A Brief Introduction to a Pilot Cool-heat Dual-supply Project Utilizing Heating Pump and Heat Source From Shallow Groundwater On a Household Metering Basis In Zibo High-tech Zone

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Abstract: To implement China's *Stipulations on the Energy Economy Administration*, considering the fact that heat-supplying products cannot meet the needs of market and diversification, and on the basis of basic principles of developing and saving energy, of reducing the expenditures and of minimizing pollution, a pilot energy-saving heating system project, able to supply both cool and heat by utilizing heating pump and heat source from shallow groundwater on a household metering basis, was established in 1999 in Hexiangyuan residential living area of Zibo High-tech Industrial Zone. The experiences, accumulated in 3 years' operation, have proved that this system runs smoothly and stably, and that the results of saving energy and reducing expense are very obvious. After many years' operation, system softwares and hardwares, concerning low-grade heat resource development, large-scale heating pump modification, shallow underground water source development back-irrigating observation protection, energy economy operation during the change of the running status, financial evaluation indices of system planning construction, have been developed. The system consists of 5 sections: low-grade heat resource, cooling and heating stations, outside network, individual household cool and heat metering, and indoor end part. Its cooling and heating costs are over 50% lower than the state prices in the local. All of its economic, environmental, and social results are obvious.

Key words: low-temperature shallow groundwater heat source heating pump individual household metering and cool-heat dual-supply energy economy cool-heat system

1. Introduction

To implement China's *Stipulations on the Energy Economy Administration*, to meet the increasing demands of residents for living comfort level and personality, facing the mono function of China's city central heat-supplying manner, the large and complicate heating system, high consumption of the energy, expensive price and serious pollution, and considering the fact that heat-supplying products cannot meet the needs of market and diversification, and on the

basis of basic principles of developing and saving energy, of reducing the expenditures and of minimizing pollution, a pilot energy economy heating system project, able to supply both cold and heat by utilizing heating pump and heat source from shallow underground water on a household metering basis, was established in 1999 in Hexiangyuan residential living area of Zibo High-tech Zone. The experiences accumulated in 3 years' operation have proved that this system runs smoothly and stably, and that the results of saving energy and reducing expense are very obvious. According to the system operation practices, system softwares and hardwares concerning low-grade heat source development, large-scale heating pump modification, shallow groundwater source development back-filling monitor protection, energy economizing operation during the change of the running situation of the cool-heat station, financial evaluation indices of system planning construction have been developed.

This pilot project of heating system is situated in Hexiangyuang residential area of Zibo Hi-tech development zone in Shandong province. Its present service area is 34,000 square meters among which the six-floor living building area is 26000m^2 and the five-floor public building is 8000m^2 with construction height of 20 meters. The first floor of the public building is a dinning hall, and the 2^{nd} to 5^{th} floors are offices. Its construction is a frame structure with glass windows of aluminum alloy. The second phase service area of the project reaches 50,000m^2, and the planning service area 300,000$m^{2.}$

Near the residential area is a centered heat-supplying boiler, which only supplies the heat in winter. The state prices of heat-supplying pipe opening fees in RMB are as follows: 90 yuan/ m^2 for a public building, and 70 yuan/ m^2 for a civil building; The heat-supplying price is 18 yuan/ m^2 for a public building and 16.5 Yuan/ $m^2$for a civil building. The cool-supplying pipe opening fees are 100 yuan/ m^2 for a public building, and 80 yuan/ m^2 for a civil building. The cool-supplying price is 28 Yuan/ m^2 for a public building and 25 Yuan/ m^2 for a civil building. If the cool-heat centralized co-supplying calculated area is 34,000 m^2, cool-heat pipe-opening fee is 5.42 million yuan in RMB, and the cool-heat pipe-opening fee for 50,000 m^2 is 7.98 million yuan in RMB (not including outdoor network and indoor system investments). On the basis of the cool-heat supply needs from building functions and the users in the living district along with technical economic analysis, it is decided to develop the energy-saving system.

The system consists of five parts: cool-heat source, cool-heat station, outside network, individual household metering, and indoor end terminal. The initial investment of this system is very low. Cool-heat operation fees in summer and winter are over 50% lower than the local state price. The heating pump energy efficiency rate is high, and cool-heat source is not pollutant to the environment. Groundwater back-irrigating ratio is 100%. The results of economy, environment protection and social are marked.

