DEVELOPMENT AND APPLICATION OF AN INNOVATIVE SHALLOW GROUNDWATER HEAT PUMP SYSTEM

Xu Shengheng, General Manager,
Ever Source Science & Technology Development Co., Ltd, Beijing, China
Yang Ziqiang, Ph.D., Engineer,
Ever Source Science & Technology Development Co., Ltd, Beijing, China

ABSTRACT

Geothermal energy from the shallow ground is an abundant energy resource with wide geographic distribution. The energy exists in the subsurface ranging from about 30 to several hundred meters and its temperature is relatively stable. Its utilization is now spreading at high speed worldwide.

This paper presents an original and innovative technology for utilization of shallow geothermal energy—the “Single Well System of Supplying and Returning Water” technology which was invented by Ever Source Science & Technology Development Co., Ltd(ESSTD). The system operates in a sustainable manner with high efficiency and provides buildings with heating & cooling as well as with domestic hot water. Since the system came out in 2001, it has attracted lots of attention of users and government agencies in China. This paper describes its principle successfully operating systems in various parts of China.

Key Words: geothermal energy, heat pump, environmental protection, heating & cooling system.

1 INTRODUCTION

Ground-source heat pump system (GSHPs) was originated in a patent of Sweden in 1912. It applies the shallow ground geothermal energy in the depth of about 30 to several hundred meters as its energy source, this kind of energy is ubiquitous in the subsurface and its temperature is relatively stable during whole year, so the GSHPs is able to run efficiently and reliably. More and more GSHPs is now being installed for space heating & cooling and domestic hot water in Europe and the United States (EHPA 2002)(Bose and Parker 1983).

There are mainly two kinds of GSHPs, one is the ground-coupled heat pump system (GCHPs) in which vertical heat exchangers and/or horizontal ones are used for heat extraction or discharge, the other is the ground-water heat pump system (GWHPs) in which the underground water is circulated through the heat pump system. The latter is suitable in regions with extended aquifers.

In China, and especially in Beijing area, there are plentiful regions with shallow aquifers; the groundwater temperature in the depth of 30-100 m is about 15°C and relatively stable without seasonal variations. The Beijing-based company "Ever Source Science & Technology Development Co., Ltd.(ESSTD)" has developed a new, powerful groundwater heat pump system for space heating and cooling called "Single Well System of Supplying and Returning Water" (SWS).

This paper describes the SWS's principle. Its design, energy saving and environmental protection effects are also described with a practical operating system in Beijing area. Moreover, successfully operating projects in various parts of China are presented, which involves a wide range of building types and purposes. For example, residential building (villas and apartments), office building, hotel, hospital, shopping center, school, waterscape pool (China National Theatre), etc.

The systems' initial investment cost and operation fee for supplying heating & cooling and domestic hot water are relatively low; the environment benefits greatly from saving fossil fuel and avoiding CO_2 emissions, corresponding data are presented and the latest research progress is also provided.

2 THE SWS's PRINCIPLE

Generally, a standard SWS needs to drill a borehole of about 70-100m depth and with a diameter of 0.5 m(see figure 1).

