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Scope and Implementation of Ground Source Heat Extraction Technology in India for Multiple Energy Saving Applications

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ABSTRACT

India is a country of diverse geography comprising the world's highest mountain ranges to large plains, peninsular plateau, deserts and coastal areas, where climatic conditions are highly variable and extreme. Therefore, both heating and cooling are essential requirements for the inhabitants throughout the year, and in this perspective, it is envisaged that there is tremendous scope of ground heat extraction technology in India for multiple energy saving applications. Present work deal with the implementation of a ground source heat pump system, installed at one of the SASE establishment near Manali (HP) in India, and its performance evaluation towards energy saving purposes along with reduction in GHG emissions. Prior to the design of the GSHP system, a geothermal investigation of the project site was carried out. Our study revealed that relatively a higher geothermal heat flux is present in this region as compared to its reported global average value, which may likely be due to the proximity of the project site to the tectonic fault line passing across. Through drilling of a test bore hole of depth more than 100 m, the geological strata of the site shows a heterogeneous formation which was composed of small pebbles of granite, dolomite, shale and sand. The test bore hole thermal test indicates higher values of thermal conductivity relative to their documented values for above geological structures. For erection of the ground source heat exchanger, vertical U-bent closed loop comprising nearly 5200 m long HDPE/MDPE pipe networks inserted into 27 numbers of boreholes (dia. 125 mm, with total running depths more than 2500 m), is coupled to a 100 kW capacity GHP system. In this work, the antifreeze fluid is prepared using mono ethylene glycol (by 25% with water) for ground loop circuit; however, refrigerant R410a is used in GHP loop. An intermediate heat exchanger is coupled to the existing central heating plant to transfer the heat from GHP to user load side. After installation of the complete GSHP based system, its performance was evaluated in terms of energy saving. Our results show that the CoP thus achieved is about to 3.1 for peak loading of 100 kW, yielding an energy saving up to 67%. Further, during peak winter load of the existing heating plant, the GHG emission has reduced significantly. This pilot study has opened new fronts of geothermal energy in India to provide a significant energy saving as well as environmental protection.

1. INTRODUCTION

India is a land of diverse geography of varied topographical features such as highest mountain ranges of Himalaya, large Gangetic plains, peninsular plateau, coastal plains and hot desert of 'Thar' to cold desert of 'Laddhakh' region India is situated between the latitudes 804' and 3706' N and longitudes 6807' and 97025' E and it has a total covered area of 3.167 million square kilometres. Indian climatology is highly variable analogous to that manifested by its geography itself. India is seventh largest country in the world, however, it is second most populated country in the world after China, therefore for comfort dwelling requirements India has a large scope of efficient heating and cooling technologies. In this context ground source heat extraction (or rejection) techniques, providing substantial energy savings, can find wide potential applications in Indian conditions which include space heating, air conditioning, refrigeration, cooking, distillation, drying, spa, fishing, water sports, etc. According to recent report of MNRE (Ministry of New and Renewable Energy, India, Dec 2013) the total energy produced by renewable energy sector in India constituting nearly 12% of total energy produced and it has now increased up to 29.989 GW of energy. Under renewable energy sector wind energy alone contributes nearly 67.18% of total renewable energy while small hydro and solar PV contribute nearly 12.55% and 7.26% of total renewable energy in India, respectively. Remaining 13.1% of renewable energy is harvested from small biomass, bagasse co generation and bio waste. But surprisingly the proportion of geothermal energy in India is negligible as of now in its gross renewable energy production.

If we glance into the geothermal provinces of India, there are over 300 geothermal active locations as identified by various agencies such as Geological Survey of India (Razdan, et al., 2008) which mainly fall in orogenic (Himalayan) and non-orogenic (Peninsular) provinces. Razdan et al. (2008) has reported that Indian geothermal areas either comes under medium enthalpy (100^0C – 200^0C) or under low enthalpy (<100^0C) geothermal resources. Due to relatively lower enthalpy of geothermal resources in India, the scope of geothermal power generation has been drastically limited, however, if we see the low grade applications of ground energy such as in the areas of space heating cum cooling, providing significant energy saving, it seems to have tremendous scope because Indian climatic conditions (in most part of the country) require both heating and cooling over the year. According to a rough estimate over 45000 GWh capacity of geothermal potential is unutilised in India (Razdan, et al. 2008; Kumar, et al. 2012, Gera et al. 2013) which needs to be harnessed not only to explore a reliable energy alternate to meet future energy crisis but also to save our environment. The Geothermal - ground heat extraction cum rejection technology is globally established one and currently being used by over 78 countries. But India is now going to register its entry into the world geothermal map. Since, this technology utilizes the moderate Earth temperatures, say between 10^0C to 20^0C and below a depth of 6 to 7 m from surface Earth's temperature remain almost constant throughout the year, irrespective of season or place. Therefore, in Indian context this technology should work almost everywhere.

