Seawater Central Heating
HYY Ground Sourced Heat Pump System for Rebuilding the Central Heating Project in a Middle School of Dalian

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ABSTRACT

This is first one in China to use seawater medium-ground sourced heat pump system for rebuilding the Central Heating Project in a Middle School of Dalian. The system takes the seawater as a thermal medium to collect the low grade thermal energy from the shallow rock soil layer near the Sea and around the heat exchange well. The seawater temperature in the well can reach the shallow ground temperature of about 15°C. HYY (Heng You Yuan Co.) ground sourced heat pump system is used to provide the winter heating for the building.

The operation result of the system in the last winter season proves to have a very good coefficient of performance COP = 3.19 and the Renewable energy resource use of η = 68.7%. The room temperature in the classrooms in the daytime in the winter is 18-23°C. The average heating expenses (electric fee) in the heating season is \$1.7USD/m^2. The local heating standard fee is \$3.8USD/m^2 in the heating season, so the system only used 44.3% of this fee. The system saves a coal of 192 ton per year. During the system operation, there is no CO_2, SO_2 and particles emitted. The system can perfectly protect the seawater, groundwater and rock-soil layer from pollution.

This successfully project is a good example to spread the system application in Dalin area and along the coast of China in the future.

I. Introduction

This project is a rebuilding of the heating project in the Zhangzidao Town middle school located at Changhai County, Dalian City, Liaoning Province. The building used mainly for teaching function has a construction area of 4914m^2, 5 floors with a floor height of 3.6m. The coal fired boilers were used in the winter for the building heating before 2006.

The minimum distance between the school outside wall and the Yellow Sea coastline is 50m. The project dug a well near the Sea as a heat exchanger, took the seawater as a thermal medium to collect the heat from the rock and soil around the siphon pipeline and the well. In the winter, the seawater average surface temperature is about 3°C, after collecting the low grade thermal heat, the seawater temperature in the well reached at 10-15°C. The HYY ground sourced heat pump promoted this low grade thermal energy to provide the winter heating for the building (Xu et al, 2003).

II. Design Principle

1. Design parameter

1) *Indoor parameter:*

Indoor room temperature in daytime in winter: 18~20°C.
Duty room temperature in nighttime in winter: 10~12°C.

2) *Weather and geography information in Dalian, N.E of China in following (See Table 1, overleaf).*

III. System Coefficient of Performance (COP$_{th}$) in Theory

1. Design Heating Energy in Daytime

1) *Heating load in daytime*

$$Q_{r1} = F \times q/1000 = 4915 \times 70/1000 = 344.05\text{kW} \quad (1)$$

Where F is heating area in m^2, q is daytime heating average index (W/m^2).

Table 1. Weather and geological information.

No.	Item			Data
1	Place			Dalian
2	Location	North latitude		38°54’
		East longitude		121°38’
		Elevation (m)		92.8
3	Atmosphere pressure (mbar)	Winter		1013.8
		Summer		994.7
4	Average annual temperature (°C)			10.2
5	Outdoor dry temperature (°C)	winter	Heating	–11
			Air-condition	–14
			Ventilation	–5
		Summer	Ventilation	26
			Air-condition	28.4
			Average per day	25.5
			Avg. variation per day	5.6
6	Summer outdoor wet temperature (°C)			25.0
7	Best hot month average temperature (°C)			23.9
8	Outdoor relative humidity (%)	Winter air-condition		58
		Best hot month average		83
		Best hot month average at 14:00		76
9	Outdoor wind speed (m/s)	Winter average		5.8
		Summer average		4.3
10	Most wind direction & frequency (%)	Winter	Wind direction	N
			Frequency (%)	25
		Summer	Wind direction	SE
			Frequency (%)	15
		Full year	Wind direction	N
			Frequency (%)	15
11	Maximum frozen earth depth (cm)			93
12	Extreme minimum temperature (°C)			–21.1
13	Extreme maximum temperature (°C)			35.3
14	Heating days			132
15	Statistic year			1951~1980