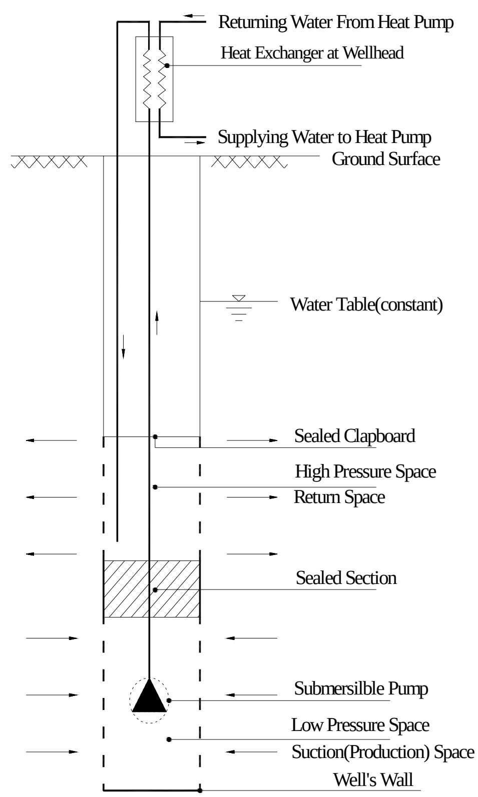

Figure 1 A typical schematic of single well system

In winter, groundwater with about 12-15 is pumped from the well at a rate of 100m3/h and passes through the heat exchanger at wellhead to release heat to the circulating water, which is circulated between the evaporator of heat pump and the heat exchanger; heat pump absorbs the heat from the circulating water and supplies warm water with temperature of about 35   to floor panel radiator or hot water with temperature of about 50-55   to fan coil units for space heating whereas the well water temperature is lowered down to 8-10   after heat releasing. This water is then injected to the same well where the water passes through a special soil heat exchanger and takes the heat from the surrounding gravel and sand. By this means, the water temperature gets back to its original temperature.

In summer, heat pump takes the heat from the building space and releases it to the groundwater for space cooling. Sometimes, "free cooling" with heat pump switched off is provided by the groundwater after heat exchanger when outdoor temperature is below 30℃ and the indoor temperature can be controlled under 28℃.

Since the water pumped from a well is returned to the same well, so this technology is called "Single Well System of Supplying and Returning Water".

The prerequisite of the SWS for hydrogeology condition is to have a shallow aquifer with reasonable hydraulic conductivity: 10-3m/s or higher (Xu and Rybach 2004).

3 MODEL PROJECT DESCRIPTION

3.1 Design Loads

The model project named Beijing Haidian Foreign Language School is located in the northwestern part of Beijing with a total construction space area of 65,300 m^2. The school consists of nine buildings, including Classroom, Dining Hall, Gymnasium, Indoor Swim pool, etc. The summer climate is hot and the winter is cold in Beijing area, the design loads of heating and cooling are listed in Table 1.

3.2 The System's Operational Flow

All buildings in Beijing Haidian Foreign Language School use the groundwater as the heating source and apply heat pumps to absorb the heat and provide hot water to different terminals, such as fan coil units, floor panel radiators, etc. Figure 2 shows the flow chart of the system. The surface equipment consists of routine components like heat pumps, heat exchangers, pumps, valves, control instruments, storage tanks, etc; the subsurface component is the new, powerful SWS(patent holder: ESSTD).

3.3 The Operational Situation

The SWS was installed and tested in 2001. It has been operated for 3 years and is always in good condition. The indoor temperature satisfies the design requirements in winter and summer. The amount of electricity consumption and the energy supplied by the SWS for Beijing Foreign Language School is shown in Table 2.

Table 1: Design loads of heating and cooling for the various buildings

No.	Name of Buildings	Area (m^2)	Design Cooling Load: Cooling Index (W/m^2)	Design Cooling Load: Cooling Load (kW)	Design Heating Load: Heating Index (W/m^2)	Design Heating Load: Heating Load (kW)	Indoor Temp.in Winter (℃)	Indoor Temp.in Summer (℃)
1	CM	8,047	85	547	75	604	18-24	22-28
2	CP	8,897	80	567	75	667	18-24	22-28
3	DH	4,455	80	285	75	334	18-24	22-28
4	BD	6,296	110	554	75	472	18-24	22-28
5	GD	6,296	110	554	75	472	18-24	22-28
6	AB	6,009	90	433	75	451	18-24	22-28
7	ST	5,248	70	294	75	394	18-24	22-28
8	GY SW	5,603	52	291	75	420	18-24 26-28	26-28
9	TD	12,000	110	1,056	75	900	18-24	22-28
10	Total	62,851		4,581		4,714		

Notes: CM-Classroom for Middle School, CP-Classroom for Primary School, DH-Dining Hall, BD- Boy's Dormitory, GD-Girl's Dormitory, AB-Administration Building, ST-Science & Technology Building, GY-Gymnasium, SW-Indoor Swimming Pool, TD- Teachers' Dormitory