2. System cool-heat source:

2.1 Basic situation of cool-heat source:

Low temperature shallow groundwater is a cool-heat source, which belongs to a low-cost, reproductive, and pollution-free energy resource; and which spreads widely. Its development and utilization conform to the state's environmental protection policy of energy resource. But it should be in accord with local water resource policy.

Zibo's northern plain district is rich in shallow groundwater with high water level. Water level is about 10 meters from the earth surface. This district belongs to alluvial plain in front of mountain. Its earth stratum is mainly silt and clay bed. Its underground water being highly

mineralized degree is of inferior quality, thus it is not applicable to industrial water. Underground water, whose temperature is about 16°c, can provide a good condition for the system operation if using it as cool-heat source. Based on this determination, wells can be locally laid out to use as system cool-heat source. After the local government comprehensively balanced the factors like environmental protection, energy economy, and water resource protection, water resource department determines an administrative policy on and requirement to the metering of the shallow groundwater drawing and back irrigating quantity, and balance fees for utilizing shallow groundwater and low-temperature underground heat source. Therefore, many items of the special technology have been developed for this system in order to guarantee the overall balance of shallow groundwater drawing and back-irrigation quantity.

2.2 Layout of shallow underground well

The wells are ladder-like laid out, one draw well at the bottom and one irrigating well at the above. There are two draw wells and two back-irrigation wells; altogether there are 4 wells. Furthermore there is one shallow groundwater observation well.

Water quality is listed in Table 1.

Table 1. Parameters of cool-heat source well

Well depth	Pipe-well Diameter	Salt content	Sand content	Water temp.	PH value
m	mm	G/L	mg/l	°c	
58	300	6	0.1	16	7.1

2.3 Scale of cool-heat source

To be determined by the present status, planning service scale and other factors: 50～100 cubic/hour at the present status and 200～500 cubic/hour for the planning scale.

2.4 Basic parts and operation situation of cool-heat source system:

The cool-heat system is made up of three parts: diving pump, flow meter and sand remover. The operation situation is a completely sealed and open circulation. Water levels of the draw well and back-irrigation well are changing between –5 meters and +8 meters vs. the quiet water level. The current service area is 80～90 cubic per hour while the groundwater back irrigating rate is 100%. In three years' operation, water quality and water temperature of the observation well keeps at 16°c without any change while water temperature of the draw well changes between –2°c and +2 °c, and the changes of the water temperature of back-irrigation well are between –5°c and +5°c. The shallow earth heat energy utilized per year is 1741Mw.h/a.

3. Cool-heat station:

3.1 According to the living district plan, and the design of construction schedule and service scale, the local position of cool-heat station is determined at the north side of the first phase of the project: It is integrated into transformer substation, water supply station, fire pump station and neutralizing water station in the living district. It has versatile functions, occupies a compact land with low investment, and is very easy for the management. Its operation shop is 20 meters long, 9 meters wide and 4.2 meters high. The first phase of the project has two sets of 850kw heating pumps with the service area of 34,000 m^2. During the peak hour, its load rate may reach 70%. 2 —3 sets positions have been pre-left, thus its service area may be enlarged to 10 —20 square meters.

3.2 Constitution of cool-heat station system

Its plan layout is made up of heating pump zone, circulation system zone and shift control zone.