This paper primarily emphasizes that how we can save a good amount of energy (carbon free) at small scales by utilizing free reserve of ground energy through demonstration of a 100kW ground source heat pump system, installed in the Himalayan region of India. In this work, mainly three issues are discussed - first the geothermal evaluation of the project site through drilling of a test borehole with depth > 100 m, installation of U-tube HDPE pipe, grouting and then the experimental estimation of thermal conductivity, thermal diffusivity and volumetric heat capacity. After collecting geological and thermal information of the formation design of 100 kW space heating system is discussed. Secondly, based on the first phase study, the GHP system for space heating cum cooling is installed and demonstrated for output load of 100 kW. This work could be completed through drilling of vertical boreholes with total running length >2500 m and erection of vertical-horizontal ground loop measuring > 5400 m. Thereafter installation of manifolds, electro-thermo fusion of joints/fittings, pressure/leak testing, grouting / backfilling, installation of ground source heat pump and its other accessories, control unit, circulating pump, etc. Thirdly, the measurement performance of GSHP system to yield stable output of 100 kW at preheated water temperature of 53^0C. Further, the performance of the system was also estimated in terms of electric power consumption and saving of diesel being burnt to provide heating by existing central heating plant to the adjacent dwellings at a rate i.e. 8 kW per dwelling. With this GSHP based heating system, 12 accommodations are being benefitted. At the same time the emission of carbon and other green house gases have significantly reduced up to 5%, during the burning of diesel by boiler of existing heating plant. This project has successfully demonstrated the ground source heat extraction technology in the cold environmental conditions of Indian Himalaya and it may find wide opportunity within India and also within other nations while utilizing this reliable, cost effective and green technology in a larger perspective not only to save energy but also to save our environment.

2. PROJECT SITE AND ITS CLIMATIC CONDITIONS

The project site is located near Manali (Himachal Pradesh) which fall at the foot hill of Pir-Panjal range of Indian Himalaya. This site is situated at latitude 32016'14.6'' N, longitude 77010'58.3'' E and altitude of 1998 m (mean sea level). This site falls within campus of Snow & Avalanche Study Establishment (SASE), Bahang in a plain riverbed of Beas (Fig.1 (a)). Because of its proximity to river Beas, it's geological structure is primarily composed of river pebbles and boulders. In the vicinity of the project site the tectonic fault line passes nearly 25 km away from is, however, few natural hot water springs are also located at places Vashishth, Klath and Manikaran where spring water temperatures at ground surface are observed from 70^0C to 100^0C. As a result of the nearby tectonic fault line the relatively higher geothermal heat flux can be assumed in this region, however, in our measurements there is no effect of fault line and hot water springs in the geothermal structure of this project site. During winter this region receives good amount of snow and a winter view of the nearby dwellings is shown in Fig 1(b). The annual average maximum temperature in this area has been recorded up to 29^0C and annual average of minimum temperature has been recorded up to -5^0C. Figs. 2 (a & b) represent the annual max. and min. temperatures of the project site from year 2003 to 2010. The peak maximum temperature recorded so far is 34.3^0C and lowest minimum temperature up to -9.3^0C. The total snowfall in a season is recorded up to 193 cm, however, the annual total rainfall is 1668 mm. The past climatological data of the site has been collected by snow & meteorological observatory of SASE.

Figure 1: (a) Project site as marked within SASE campus at Manali (HP), India (b) The winter view of the dwellings in vicinity of the project site.

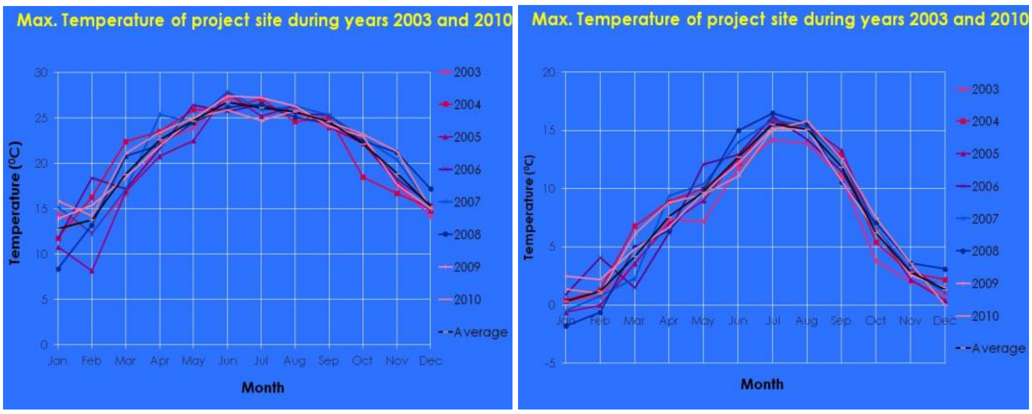

Figure 2: (a) Annual maximum temperature of the project site from year 2003 to 2010, (b) Annual minimum temperature of the project site from year 2003 to 2010 (Courtesy: Data centre SASE).