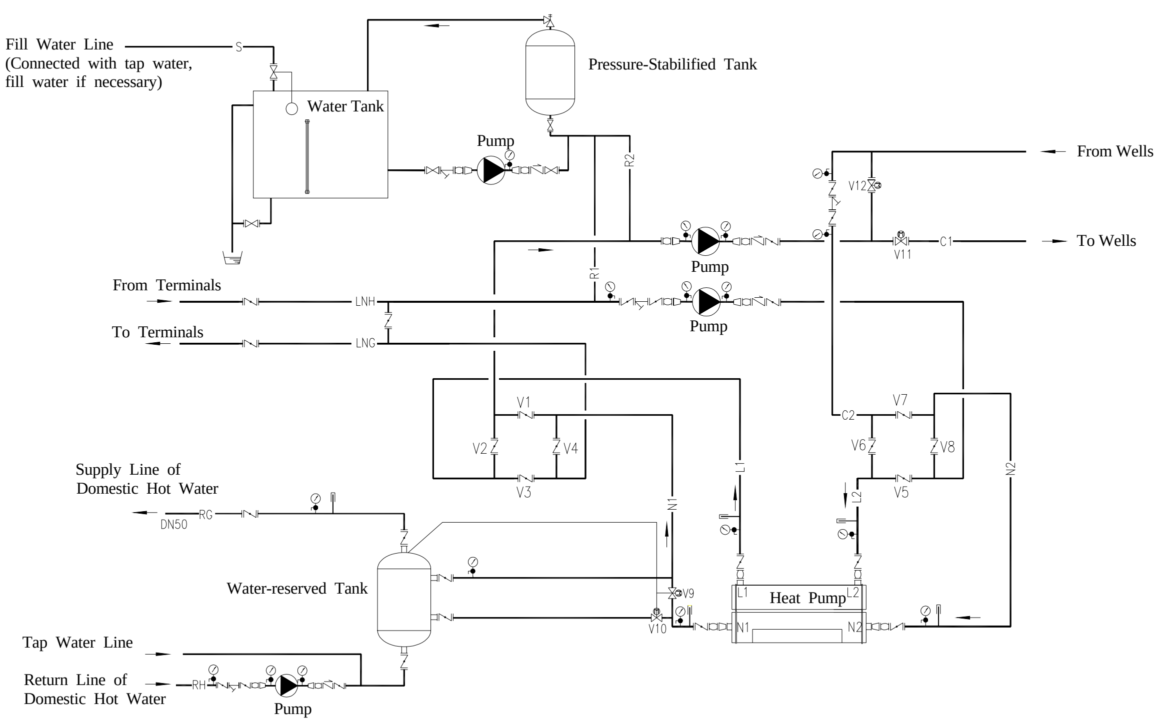

Figure2 Principle components of the "Single Well System of Supplying and Returning Water"

Table 2: Annual energy production and electricity consumption in 2003

No.	Buildings	Total heating energy (MWh)	Total cooling energy (MWh)	Total heat extracted from ground (MWh)	Total heat injected into ground (MWh)	Total electricity consumption for heating (MWh)	Total electricity consumption for cooling (MWh)
1	CM	664	364	498	468	166	104
2	CP	732	375	549	482	183	107
3	DH	416	242	312	310	104	69
4	BD	1,180	382	885	490	295	109
5	GD	864	256	648	328	216	73
6	AB	724	284	543	364	181	81
7	ST	396	259	297	333	99	74
8	GY SW	1,348	182	1,011	234	337	52
9	TD	2,704	683	2,028	877	676	195
10	Total	9,028	3,027	6,771	3,886	2,257	864

Table 2 shows that the total electricity consumption for heating is 2,257MWh in 2003. The electricity rate for the school is RMB 0.54Yuan (nearly 0.065USD/kWh) without considering the different rate at on-peak and off-peak, so the total expense of electricity is about 1.22 million Yuan (14.7 thousand USD) or 19.39Yuan/m^2 (2.34USD/m^2) during winter season. The operation cost is almost as low as the heating cost using coal; the latter is about 18 to 24Yuan/m^2 which is regulated by local government.

Comparing with traditional heating and cooling techniques, its initial investment is equivalent.

4 FURTHER SYSTEMS OPERATED

Since the invention of the new technology of SWS, it has been applied widely in Beijing. Subsequently it has been adopted even in remote provinces and areas of China such as Sichuan and Tibet. Up to now, over 180 projects have been installed with a total construction area about 2,500,000m^2, including various buildings such as hotels, residential buildings, shopping centers, buildings of administration, schools and gymnasiums, hospitals, archives and factories, landscape buildings such as China National Theatre, etc. Table 3 shows some main installations in operation.

