STUDY ON ENERGY EFFICIENCY EVALUATION AND INFLUENCING FACTORS OF GROUND SOURCE THERMAL ENERGY MANAGEMENT SYSTEM OPERATION

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The paper combines the testing work of ground source heat pump systems, discusses the installation, use methods and test errors of various testing instruments, combines the field test experience, gives the main points of ground source heat pump energy efficiency testing; and according to the problems encountered during the test The faults with high frequency are analyzed, and the methods of fault diagnosis and troubleshooting are given. This paper uses the ground-source heat pump experimental platform to set up multiple sets of experimental schemes to study the impact of factors such as pipe diameter, single and double U, and flow rate on system energy efficiency. At the same time, it combines engineering cases to "large flow small temperature difference", "Imbalance" phenomenon is analyzed, and feasible solutions and suggestions are given. By analyzing the energy efficiency and benefits of actual engineering of multiple ground source heat pump systems, the paper concludes that ground source heat pump systems have a wider application prospect in a certain area of Hubei.

Key words*: Ground source thermal energy management system; effectiveness evaluation; effectiveness influencing factors*

1. Introduction

Local conditions the development of heat pump system, help to optimize the energy structure, improving energy efficiency. The use of geothermal ground source heat pump, air-conditioning as a way of saving and green environmental protection, will become an important and effective HVAC technology. However, due to the late development of the country, ground source heat pump technology is still immature in engineering applications, there are many problems to be solved, and ground source heat pump system by the geological location of the project, the larger meteorological environment in the design and construction not one is concerned, it is necessary to guide the analysis and design experience in similar projects. Further, the specific energy savings using ground source heat pump system is how in practical applications, it is necessary to analyze engineering example [1].

Based on the field test experience, this paper summarizes the problems in the use of the test instrument, summarizes the installation, use of the test instrument, and related precautions, and provides a reference for the use of the ground source heat pump test instrument to improve the accuracy of the test. The actual measurement situation on the paper, summarizes and analyzes the system operation problems encountered during the test, and uses the test platform of the ground source heat pump test center to design different test schemes and analyze the factors affecting the energy efficiency of the system operation.

2. Basis and method for energy efficiency test of ground source heat pump system

2.1. Calculation method of thermal balance of Lake Ku

For surface water source heat pumps summer heat discharging into water bodies, from taking hot water, it would be the water temperature changes in winter, may even cause some degree of thermal pollution of water bodies, and therefore respond to the reservoir and lake water before the lake are ground source heat pump system design heat balance calculation. For reservoirs and lakes retained water, the heat exchange surface water with the outside world includes: solar radiation, atmospheric longwave radiation, water longwave radiation, evaporation of the water body, with the convective heat transfer of the air, the bed of convective heat transfer and heat pump the row unit (take) heat, the heat transfer mechanism shown in Fig.1.

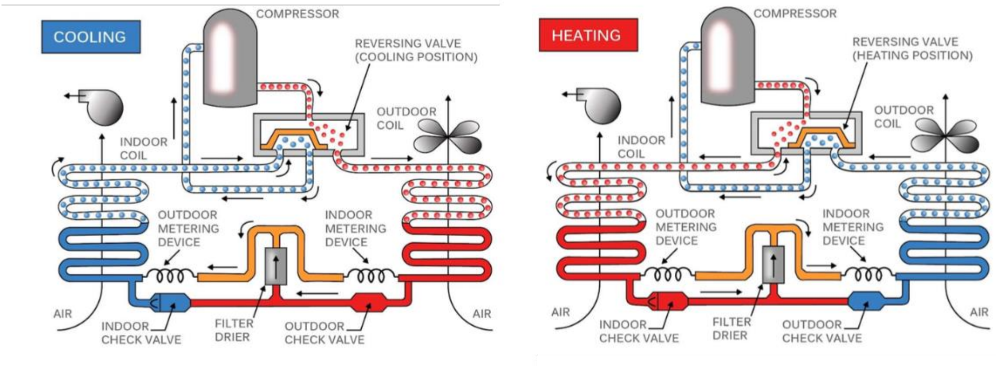

Fig. 1 Heat exchange mechanism of Lake ground source heat pump system

2.1.1 Thermal balance equation

The heat transfer mechanism of the reservoir lake ground source heat pump system shown is based on the principle of conservation of the reservoir lake energy, and the lumped parameter method is used to establish the reservoir lake governing equation:

