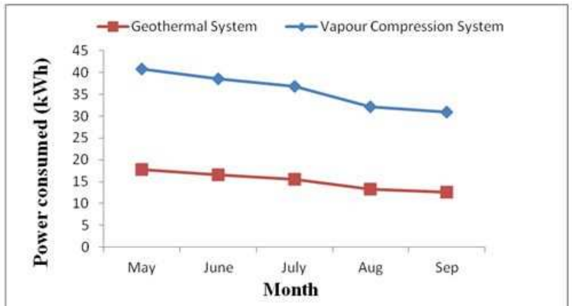

Fig. 4. Electricity consumption per day.

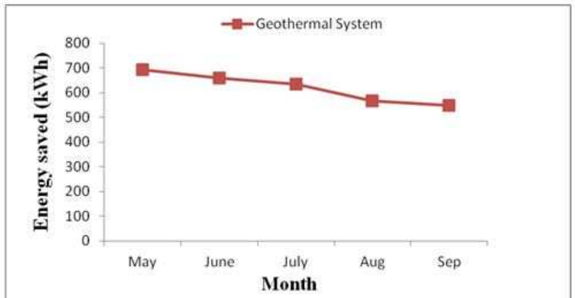

Fig. 5. Energy saved per month

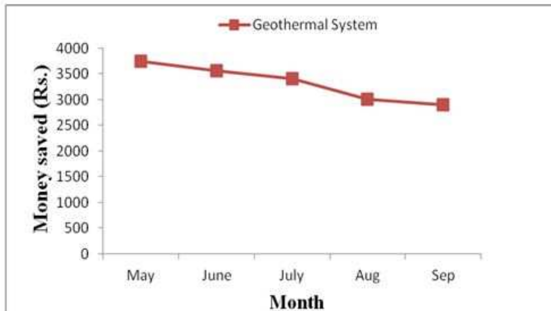

Fig.6. Savings in terms of money per month

Conclusions

Geothermal cooling system is very efficient and economical method of cooling the buildings. Maximum heat gain by the building and the flow rate of water through the pipe are for the month of May. The energy consumed is less in case of geothermal cooling unit. Maximum savings are obtained for the month of May in terms of energy and value. The maximum savings in terms of energy are 692 kWh of electricity and in terms of value Rs. 3742.

Abbreviations

I	=	Insolation
Ar	=	Area of the roof
Aw	=	Area of the wall
C_{pw}	=	Specific heat of water

T_c = Temperature of the concrete (roof/wall)
T_w = Temperature of the water
ε_r = Heat exchanger efficiency at roof
ε_g = Heat exchanger efficiency in the ground
ε/D = Relative roughness
D = Internal diameter of the pipe
Re = Reynolds number
L = Length of the pipe
V = Velocity of water
ρ_w = Density of water
p_w = Pressure of water
Z = Datum head.
η_{pump} = Pump efficiency
n = Number of hours.

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