5 THE LATEST RESEARCH AND DEVELOPMENT

An extended monitoring program has been finished by the Water Source Monitoring Center of Beijing Municipality. They checked the underground water quality of SWS over 11 projects in the last three years, with intensified monitoring during the last 9 months. 21 index properties of the water quality were analyzed and none of the indexes had significant changes except the water temperature. This indicates that SWS doesn't affect the quality of groundwater.

More comprehensive research has been implemented through corporation between ESSTD and universities and research institutes home and abroad, some progress has been made (Ni 2004).

Table 3: Operating installations with various buildings

No.	Object	Construction area(m^2)	Location	Usage type	Note
1	Jintai Apartment Building	14,130	Beijing	Residential Building	
2	Delinyijing Residential Building	71,374	Beijing		
3	Fuyuan East Villa	64,702	Beijing		
4	Office Building of District Government	58,915	Beijing	Office Building	
5	Second Office Building of District Government	64,000	Beijing		
6	Tibetan Hall	70,295	Lhasa,Tibet		
7	Haidian Foreign Language School	65,308	Beijing	School	
8	Xingming Lake Holiday Inn	14,000	Beijing	Hotel	
9	Songlu Hotel	12,000	Beijing		
10	Shopping Center	118,000	Beijing	Commerce	
11	Senior Citizen Hospital	24,971	Beijing	Hospital	
12	Sijiqing Nursery School	6,963	Beijing	Nursery School &	
13	Sijiqing Elder People's Home	18,429	Beijing	Elder People's Home	
14	Beijing Rural Credit Cooperatives	3,600	Beijing	Bank	
15	Archive Hall	13,066	Beijing	Archive	
16	Exhibition Center	10,000	Beijing	Exihibition	
17	Donggaodi Cultural Center	7,418	Beijing	Gymnasium	
18	Jiuzhi Company	9,200	Hebei Pro.	Factory	
19	Changping Sewerage Plant	4,497	Beijing	Utilization of Sewerage's Heat Energy	
20	China National Theatre	35,000	Tiananmen Square	Landscape	Water temperature Control
21	Huangzhuang Petrol Station	750	Beijing	Special Usage	

6 DISCUSSION

In table 2, the total electricity consumption of every building for heating and cooling was metered and recorded year-by-year, the energy consumption for heating and cooling was measured only in the building of Classroom for Middle School (CM), the other buildings' energy consumption was calculated by the rule of CM; So there could be a little bit difference between the real energy use and the calculated one. But all of the buildings' operational conditions were the same; the calculated figures in table 2 were acceptable.

7 CONCLUSION

The shallow geothermal energy is a widespread, renewable resource. Exploiting and utilizing this energy could promote sustainable development of human being.

The SWS is especially suitable for using the shallow geothermal energy where the aquifer is abundant, it takes underground water as the medium and adopts closed circuit without emission of any gas, solid and liquid pollutants.

The operation cost of the SWS is quite low, widespread application of the SWS will improve the efficiency of utilization of the shallow geothermal energy and promote environment protection.

Further study about the range and extent of the effect of SWS on the surrounding hydro geologic conditions should be done, including the variation of the temperature, flow direction and piezometric level of groundwater.

8 ACKNOWLEDGMENT

We are thankful to professor Lu Diantong and Miss Zhao Yan for their support during preparing this manuscript.

9 REFERENCES

Bose J. E., Parker J. D. 1983. "Ground coupled heat pump Research", ASHRAE Transactions, Vol. 89, Part II, pp. 375-390.

EHPA 2002. "Heat Pump Market Overview Europe".

Ni Long 2004. "Simulation of Transport in Groundwater Flow Caused by GRHPPRSW", Dissertation for the Master Degree in Engineering, Harbin Institute of Technology.

Xu Shengheng, Rybach, L. 2004. “An innovative renewable energy system for space heating and cooling-using ubiquitous shallow geothermal resources”, World Renewable Energy Congress VIII, Denver/USA