$$q_{in}\text{-}q_{out}=V\rho c_p\frac{dT}{dt} \tag{1}$$

Among them: q_{in} represents the heat gain of Lake Ku; q_{out} represents the heat loss of Lake Ku; V represents the volume of Lake Ku; ρ represents the density of water; c_p is the specific heat capacity of the lake water; dT/dt is the rate of temperature change of the lake water .This method assumes that the temperature of the lake itself is negligible. According to the heat transfer mechanism in Figure 1, formula (1) can be expressed by the rate of change of the average temperature of the Ku Lake:

$$\frac{dT}{dt}=(q_{\text{solar}}+q_{\text{thermal}}+q_{\text{convection}}+q_{\text{ground}}+q_{\text{groundwater}}+q_{\text{evaporation}}+q_{\text{fluid}})/\rho Vc_p \tag{2}$$

Among them: q_{solar} represents the heat generated by solar radiation on the surface of Lake Ku; q_{thermal} represents the radiant heat transfer on the surface of Lake Ku; $q_{\text{convection}}$ represents the convective heat transfer on the surface of Lake Ku; q_{ground} represents the heat transfer of Lake Ku in the earth; $q_{\text{groundwater}}$ represents the seepage heat transfer of Lake Ku water; $q_{\text{evaporation}}$ represents the mass or heat transfer caused by evaporation from the surface of Lake Ku; and q_{fluid} represents the total heat transfer of the Lake Ku heat exchanger [2].

2.1.2 Convection heat transfer on the surface of Lake Ku

Finally, the convective heat transfer density $q_{convection}$ on the surface of the Lake Ku is calculated by the following formula:

$$q_{convection} = h_c A_{pond} (T_{air} - T_{pond}) \tag{3}$$

Among them: T_{air} represents the outside air temperature; h_c represents the comprehensive convection heat transfer coefficient of natural convection and forced convection.

2.2. Calculation method of related energy efficiency index of ground source heat pump system

2.2.1 The performance index of the heat pump unit represents the representative coefficient of performance

The cooling (heating) coefficient of performance COP of the unit is calculated according to the test results according to formula (4) [3].

$$COP = \frac{Q}{N_i} \tag{4}$$

Where: COP represents the cooling (heating) coefficient of the unit during the test; represents the average cooling (heating) amount of the unit during the test, kWh; N_i represents the average input power of the unit during the test, kW.

2.2.2 Energy efficiency ratio of heat pump system in typical season

The operation process of the ground source heat pump system is a process of transferring heat. It achieves the purpose of heat transfer through the coordination of the three subsystems of the refrigerant circulation system, the user-side water system and the ground-source side water system. According to the test data, the system cooling energy efficiency ratio and heating energy efficiency ratio of the ground-source heat pump system in typical seasons are calculated according to formula (5) and formula (6), respectively.

$$EER_{SL} = \frac{Q_{SL}}{N_i + \sum N_j} \tag{5}$$

$$EER_{SH} = \frac{Q_{SH}}{N_i + \sum N_j} \tag{6}$$

Where: EER_{SL} represents the cooling energy efficiency ratio of the heat pump system; EER_{SH} represents the heating energy efficiency ratio of the heat pump system; Q_{SL} represents the total cooling capacity during the test, kW · h; Q_{SH} represents the total heating capacity during the test, kW · h; N_i represents The power consumed by the heat pump unit during the test, kW · h; N_j represents the power consumed by all water pumps during the test, kW · h. The total cooling (or heating) amount Q during the test is calculated according to formula (7).

$$Q = V\rho c\Delta t_w / 3600 = \sum_{i}^{n} q_i \tag{7}$$

Where: V represents the average flow on the user side of the heat pump unit, m^3/ h; Δt represents the temperature difference between the inlet and outlet water of the user side of the heat pump unit, ℃; ρ represents the average hot water density, kg / m^3; c represents the average constant pressure specific heat of the hot water,, $kJ\left(kg\bullet^{\circ}C\right)$ ρ, c can be obtained from the physical parameter table according to the average temperature of the inlet and outlet of the medium.