3. GEOTHERMAL INVESTIGATION OF SITE AND TEST BOREHOLE STUDY

The test borehole (TBH) study is quite essential work for design of a geothermal heating or cooling system because all design parameters depend on the geological structure and the thermal properties of a particular site. Therefore, in this work a test borehole was drilled and the geological samples of the drill log were recorded.

3.1 Drilling of Test Borehole

For design of a geothermal space heating system of output load 100 kW at temperature 50 ± 5^0C, the evaluation of geological strata and its thermal properties is quite essential. In this project the test borehole was drilled up to 102 m with its diameter 127 mm. The geological samples were collected with different depths and after analysis of the samples it was observed the geological structure is mainly composed of dolomite, shale, granite, sand and clay. There were small pebbles to big boulders in between but there is no hard rock found up to the depth of 102 m. Since the ground strata is loose therefore to prevent the borehole from collapsing the permanent MS-casing of 5 inch is provided up to full depth, however, to reach up to the depths beyond 70 m, additional temporary MS-casing of 7 inch was provided. After drilling of the TBH, the vertical U-bent HDPE pipes were inserted into the borehole up to full depth (total running length 210 m). The TBH was later grouted and backfilled using the mixture of bentonite and E-Z mud. Figure 3 (a) shows the on-going drilling work at the project site and the drilled borehole with casing and HDPE pipes (U-tube) inserted into the TBH. Further, to understand the geological strata of this site another boreholes were drilled nearby to the TBH and time was recorded during insertion of each segment of 20 ft long at a constant engine power of the rig. It was observed at a depth of 220 ft (67 m) to 310 ft (94 m) the machine has taken much more time as compared to other depths. It reveals that ground hardness and heterogeneity at depths of 67 m to 94 m depth is very high, hence to go upto depth of 100 m temporary casing would be essential at first top depth up to 30m. It would support to the drilling rig at depths below 67 m.

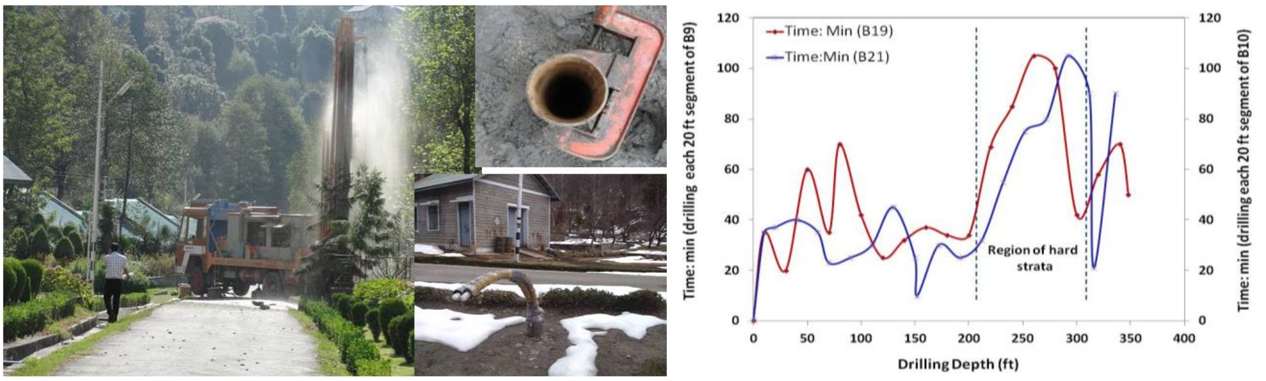

Figure 3: (a) Drilling of test borehole (TBH) on progress at the project site. The right side (top), the 5 inch MS-casing provided to the TBH and at right side (bottom) the TBH with HDPE pipe of vertical U-tube installed, (b) drill log of the nearby boreholes in terms of time taken by rig to drill each 20ft segments at a constant power which is aimed for better understand about the geological structure of the project site.