2) Total heating energy in daytime ($n_{1=}$12h) of 120 days (n=120day),

$$Q_{day} = Q_{r1}\times n_1\times n = 344.05\times 12\times 120 = 49.54\times 10^4 \text{ kWh} \quad (2)$$

2. Design Heating Energy in Nighttime

1) Heating load in nighttime

$$Q_{r2} = F\times q_2/1000 = 4915\times 50/1000 = 245.75\text{kW} \quad (3)$$

Where F is heating area in m^2, q_2 is night heating average index (W/m^2).

2) Total heating energy in nighttime ($n_{1=}$12h) of 120 days (n=120day),

$$Q_{night} = Q_r\times n_1\times n = 245.75\times 12\times 120 = 35.39\times 10^4 \text{ kWh} \quad (4)$$

3. Total Heating Energy in 120 Days

$$Q_r = Q_{day} + Q_{night} = 49.54\times 10^4 + 35.39\times 10^4 = 84.93\times 10^4 \text{ kWh} \quad (5)$$

4. Design System COP_{th} in Theory

During the HYY system operation, the total electric power need in theory is 208.6kW (See Table.2).

Total electric energy need during the heating season of 120 days, (from 11/15/2006 to 03/15/2007) 12 hours per day is N = 30.0384×10^4 kWh.

$$COP_{th} = Q_r/N = 84.93/30.0384 = 2.83 \quad (6)$$

IV. HYY System Design

1. Energy Collection Subsystem

The energy collection subsystem is a key component of the ground sourced heat pump system, which function is to help the entire system operate safely, stably, reliably and economically (Xu et al, 2006).. This project uses a siphon pipeline and a heat exchange well system to collect the low grade thermal energy from the shallow ground rock-soil layer in the surrounding of the siphon pipeline and the seawater well.

The heat exchange well is built in the distance of 50m from the coast and in a lawn near the building, hid underground in the depth of 10m below the seawater level, the iron well cover is as same as usually used water well cover by city utility, in perfect harmony with the surrounding environment.

Based on the weather information of Dalian, the annual average seawater temperature of surface layer is 12°C, the average seawater temperature in the coldest month is 1°C, the average seawater temperature in the hottest month is 24°C, the minimum seawater temperature in the winter is -0.7°C, the seawater is ice-free all year around.

The heat exchange well (seawater well) in this project is designed as following, with a water flow rate of 200 t/h. The energy collection principle is shown in Figure 1.

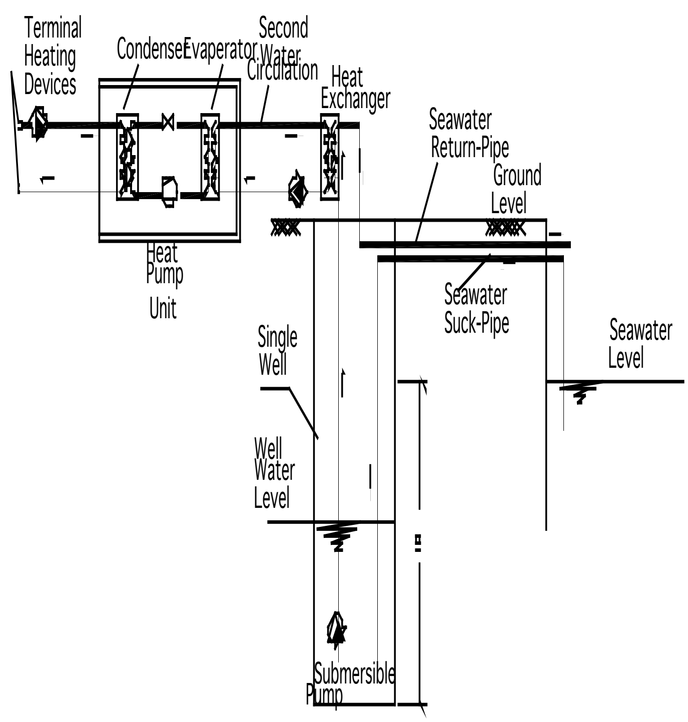

Figure 1. Energy collection subsystem of single well.