2.2.3 *Efficiency of conveying equipment*

The key to energy savings. Through statistics of pump inlet and outlet pressure, power, flow and other parameters related to the operation of the pump during the statistical test, understand the delivery efficiency of the conveying equipment under the actual operating conditions of the system [4]. According to the test data, the efficiency of the conveying equipment is calculated according to formula (8).

$$\eta = V \rho g \Delta H / 3.6P \tag{8}$$

In the formula: V represents the average water flow of the pump, m^3 / h; ρ represents the average density of the water, kg / m^3, which can be obtained from the physical parameter table according to the water temperature; g represents the free-fall acceleration, $9.8 m / s^2$; ΔH represents the average of the pump Head: average pressure difference between inlet and outlet, m; P represents average input power of pump, kW.

2.3. Energy Efficiency Test

2.3.1 *Test process*

In order to complete the energy efficiency evaluation of ground source heat pump system accurately, efficiently and completely, a set of relatively complete evaluation process is summarized based on actual evaluation experience and work, as shown in Figure 2.

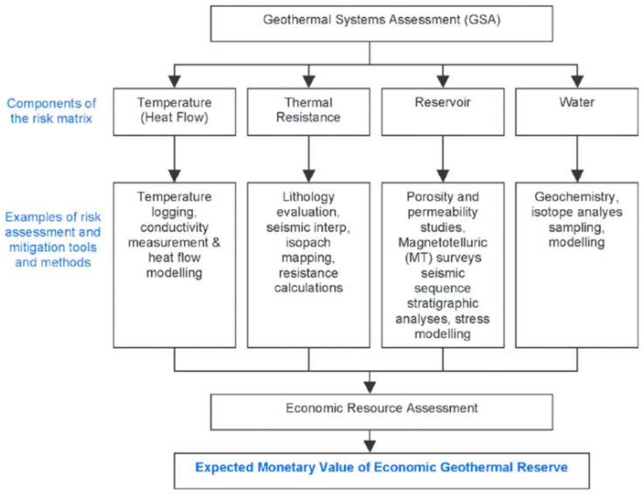

Fig.2 Evaluation flowchart

2.3.2 *Test conditions*

Ground source heat pump system of assessment should be carried out after the completion of the project to acceptance and put into normal use. Evaluation GHP systems in cooling performance should be a typical cooling season, heating performance assessment should be carried out in a typical heating season. Test conditions of the heat pump coefficient of performance cooling / rated conditions as close to the unit, the unit load ratio should be more than 80% of the rated value; EER system test conditions as close to design conditions of the system, loading rate of the system should meet the design value of 60% or more; indoor air temperature, the humidity is detected in a building should be reached after thermally stable. While the outdoor meteorological parameters monitored during the test, recording changes in the weather, outdoor air temperature and humidity.

3. Case analysis

3.1. Project Overview

Hubei Province, a total construction area of 34216.2m^2 hotel, including air-conditioning area 21107.6 m^2. Cooling load is 3124kw, air-conditioning heat load of 1655kw, maximum domestic hot water consumption is 60T / day. The use of water source heat pump cold and heat sources, sanitary hot water using solar energy + water source heat pump hot water unit auxiliary heat source. Water resource and water as a river nearby, the way water is percolating [5].

The unit selection and related technical parameters are as follows: 2 SGHP1600AII water source heat pump units; 1 SGHP300AII water source heat pump hot water unit. Table 1 and Table 2 show the relevant parameters of the hotel geothermal pump.