3.2 Estimation of TC, TD and VHC of Formation

The thermal conductivity (TC), thermal diffusivity (TD) and volumetric heat capacity (VHC) of the formation is quite essential information required to design of the ground loop heat exchanger. In the present work these parameters were estimated using infinite line source method and a numerical method of Oak Ridge National Laboratory (ORNL), USA. Figure 4 shows the TC setup installed at the site and connected to entry & return ends of the U-bent HDPE pipe inserted into the TBH. In this figure the project site is covered by snow because experimental measurements were taken during October 2012. For estimation of thermal conductivity (k) using the infinite line source method, following relation suggested by Carslaw and Jaeger (1959) was used,

$$k = \frac{\dot{q}}{4\pi}\left[\frac{\ln(t_2)-\ln(t_1)}{(T_2-T_1)}\right] \tag{1}$$

where q' is the heat transmitted by per unit length of the line source, the T1 & T2 are the initial and stabilized temperatures during the time interval of t2 - t1. The slope of the logarithmic time to temperature curve was used to measure effective thermal conductivity of the formation. In this test procedure the hot water at a temperature of 810F was passed through one end of the U-tube and time was recorded till the return water from other end reached to the entry temperature. In this case total electric power was given equal to 4556 W and total test duration took 43.1 hour till the entry and return waters were stabilised at 810F. In this case q' was equal to 44.67 Wm-1. Fig. 5 (a) shows the inlet and outlet temperatures of water recorded by TC setup with time in the logarithmic scale, however Fig. 5(b) showing the actual electric power taken during the experimental course. In the present case there were some electric fluctuations in the line, however, the temperature started stabilizing after 32 hours of the continuous passage of hot water. In the present case the undisturbed earth temperature was found at 8.9^0C.

The thermal conductivity (TC), thermal diffusivity (TD) and volumetric heat capacity of the TBH were estimated in consultation to Water Furnace International (WFI) experts and results are listed in Table 1, using both the methods of line source and ORNL numerical method, along with their average values. In this case the soil was composed of gray shale (40%), granite/dolomite (35%) and sand/clay (25%). Further, this site was saturated by water almost up to full depth. For this soil composition, the thermal conductivity values should be typically between 1.1 and 2.1 Btu/hr-ft-°F (1.8 W/m-K and 3.7 W/m-K) and TD values between 0.8

and 1.5 ft^2/day (0.072 and 0.13 m^2/day), following the ASRAE guidelines. Our results are relatively higher side for the geological composition found at the project site as compared to their reported values. The major source of error in our measurements is that the voltage has fluctuated in between during the long continuous test duration of over 43 hours and it has caused an uneven heat flow rate in the test borehole. In the present case, the geothermal probe field doesn't look computationally dimensional for a 100 kW load because in this case (first stage) the system is designed for a 100 kW output load, however, the same system would be upgraded to higher output loads in future in order to harness the full potential of the ground loop. In regard to this planning the test borehole was drilled up to 102 which is computationally dimensional to output loads of 400kW or more.

Figure 4: Onsite measurement of TC, TD and VHC of the 102 m deep geological formation.

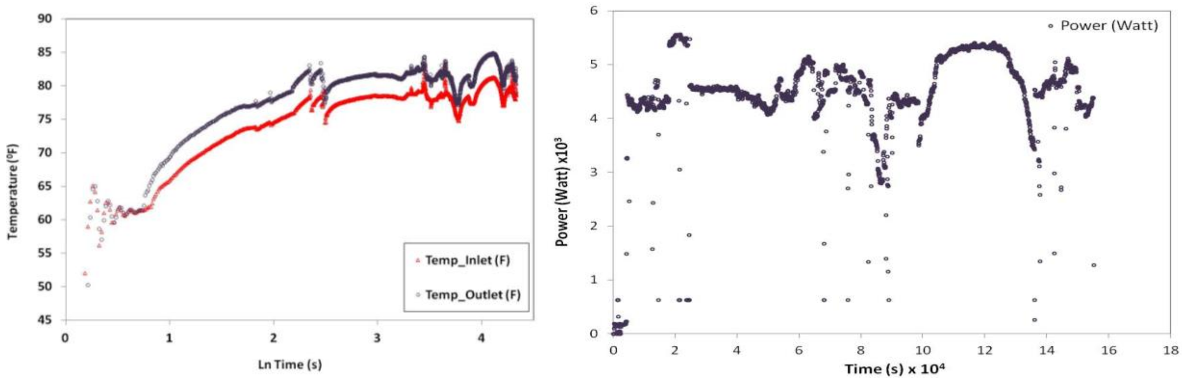

Fig. 5: (a) Entry (T1) and return (T2) temperatures as recorded by the TC setup as function of time in logarithmic scale, (b) the electric power consumed during experimental course.