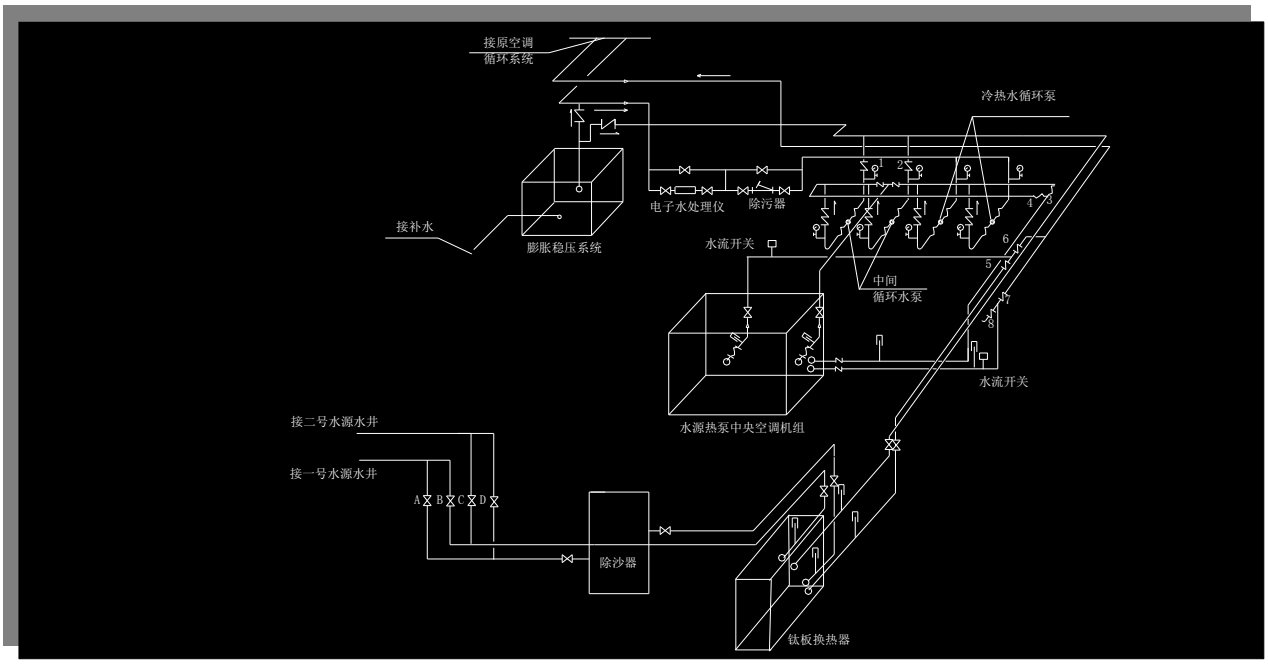
The application of heating pump:

The first phase of the project utilizes a set of traversing compressor while the second phase uses a set of screw compressor. Temperature difference will be automatically controlled. In the first phase of the project, the transform of the operation status between the winter and the summer is taken place in the outside of the heating pump set. In the system of heating pump sets, there are 8 transform valves used for the change of operation status. In the summer operation, No. 1, 3, 5, 7 valves are open while No.2, 4, 6, 8 valves closed: In the winter operation, No. 1, 3, 5, 7 valves are closed while No. 2, 4, 6, 8 valves open. In the second phase of the project the transform of operation status between winter and summer will be taken place in the inside of the heating pump set.

Three years' running records and inspection results show that the operating COP of heating pump set is 4～5. Energy-economizing results are notable.

In cool-heat water circulating system, the main equipments are automatic water re-supply facility, electronic contaminant releaser, dirt remover and water separator.

Constitution of cool-heat station system



4. Outside network of the system:

The outside network is scheduled in one time and will be implemented by stages. According to the overall layout of the living district, it is divided into 3 zones of the east, the middle and the west. In the first phase of the project, there are two pipelines in the middle zone. One pipeline is for the public building area, and the other is for the residential area. They are located on the basis of the comprehensive demand for the pipe net of the living district. The pipes are insulated by polyurethane and buried directly. The circulating water pipeline, based on the actual situation, is equipped with drain valve, vent valve and connection valve.

5. Indoor individual household metering cool-heat system:

To carry out the related policy on the save of the energy in the construction, and to meet the market demands, an individual building utilizes cool-heat metering on an individual household basis and separately controlled. This system is designed with main pipeline on one unit basis. Each household utilizes horizontal and parallel dual-pipe system. The head part of an inlet pipe is equipped with one piece of Shuangneng Brand cool-heat metering gauge manufactured in China.

The end part is a piece of coil pipe for the blower, which may be used by the users to adjust and control room temperatures by themselves. The insulation material for pipeline is foamed rubber plastic.

6. Automatic control:

The project automatically controls the equipment that needs to be controlled. It can achieve a sequence of automatic start and stop between the central air conditioner of water source heating pump and water pump. When water pump stops suddenly, water flow switch will be used to stop the running compressor of main machine in order to protect the central air conditioner of water source heating pump.