Table 1 Unit selection and related technical parameters

project			SGHP300AII	SGHP1600AII
Refrigeration conditions	Nominal cooling capacity kw		294	1476
	Input power kw		54	263
	Evaporator	Cold water inlet / outlet temperature ℃	12/7	12/7
		Cold water flow m³ / h	51	254
		Cold water resistance kpa	≤100	≤100
	Condenser	Water inlet / outlet temperature ℃	18/29	18/29
		Cold water flow m³ / h	27	136
		Cold water resistance kpa	≤100	≤100
Heating conditions	Nominal cooling capacity kw		330	1630
	Input power kw		73	355
	Evaporator	Cold water inlet / outlet temperature ℃	15/7	15/7
		Cold water flow m³ / h	27	136
		Cold water resistance kpa	≤100	≤100
	Condenser	Hot water inlet / outlet temperature ℃	40/45.5	40/45.5
		Hot water flow m³ / h	51	254
		Hot water resistance kpa	≤100	≤100

The pump selection is shown in Table 2:

Table 2 Model and related parameters of water pump

Serial number	name	model	specification	unit	Quantity	Remark
1	Air-conditioning circulating water pump	200-3151A	G=260m³/h, n=2900r/min, H=32m, N=45KW, 560kg	station	3	Two for one preparation

2	High-temperature air-conditioning circulating water pump	100-160	G=100m³/h, n=2900r/min, H=32m, N=15KW, 191kg	station	2	One use, one preparation
3	Air-conditioning cooling water pump	ISL125-125A	G=250m³/h, n=2900r/min, H=16m, N=18.5KW, 305kg	station	3	Two for one preparation
4	High temperature air conditioning cooling water pump	100-125A	G=89m³/h, n=2900r/min, H=16m, N=7.5KW, 118kg	station	2	One use, one preparation

The layout of the pump room is shown in Figure 3, and the piping principle of the refrigeration station is shown in Figure 4.

Fig. 3 Plan view of the pump room

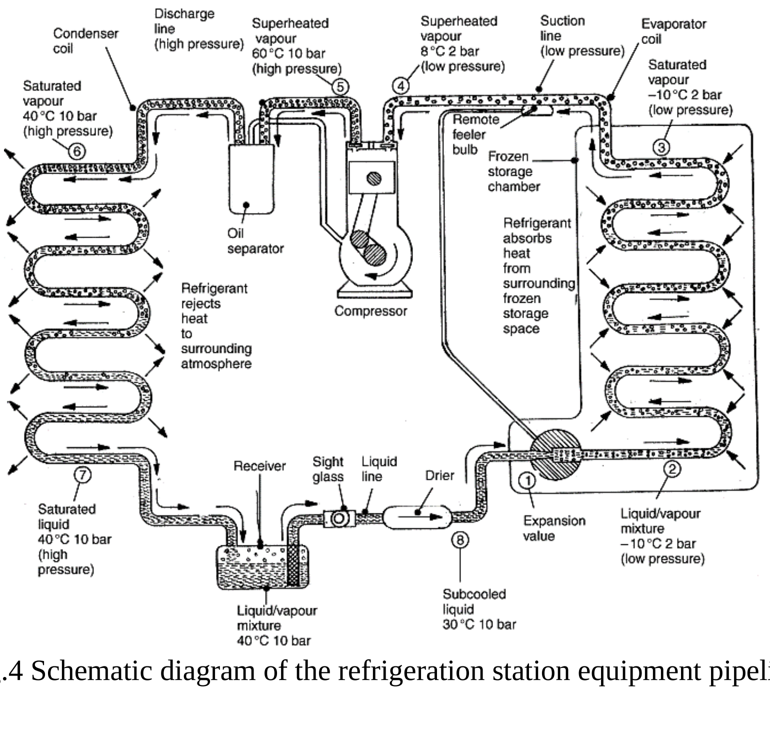

Fig.4 Schematic diagram of the refrigeration station equipment pipeline

3.2. Overview of withdrawal and withdrawal

The total water supply demand of the water source heat pump is 1000 m^3/h (24000 m^3/d), of which 400 m^3/h is for large hotels; 200m^3/h is reserved for other projects. The flow of the river during the dry season is 10188m^3 / s, and the total water supply demand is only 9.82% of the flow of the river during the dry season. The minimum water temperature of the river in winter is 8 ° C and the highest water temperature in summer is 25 ° C. The width of the river is about 40m, and the depth of the river when it is not raining is about 1m. Most of the dry season is dry beach. The width of riverside wasteland is about 15-20m. In order to ensure that the proposed water intake structure does not hinder flood control, the water intake structure is mainly set up in the wasteland of the river bank. The water intake structure adopts a first-level filter sedimentation tank and a second-level filter collection tank. Pools and secondary filter sumps. The fixed water intake structure includes: coarse grid, inlet gate, first-stage filtering sedimentation pool, fine grid, second-stage pool, and submersible pump located in the second-stage pool [6].