Table 1: Geothermal parameters of the borehole formation estimated through Line source method (Carslaw and Jaeger, 1959) and ORNL (Oak Ridge National Laboratory) numerical method.

S. No.	Measured Parameter	Method used	Estimated Value	ASHRAE (2007) reported range
1.	Thermal Conductivity	Line Source	3.726 Btu/hr-ft - ^{0}F [6.449 W/m-K]	1.1 - 2.1 Btu/hr-ft-°F
		ORNL	3.419 Btu/hr-ft - ^{0}F [5.918 W/m-K]	(1.8 - 3.7 W/m-K)
		Average	3.573 Btu/hr-ft - ^{0}F [6.183 W/m-K	
2.	Thermal Diffusivity	Line Source	2.685 ft^2 /day [0.2494 m^2 /day]	0.8 to 1.5 ft^2/day
		ORNL	2.464 ft^2 /day [0.2289 m^2 /day]	(0.072 to 0.13 m^2/day)
		Average	2.574 ft^2 /day [0.2392 m^2 /day]	
3.	Volumetric Heat Capacity	Line Source	3330 Btu/hr.ft^3 ^{0}F [1241 kJ/m^3 - ^{0}K]	1980 - 2016 Btu/hr.ft^3 ^{0}F [2160 -2459 kJ/m^3 - ^{0}K]

4. DESIGN OF GEOTHERMAL SPACE HEATING SYSTEM

Based upon the geothermal investigation of the project site and thermal properties of the formation the ground source heat pump based space heating system was designed in consultation to the experts of Efficient Energy System (EES), India and Water Furnace International (WFI), USA. The schematic diagram of the geothermal space heating system is depicted by Fig. 6. This system has three independent circuit loops; the ground loop, GHP loop and user side heat transmission loop. In this case the undisturbed earth temperature is 8.9^0C which is relatively low and also soil is saturated by cold water coming from glaciers, therefore, keeping in mind all other aspects including heterogeneous ground structure of the site we can assume that a 4 to 5 kW per meter depth (vertical u-tube for heating) would be the design parameter for ground loop. In this way we require more than 25 Nos. of boreholes with each 100 m depth. Thus for safety the total ground loop length should be more than 5000 m. The ground loop is closed vertical U-bent type in which the HDPE (High Density Poly Urethane) pipe with ID 32 mm would be used for vertical loop and MDPE (Medium Density Poly Urethane) pipe would be used for horizontal loop. Further this system is designed for user requirement of output load 100 kW, therefore to meet the transmission losses and high altitude effect the actual GSHP power is kept 130kW. The refrigerant R410a would be best for high pressure application up to 4400 kPa (44 bar). The antifreeze mono ethylene glycol (20% by vol) would be used in the ground loop. For backfilling/grouting of the vertical loop the paste of bentonite with E-Z mud would be used.

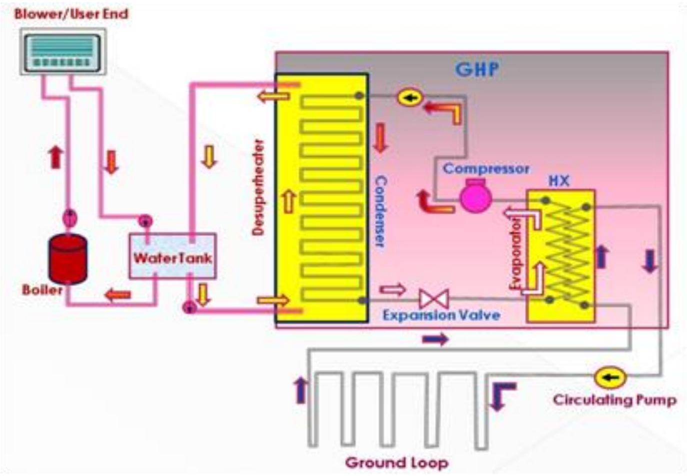

Fig. 6: Schematic design of 100 kW geothermal space heating system.