Table 2. HYY system components list.

No.	Name	Tape	Amount	Power input (kW)	Parameter	Note
1	Ground heat pump	HD660B	1	160.4kW	Power output 634kW	
2	Terminal circulation pump	QPG80-315B	2	5.5	Flux: 43.3m^3/h Lift : 24m	1 used
3	2nd circulation pump	QPG80-315B	2	5.5	Flux:43.3m^3/h Lift: 24m	
4	Soft water device	TF-250	1		Treating flux: 1.0~2.0 m^3/h	
5	Filling water tank	900×900 ×900	1		Volume: 0.61m^3	
6	Filling water pump	QPG25-160	1	2.2	Flux: 2 m^3/h Lift: 32m	
7	Pressure tank	24L	1			
8	High water tank	900×900 ×900	1		Volume: 0.61m^3	
9	Plate heat exchanger	BR65-50	2			
10	Storage energy circle pump	QPG100-220	2	5.5	Flux: 100m^3/h Lift: 12.5m	
11	Storage energy tank	6000×6000 ×2500	1		Volume: 90m^3	
12	Seawater submersible pump	250QJ200 -20/1	1	18.5	Flux: 200m^3/h Lift: 20m	
13	Heat exchanger	I0.6T150	1			
14	Seawater treating device	DN250	1			
	Total Power			208.6 kW		

The Process of the System Operation

(1) When the system starts working, a vacuum pump empties the air in the siphon pipeline. The seawater is full of the siphon pipeline and the well. The submersible pump draws seawater from the well, the water level in the well falls. Since the seawater horizontal level is higher than the well water level, the seawater flows into the well by a siphon pipe. So, the submersible pump draws seawater continuously, and the seawater flows into the well continuously. The seawater in the pipeline and the well absorbs the thermal heat from the shallow ground rock and soil, the seawater temperature in the well reaches about 15°C. The submersible pump drives the well water up to the heat exchanger to release the thermal energy, then the well water with a lower temperature than 15°C returns to the ocean.

(2) The obtained thermal energy at the heat exchanger is transferred into the heat pump evaporator by the second water loop. After upgrading this thermal energy by the heat pump, the heat energy is delivered to the terminal heating devices (Radiators) to release the heat for the building.

(3) There are lots of alga and seashells in the seawater, which are easy to attach and grow in the seawater pipe, blocking the pipe and dropping the water flow rate rapidly. Electrolyzing seawater equipment is used to prevent pipe-pollution, and to solve the pipe-blockage. The equipment has some advantages: small volume, easy installation and maintenance, long lifetime, no chemical materials used, and no pollution to the environment.

UPVC (Unplasticized Polyvinyl Chloride) water pipe with a diameter of DN250 is adopted as the seawater siphon pipeline, which is installed under the seabed in the Sea and at a depth of 1.0m in the land, respectively.

2. Energy Promotion Subsystem

According to the above information and HYY system parameter, we use one set of ground sourced heat pump-HD660B to meet the need of the heating load for the building, which needs an electric power of 160.4kW to produce the heat quantity power of 634kW. The heat pump system promotes the collected thermal energy with 15°C and provides the higher thermal energy with 60°C to the terminal radiators of the building.

3. System Water Treatment and Filling Water at a Fixed Pressure

1) Water treatment: Fully automatic soft water device is used for the system water treatment.

2) Filling water: The soft water tank, filling pump and close pressure tank are used for the system water filling.

4. System Component List (See Table 2)

V. System Coefficient of Performance (COP) in Fact

The system was run during the last heating season from 11/15/2006 to 03/15/2007 (for 120 days). We had the following results.