In order to meet the requirements of water intake and Yang Cheng, each hotel chooses two types of 200WQ400-30-55 water intake pumps, the specific parameters are shown in Table 3.

Table 3 Model and related parameters of water pump

Serial number	name	model	Model and parameters	unit	Quantity	Remark
1	Water pump	200WQ400-30-55	Q=400³/shah=30m	station	2	One use, one preparation

3.3. Technical parameters of other equipment

The technical parameters of other equipment (including water treatment equipment) are shown in the following table 4.

Table 4 Technical parameters of other equipment

Serial number	name	model	specification	unit	Quantity	Remark
1	Bypass processor		Capacity: 100m^3 / h-50m^3 / h	station	1/1	
2	Bypass processor		Capacity 600m^3 / h	station	1	
3	Trap		DN=600X800, L=3500mm	station	1	
4	Water trap		DN=600X800, L=3500mm	station	1	
5	Expansion tank	V=2.0m^3	Q=4-6m^3/hand=1.1kw	station	1	
6	Pressure hot water tank		V=16t	station	2	
7	Cistern		V=100t	station	1	

4. Analysis of test results

4.1. Test records and data analysis

During the test, the average outdoor temperature was 36.47 ° C and the relative humidity was 84.4% RH; the average temperature in the air-conditioned area was 24.22 ° C and the relative humidity was 73.53% RH. The flow, temperature and power test records are shown in Figures 3 and 4.

(1) See Fig. 3 for the change of frozen water flow during the test. The average chilled water flow of two units running in parallel is 355.47 m^3 / h (Figure 5 left), which is 9.7% higher than the sum of the rated flow of the units; the average chilled water flow of a single unit is 216.7 m^3 / h (Figure 5 right). 33.8% higher than the rated flow of the unit.

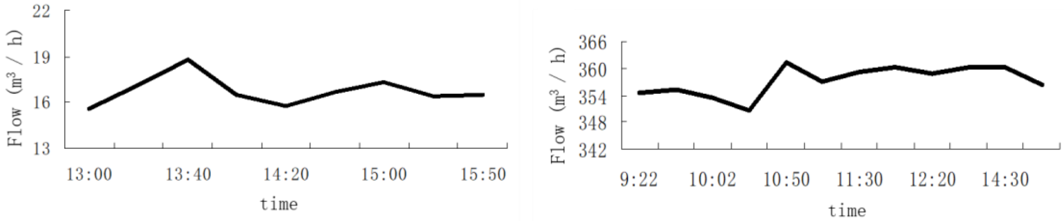

Fig.5 Change curve of frozen water flow during the test (left: working condition one; right: working condition two)

(2) See Figure 6 for cooling water temperature changes. A condition (left in FIG. 6): a cooling water inlet and outlet average temperature of 31.2 ℃, 34.1 ℃, the temperature difference is 2.9 ℃; chilled water inlet, an outlet average temperature of 12.1 ℃, 14.8 ℃, the temperature difference 2.7 ℃. Two conditions (FIG. 6 right): cooling water inlet, an outlet average temperature of 30.3 ℃, 32.4 ℃, the temperature difference is 2.1 ℃; chilled water inlet, an outlet average temperature of 12.7 ℃, 15.7 ℃, the temperature difference 3.0 ℃.