5. DESIGN AND INSTALLATION OF GROUND HEAT EXCHANGER

The ground loop heat exchanger is in fact the heart of the entire geothermal heat extraction technology; by and large it would determine the successfulness of the project and stability of output heat load. The schematic of ground loop heat exchanger is shown in Fig. 7. In this figure the dark rectangular strip is the horizontal trench in which the vertical loop, horizontal loop and manifolds would be erected. In the present case the total trench length is 115 m (first major section 95 m and second smaller portion with bifurcation is 20 m) . The width of the trench is 1.5 m and depth 1.0 m. In the entire loop there are three manifolds (1x9) for entry cold water (blue) and three for return (9x1) mild hot water (red). Each manifold connects to 9 different U-bent in the boreholes, as shown by red spots encircled by violet color. The vertical U-bent of HDPE pipe is having OD 32 mm however, the MDPE horizontal loop is with OD 90 mm 63 mm and 32 mm, respectively. In order to maintain required uniform pressure within the horizontal and vertical loops, reducers are used between 90 mm and 63 mm line and between 63 mm and 32 mm line. Also pressure can be controlled manually through the valves connected at each inlet/exit of the manifold line. In the horizontal loop more or less laminar flow is maintained (Reynolds Number, Re<100), however, within vertical U-tube turbulent flow is maintained (Re >3000) in order to have better heat transfer from ground to the U-tube. Therefore, the pressure in horizontal loop is kept between 1 to 1.5 bar, however, in vertical U-tube it can be between 2 to 4 bar, which is one of the important criteria to design a ground loop heat exchanger.

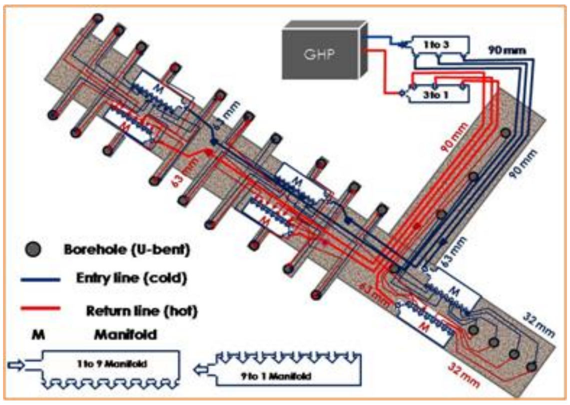

Figure 7: Schematic diagram of ground loop heat exchanger and manifolds.

5.1 Borehole Drilling and U-bent Installation

For installation of the complete geothermal space heating system, there were 27 Nos. of boreholes drilled up thus measuring total running length of 2500 m with bore dia. 127 mm (5 inch). The permanent MS-casing (5 inch) as discussed in the previous section is provided up to full depth, however, temporary MS- casing of 7 inch is provided first top depths 70 to 90 feet. The bore to bore spacing was kept between 5 to 6 m. Figure 8(a) shows the positions of the drilled boreholes, represented by uncut top portions of the 5 inch MS-casing, however Fig. 8(b) shows the trench with cut top portions of MS-casing. After cutting the top portions of the MS-casings, their top portions were covered by cello tape and trench was cleaned to make it ready for vertical U-tube installation.

Figure 8: (a) The drilled boreholes as shown by uncut top portion of MS-casing in trench, (b) the top cut view of covered borehole and trench after cutting top portion of the MS-casing (ready for installation of U-bent).

5.2 Installation of Vertical Loop of U-bent HDPE Pipes

After carrying out the pressure and leak testing of the vertical U-bent, they were carefully inserted into the boreholes. Figure 9 shows the roll of U-bent HDPE pipe and unrolled HDPE U-bent pipe to make them ready for installation. The end of the U-bent is shown at right side (bottom). Since the cased boreholes were partly full of water which entered from saturated soil. Therefore, to prevent the U-tube from floating additional weights were attached to the U-bent using two 20 mm MS-rod of length 3 m each. In this U-bent (already filled with water) could easily go up to the depth of 100 m. The total 27 Nos. of U-bent were inserted into the all 27 Nos. boreholes drilled thus making total U-bent running length up to 5100m

Fig. 9: HDPE U-bent for vertical boreholes installation, top view is the roll of HDPE pipes (U-bent) and bottom view id the end of U-bent.

After complete installation of vertical U-bents into the boreholes, the horizontal loop was laid on the trench. First 90 mm MDPE pipes (SDR 11) were installed 10 feet away from respective manifold. Thereafter the 63 mm line was laid connected to respective manifold, similar to the design as discussed in previous section. Finally the exit distribution (1 to 9) / entry collection (9 to 1) line was connected by 32 mm MDPE pipe to the respective U-bent inserted into boreholes. The three 90 mm lines each for entry and return then converts into 3 to 1 or 1 to 3 lines for connection to the GSHP. All U-bents are connected in parallel fashion, rather than series. The joints/fittings were connected using electro-fusion and thermo-fusion methods. Since joints are the weakest links determining the life of a loop, therefore, the jointing work was done carefully. Figure 10(a) depicts how horizontal and vertical loops are erected. Further during laying of horizontal loops, a sand bed was provided beneath the pipes in order to provide more safety and life to the ground loop. Figure 10(b) shows the distribution of lines at the exit or entry of a manifold and Fig 10(c) the header connection to the GSHP. In Manifolds, each line has a valve to control the pressure in U-bent. The electro-fusion onsite is shown by Fig. 10(c) along with the electro-fusion fitting on right lower side. The electrical terminals as seen in this figure are used to connect the joint to the electro-fusion controller, as shown in right upper side of this figure. But for connection at manifolds, the thermo-fusion was used, in which the jointing part is melted over a thermo-fusion plate (hot plate) and joints/parts are connected straightway, this method is rather a simple method.