1. System Provides the Daytime Heating Energy per Hour

The terminal circulation pump has a flux of 43.3m^3/h, the water temperature at condenser inlet and outlet is over 60°C and 50-55°C, respectively. The room temperature of the building in the heating season reaches 18-23°C. The average water temperature difference between inlet and outlet of the condenser in the heating season is about 5-10°C (average $\Delta t = 7.0$°C). The water density at 2 Bar = 0.2 MPa, 60°C is ρ = 983.1875 kg/m^3.

1. The System Terminal Supply Heat Quantity Per Hour For Daytime Heating

The heating season had 120 days last year, the average temperature difference in supply and return water of the terminal heating devices (Radiators) was $\Delta t = 7.0°C$ in this system.

The water flow in the terminal circulation unit was $G=43.3m^3/h$ in 120 days. The water density was $\rho=983.1875$ kg/m^3 with a specific heat: $c = 1.163$ kWh/(kg.°C).

The average supply heat quantity per hour for heating in daytime:

$$Q_{pj} = c\times\rho\times G\times\Delta t \quad (7)$$
$$=1.163\times983.1875\times43.3\times7.0 =346.58kWh/h$$
$$=346.58kW$$

2. Daytime heat supply in 120 days, 10 hours per day for the building:

$$Q_r = d\times h\times Q_{pj} \quad (8)$$
$$=120\times10\times346.58 =41.59\times10^4 \text{ kWh.}$$

3. Total Heat Energy Supply in the Heating Season of 120 Days

$$Q_r = Q_r \quad (9)$$
$$= 41.59\times10^4 \text{ kWh}$$

In the nighttime, there is no heating.

4. System Coefficient of Performance (COP)

The system operated from 11/15/2006 to 03/15/2007, for 120 days, the total electric energy consumed was $N=13.044\times10^4$ kWh. The system has a coefficient of performance (COP):

$$COP = Q_r/N \quad (10)$$
$$= 41.59\times10^4/13.044\times10^4$$
$$=3.19$$

The system COP of 3.19 in fact is better than the design system COP_{th} of 2.83.

5. Renewable Energy Resource Use

The renewable energy resource use in the heating season for building is:

$$\eta = (1-1/COP) \times100\%=68.7\% \quad (11)$$

VI. Terminal Scheme

The terminal subsystem in this project mainly uses the original heating devices (Radiators). In addition, the fan-coil units are added in the big classroom. In this way, the project cost is greatly decreased.

VII. Conclusion

Before 2006, Xing Huan Co. (one of the 6-centralized heat supply companies in the town) was responsible for delivering the winter-heating supply for the school. The coal fired boilers in Xing Huan Co. were used to provide the winter heating for the total construction area of $8.9\times10^4m^2$. The Xing Huan Co. had a boiler room of $1000m^2$ and a coal depot and cinder yard of $800m^2$.

After reforming the heat supply system in the middle school, the HYY ground sourced heat pump system provides the winter heating for the building. HYY system uses the shallow ground thermal energy (not coal) as the energy resource, does not release any harmful gas, vapor and particles. HYY system saves the coal of 192 ton every year for the heat supply company, and reduces the emissions of CO_2 with 297.6 ton/y, SO_2 with 6.2 ton/y, NO_x with 2.0 ton/y, the solid particles with 14.3 ton/y, and the smog with 157 Nm^3/y, respectively.

Running the system obtained an excellent economical result: the room temperature in the heating season reached 18-23°C, the total heating expenses of electric fee was \$1.7USD/m^2, which was only 44.3% of the local standard heating fee of \$3.8USD/m^2.

The operation result of the HYY system in the last winter season had a very good coefficient of performance COP: 3.19. The Renewable energy resource use in a heating season for building is $\eta = 68.7\%$.

This project is first one in China utilizing the seawater-ground sourced heat pump system to provide the winter heating for building. This is as a good example to spread HYY system application in Dalin area and along the coast of China. HYY systems will have a bright future.

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