7.Operation status:

Since the system was erected, commissioned and put into operation in June 1999, it has kept a good overall result, and at the same time it reaches a notable energy-saving result. Its major section parameters are as follows:

In summer — Cool water supply and return water temperature of the circulating system: $7^{o}c/12^{o}c$;
Inlet and outlet water temperature of shallow groundwater: $15^{o}c$ /$20^{o}c$;
Indoor temperature: $22\sim28^{o}c$;
During the refrigerating period, the heating pump sets run 16～24 hours per day, and the operation cost is 4.6 yuan/m^2

In winter — Circulating water supply and return water temperature: $46^{o}c$ /$42^{o}c$
Shallow groundwater supply and return temperature: $15^{o}c$ /$10^{o}c$;
Indoor temperature: $16\sim20^{o}c$;
During the heating period, the set of heating pump runs 16～24 hours daily, and the operation cost is 11.5yuan/$m^{2.}$

8. System inspection data:

The system has been comprehensively inspected for its running states in two summers and

one winter separately by the Inspection Center of the Ministry of Nation Defense Science & Industry Committee, Shandong Refrigerating Equipment Inspection Center, and Jiangsu Chiller Quality Inspection Station etc. Its main parameters are listed in the following:

8.1 Heat-supply quantity, COP and heat energy abstraction quantity:

Test data from February 16, 2000 to December 23, 2000 are listed in the following tables:

Performance test of heating pump sets in winter

Time	Circulating water temperature(^{o}c)	Output heat quantity	Heating pump input power (KW)	COP
02-16-2000	1.4	388	37×2=74	5.2
02-18-2000	1.3	348	37×2=74	4.7
02-23-2000	1.2	320	37×2=74	4.3

Test of the utility quantity of low-temperature shallow groundwater heat energy in winter

Time	Water quantity (m^3/h)	Well temperature (^{o}c)	Back irrigating water temperature (^{o}c)	Temperature difference (^{o}c)	Heat energy abstract quantity
12-16-2000	160	16.0	13.0	3.0	558
12-18-2000	160	16.0	13.0	3.0	558
12-23-2000	160	16.0	13.0	3.0	558

8.2 Refrigerating quantity, COP and heat energy abstraction quantity:

Test data from June 20, 2000 to August 18, 2000 are listed in the following tables:

Performance test of heating pump sets in summer

Time	Circulating water temperature(^{o}c)	Output heat quantity	Heating pump input power (KW)	COP
06-20-2000	1.2	362	37×2=74	4.9
07-21-2000	2.2	652	37×4=148	4.4
08-18-2000	2.3	669	37×4=148	4.5

Test of the utilization of low-temperature shallow groundwater heat energy in summer

Time	Water quantity	Well temperature (^{o}c)	Back irrigating water temperature (^{o}c)	Temperature difference (^{o}c)	Heat energy abstract quantity
06-20-2000	120	16.0	18.5	2.5	397
07-21-2000	120	16.0	21.0	5.0	698
08-18-2000	120	16.0	20.5	4.5	688

8.3 Inspection of the changes of water level and temperature in pump wells,

back irrigation wells and observation wells

Inspection of changes of water level and temperature in No.1 pump well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	16.0	11	Clear	No Change
07-21-2000	16.0	11	Clear	No Change
08-18-2000	16.0	11	Clear	No Change

Inspection of changes of water level and temperature in No.2 pump well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	16.0	16	Clear	No Change
07-21-2000	16.0	16	Clear	No Change
08-18-2000	16.0	16	Clear	No Change

Inspection of changes of water level and temperature in No.1 back-irrigating well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	18.5	3~4	Clear	No Change
07-21-2000	21.5	3~4	Clear	No Change
08-18-2000	21.0	3~4	Clear	No Change

Inspection of changes of water level and temperature in No.2 back irrigating well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	18.5	3~4	Clear	No Change
07-21-2000	21.5	3~4	Clear	No Change
08-18-2000	21.0	3~4	Clear	No Change

Inspection of changes of water level and temperature in No.1 observation well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	16.0	11	Clear	No Change
07-21-2000	16.0	11	Clear	No Change
08-18-2000	16.0	11	Clear	No Change

Inspection of changes of water level and temperature in No.2 observation well

Time	Water Temp. (^{o}c)	Water Level (m)	Turbidity	Water Quality
06-20-2000	16.0	11	Clear	No Change
07-21-2000	16.0	11	Clear	No Change
08-18-2000	16.0	11	Clear	No Change

9. Analysis on the comprehensive results

Whether the system is advanced or not, it should reflect many directions of the composite results while composite results are mainly composed of construction investment, operation cost, energy economy result and environmental protection result.