Figure 10: (a) Erected horizontal and vertical loop, (b) connection to manifolds, (c) the header connections (1X3 and 3x1) to GSHP, (d) ongoing onsite electro fusion work of the pipe joints/fittings.

5.4 Ground loop Leak and Pressure Testings

After completion of the ground loop installation work, the pressure and leak testing of the entire loop (vertical and horizontal) was carried out. For pressure testing the motorized (Fig 11(a)) and manual pumps (Fig. 11(b)) were used. The pressure testing was carried out at a pressure of 10 bar and observed the pressure stability up to 30 minutes consecutively three times. It was found that there was no leakage or pressure drop in the entire ground loop.

Figure 11: Pressure and leak testing of the ground loop, using (a) motorized pressure pump (150 bar), (b) manual Pressure pump (50 bar).

5.5 Grouting of Ground Loop

Grouting is one of the important task of the project making perfect thermal contact of U-bent to the adjoin ground. In this work we have used the paste of Bentonite mixed with E-Z mud. In this work, a special grout pump was used to mix both the components and then allowing to pass inside the borehole with high pressure. The grout pipe starts filling the borehole from bottom to top. In the present case stopper were provided to the U-bent at a depth of 50 m therefore lower portion of borehole was filled by natural water and top portion by bentonite paste. The grouting was completed in steps of 2 m.

6. INSTALLATION OF GROUND SOURCE HEAT PUMP

In the next phase the installation of ground source heat pump and its other accessories were completed. Fig. 13 shows the GSHP (model NKW130R7PE8NNSSC, supplied by WFI, USA) installed at the project site which is housed inside a hut. The right top side of this figure shows the electric control panel and right side bottom figure shows the circulating pump for ground loop. The headers as shown in Fig. 10(c) are connected to the GSHP through the circulating pump. The actual load capacity of the GSHP, in this case is 130 kW so as to meet the high altitude efficiency factors and other losses during heat transmission to the user's dwellings and ensuring 100 kW load capacity to the user side. In the present case the capacity of the circulating pump is kept 5HP and connected to flows witch towards entry side of the ground loop. The electrical control unit provide a 3-phase electric power supply (370 - 415 VAC, 50 Hz), which is compatible to the requirement of GSHP load capacity. The flow-switch can be used to regulate the flow rate in the ground loop.

Fig. 12 : Grouting work going on at the project site (a) grout pump, grout paste entering into borehole through a 32 mm pipe.

Figure 13: The Ground Source Heat Pump installed at the project site along with its control panel (right side top) and circulating pump (right side bottom).

7. EVALUATION OF SYSTEM PERFORMANCES

In the last phase of the project, the performance of the GSHP based space heating system was measured in terms of output heating load while running the GHP and ground loop circulating pump, electric power consumed and temperature achieved along with temperature stability. Figure 14 depicts the water reservoir tank of capacity 2000 litre which supplies water to the boiler of existing central heating plant and then store cum supply the return hot water from dwellings to the boiler. In the existing heating plant the two 5HP circulating pumps supply water to the dwellings at a flow rate of 30Litre/second and 14 dwellings are supplied heating. Two cascaded diesel run boilers (make - Alfa Therm, capacity 105 K calorie) are used in the heating plant to heat up the cold water. In the present arrangement the output of the GSHP is connected to this tank providing preheated water supply and it get further heated to reach the required temperature of of entry water to the dwellings. The right top side of this figure is the insulated heat line to the dwelling and right bottom figure is the heat ventilator cum blower inside the dwelling. In the present study, the output load performance of the GSHP system was measured in a separate tank of capacity 512 litre. The inlet temperature of water entering into GSHP was 130 C and return water from GSHP was re-circulated into it until the peak temperature is achieved. In our study the maximum temperature of the output water that this system could provide was 53^0C and once temperature reached at this point GSHP automatically cuts down. While to heat up the initial 13^0C of water to the peak temperature of 53^0C, GSHP took 14 minutes of time. With this information we calculated the output load as 102.4 kW, which is more than the desired load of 100 kW. The flow rate of the GSHP can be varied from 4.5 litre/second to 8.5 litre/ second. At minimum flow rate (5 litre / second) we could achieve the desired output load of 100 kW. This test was repeated many times to check the deterioration in its output load as well as peak temperature stability. It was found that output loads and peak temperatures were stabilized. Simultaneously the electric power consumption was measured while running the entire setup. It was observed that 33 kW was the electric consumption while GSHP was running, In this way we could estimate the Coefficient of Performance (CoP) of the system was estimated near about 3.1, which could yield the energy saving up to 67% at its peak loading. Further, the GSHP was connected to the user load side through tank of central heating plant. It was observed that additional heating was provided by burning diesel to further increase the water temperature up to 70^0C, in existing setup of heat line to the users. The return water temperature in this case is 40^0C. Effectively the