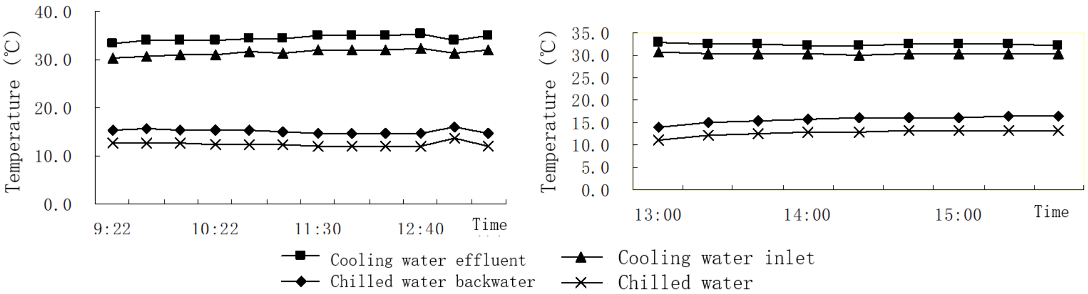

Fig.6 Temperature curve of frozen (but) water during the test (left: working condition one; right: working condition two)

(3) Working condition 1: The average temperature difference between the chilled water supply and return water is 2.7 ° C, the load rate of the main machine is 58.3%, and the system load rate is 55.4%. Working condition two: The average temperature difference between the chilled water supply and return water is 3.0 ° C, the host load rate is 80.2%, and the system load rate is 72.7%.

(4) The average performance coefficient of host # 1 is 3.76, and the average performance factor of host # 2 is 3.74; The average coefficient of performance of the host is lower than the coefficient of performance under rated conditions. Ground source heat pump host energy efficiency ratio COP = measured cooling capacity (measured heating capacity) / actual input power of the host; the integrated energy efficiency calculation formula of the host is (cooling capacity + heat recovery) / actual input power of the host.

(5) The energy efficiency COP of the system of two machines and two pumps is 2.6 (two compressors of 1 # host work, and one compressor of 2 # host works), and the system energy efficiency COP of one machine and one pump is 2.4. System energy efficiency = (total cooling capacity of the system + heat recovery capacity) / total input power of the system (unit + water pump).

(6) Indoor temperature and humidity. During the test, the average temperature in the air-conditioned area was 24.22 ° C, and the relative humidity was 73.53% RH.

4.2. Long-term monitoring

(1) Through long-term monitoring records, the annual power consumption is shown in Table 5. The power consumption per unit area is lower than the 2007 audit value of 30.37 kWh / m^2 for office building air-conditioning heating energy.

(2) Heating season: average host COP is 3.61, system COP is 2.50; cooling season: host average COP is 4.42, system COP is 2.74; transition season: host average COP is 4.52, system COP is 2.87.

(3) In winter, the full heat recovery unit is not used to make hot water, and only part of the heat recovery unit is operated.

Table 5 Accumulated power consumption throughout the year

Section	Host /kWh	Circulating pump /kWh	Hot water pump /kWh	Host	Pump	Power consumption per unit area /kWh/m^2
Heating season	92670	41166	5855	66.34%	33.66%	6.65
Transition season	1885	1543	5502	21.11%	78.89%	0.43
Air-conditioning season	79391	48464	5027	59.75%	40.25%	6.33
total	173945	91172	16384	61.79%	38.21%	13.40

4.3. Project payback period

The incremental cost of the ground source heat pump system used in the project is 2.91 million yuan, and the estimated annual operating cost is 414,500 yuan, which saves 395,700 yuan in operating costs compared to gas boiler + electric refrigeration system, and it is estimated that the incremental investment can be recovered in 7 years. The actual operation results show that the static investment payback period is 11.6 years, which is higher than the predicted time.

5. Conclusion

The paper found that the indoor temperature is low and the relative humidity is high. The reason for the relatively high relative humidity is the high temperature of the water supply; because the actual operation energy efficiency and load are lower than the theoretical calculation value, the actual investment payback period is higher than the predicted payback period; hot summer and cold winter areas, conventional air conditioning heating systems, cooling loads It is larger than the heating load, but when the heat pump is used as the cooling and heating source for cooling, heating, and sanitary hot water, the heat load may be greater than the cooling load. Whether to set an auxiliary cooling system needs comprehensive consideration. Get as close to reality as possible.

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