9.1Construction investment:

	The first phase of the project	The second phase of the project	Projection scale	Remark
Construction Scale	34,000m^2	50,000 m^2	300,000 m^2	
Initial Investment	3.45 million yuan	3.3 million yuan	13 million yuan	Ney system
Initial Investment	180×3.4=6.12 million yuan	160×5=8 million yuan	12×30=36 million yuan	Traditional system
Minimizing Funds Compared With the Same period	2.67 million yuan	4.7 million yuan	23 million yuan	Fund economy result is marked.

9.2Operation cost

Construction Scale	34,000m^2	50,000 m^2	300,000 m^2	Remarks
Cool-heat dual-supply	Cool-supply: 4.5×3.4=0.15million yuan Heat-supply: 12×3.4=0.408 million yuan Total:0.5588 million yuan	Cool-supply: 4.5×5=0.225 million yuan Heat-supply: 12×5=0.6 million yuan Total:0.885 million yuan	Cool-supply: 4.5×30=1.35 million yuan Heat-supply: 12×30=3.60 million yuan Total:4.95 million yuan	Measured according to the actual data
Traditional cool and heat supply system	Cool-supply: 25×3.4=0.85million yuan Heat-supply: 16.5×3.4=0.561 million yuan Total:1.411 million yuan	Cool-supply: 25×5=1.25million yuan Heat-supply: 16.5×5=0.825 million yuan Total:2.075 million yuan	Cool-supply: 25×30=7.50million yuan Heat-supply: 16.5×30=4.95 million yuan Total:12.45 million yuan	On the basis of the price stipulated by the state
Minimizing operation cost compared with the same period	0.8522 million yuan	1.19 million yuan	7.50 million yuan	Fund economy result is notable

9.3Energy economy result

Minimizing coal consumption amount compared with the same period (year)	2096T/a	4030T/a	24185T/a
Saving regeneration energy compared with the same period(year)	1741Mwh/a	3349Mwh/a	20054Mwh/a

9.4 Environmental protection result

Heat supply manner	MO	SO_2	Co	CmHn	Fume dust	Remark
Central boiler house	240.6	424	36	11.9	39.75	Sodium content of coat is 1%
Thermal power plant	197.8	347	5	2	22.8	The same as above.
Decentralized gas boiler	34	0.17	4.82	0.85	1.7	Sodium content of natural gas is $4.6kg/10^6 m^3$
Decentralized gas heat supply	22.7	0.17	5.67	2.27	1.7	The same as above
This system	0	0	0	0	0	No pollution

To sum up, the cool-heat dual supply system may provide remarkable results of environmental protection, energy economy and fund reduction.

10. Conclusion:

Although the result of this system has been proved by the time, there are still many aspects to be developed and studied. Therefore, from the viewpoints of low-cost circulation energy utilization, construction energy economy, city cool-heat dual-supply, and the development of energy-saving equipment product, the following six subjects has been developed for the improvement of the new system:

(1) Planning design technical demand for cool-heat dual supply system utilizing heating pump (shallow groundwater source) on an individual household-metering basis

(2) Safety operating technical specification for cool-heat dual supply system utilizing heating pump (shallow groundwater source) on an individual household-metering basis

(3) Technical specification for water supply well and water return well in cool-heat dual supply system utilizing heating pump (shallow groundwater source) on an individual household-metering basis

(4) Dynamic observation stipulation for water supply well and water return well in cool-heat dual supply system utilizing heating pump (shallow groundwater source) on an individual household-metering basis

(5) Maintenance administrative stipulation for cool-heat dual supply system utilizing heating pump (shallow groundwater source) on an individual household-metering basis

Through the above six subject studies, the system may be further improved and standardized.

From the policy points of the global environment protection and sustainable development of national energy resource, it is suggested that managing department should provide the same power price policy to cool-heat system utilizing heating pump shallow groundwater low-cost heat energy) with the preferential power price of heat supply system utilizing power boiler so as to make the state obtain the biggest results of environment protection and energy economy; and to make the enterprise get the power market enlargement and reduce the power peak difference, and to make the users minimize their capital investment and their expenditure on running

expenses.

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