GHP could save up to 60% of the diesel consumed. Because there is still need of improving the quality of heat transmission lines to dwellings and their insulation.

Fig. 14: Performance evaluation of GSHP based space heating system with existing central heating plant connected to the dwellings.

In this work we have also studied the emission of carbon and other green house gases and as a rough estimate we observed the significant decrease in the carbon emission up to 5%. This is due to the fact that initial burning of diesel is high resulting into more carbon emission because the temperature of 2000 litre of tank has to brought up to 70^0C from water temperature of close to 0^0C. Thus GSHP based heating system is providing the preheated water to the existing central heating plant at temperature 53^0C and heating the return temperature of 40^0C to 53^0C. The GSHP is providing heat through initial heating of cold water of 2000 litre capacity and the further heating of return water. Since the user requires a comfortable temperature of 25^0C to 30^0C, however, GSHP is providing a 53^0C of temperature, therefore by providing good quality of heat insulation, quality of heat transmission line and dwelling door/window arrangement the GSHP system alone is capable to supply sufficient heating to the dwellings. Also, by utilizing the full capacity of the ground loop heat exchanger and upgrading the GSHP capacity, the other dwellings can be benefitted with this geothermal based space heating system. Further, this system works in the reversible mode, hence cooling cycle can also be run during summer season. The cooling tests were done on same tank of 512 litre capacity to bring down the water temperature of 53^0C to 13^0C, and it took nearly 17 minutes to achieve this temperature which is relatively more than the heating cycle.

8. CONCLUSIONS

For implementation of the project on ground source heat pump based spaced heating system at SASE, Manali (HP) the complete tasks were executed under three different phases. In the first phase, the survey of the project site was conducted to understand its ground conditions and past climatic record. After drilling a test borehole measuring 100 m depth, the geological strata of the site was identified with depth through geological sample collection. The HDPE U-tube was inserted into the test bore hole and grouted properly. Thereafter the thermal properties of the formation were estimated in consultation to WFI, USA experts and geothermal space heating system was designed. In the second phase 27 Nos. of vertical boreholes measuring total running length over 2500 m were drilled and MS casing was provided to prevent them from collapsing. For erection of ground loop heat exchanger, a trench measuring 115 m of length was cut and 27 Nos. of U-bent (HDPE pipes) were inserted into the boreholes. The U-bent were connected to the manifolds and GSHP through horizontal loop of MDPE pipes. The total ground loop length is over 5400 m. Different segments of HDPE/MDPE pipes are fused through electro-fusion/thermo-fusion joints/fittings on the site itself. There are three headers at the entry and three at return temperature thus each distributing/collecting nine different U-bents in parallel fashion. Finally, three entry and return lines converts into one line (each for entry and return) connected to the circulating pump and flow switch and then to GSHP. The complete GSHP based space heating system with output load capacity 100 kW at output temperature 53^0C is installed and then tested. The outputs obtained are quite in good agreement as desired before execution of this project tasks. This system CoP as estimated is near about 3.1 which may provide energy saving up to 67% along with reduced carbon emission. As of now this system is providing preheated water to the existing heating plant but in next stage 100% heating would be provided by GSHP system itself which would require modification in heat transmission system. The amount of heat thus achieved by this system is sufficiently large as compared to the user requirement of 5-6 kW per dwelling.

In this exercise the geothermal heat pump based heating system has been successfully installed in the cold regions of Himalaya near Manali (HP) and this system is working satisfactorily as desired by the user. The capability of the system, both in heating and cooling cycle, has been tested and results are quite satisfactory. In view of Indian climatic conditions and requirements, GSHP based heat extraction cum rejection system find wide applications by providing significant energy savings at domestic to industrial fronts. But to make it available to common people, technological research work requires more focus on development of portable geothermal system which further would enhance the scope of ground source heat extraction technology not in Indian but in global perspectives.

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