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The Research On Heat Pump Performance Which Use The Tail Water Of Middle-deep Geothermal Heating

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ABSTRACT

In order to improve the COP of middle-deep geothermal heating system, the research was conducted to analysis the performance and COP of the heat pumps which use the geothermal tail water (10℃~40℃) after the cascade utilization of the middle-deep geothermal heating system as the heat source. The results show that:The COP of the high-temperature heat pump when the heat source inlet water temperature is 38℃ is increased by more than 40% compared with that of the ordinary heat pump when the heat source inlet water temperature is 18℃；Comparing the system COP of three different equipment configuration schemes of ordinary heat pump, high temperature heat pump + ordinary heat pump, two-stage high temperature heat pump + ordinary heat pump, it is concluded that the energy efficiency of the two-stage high temperature heat pump + ordinary heat pump is 20% higher than that of the ordinary heat pump system. The results may provide optimization recommendations for engineering design.

1. PREFACE

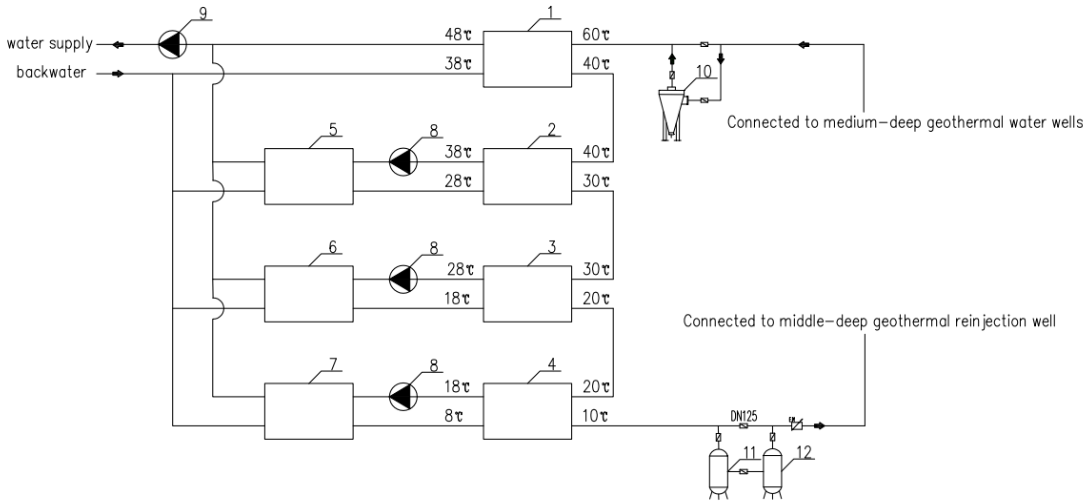
Under the dual-carbon [1] goal, it is the general trend to use clean energy to solve the winter heating problem in northern China. Geothermal energy is a green, low-carbon, recyclable and renewable energy with large reserves, wide distribution, clean, environmentally friendly, stable and reliable characteristics. It is a practical and competitive clean energy [2], which is favored by experts, scholars and clean heating enterprises.

The medium-deep geothermal energy has high taste and good economy, and is widely used in heating projects in the north. However, it is a common phenomenon that the tail water is not fully used or the efficiency is low. Therefore, it is urgent to study the efficient cascade utilization of medium-deep geothermal energy. Taking Zhoukou, Henan Province as an example, the outlet water temperature of 1300~1500 meters deep geothermal water is generally 50~60 ℃, and the temperature of the tail water discharged back to the ground is generally about 40 ℃ due to the restriction of the return water temperature of the courtyard heating pipe network in the residential area. If there is no cascade utilization, the utilization rate of resources will be greatly reduced, and the unreasonable cascade utilization will greatly reduce the COP of the geothermal heating system in the middle and deep layers. Use the heat pump system to realize cascade utilization, and compare and analyze different types of heat pump coupling utilization schemes to find the coupling scheme with high utilization rate and the best system energy efficiency is the focus of this paper.

2. INTRODUCTION TO MEDIUM-DEEP GEOTHERMAL HEATING SYSTEM AND HEAT PUMP EQUIPMENT

2.1 Medium-deep geothermal heating cascade utilization system

The principle of central heating with medium-deep geothermal water is to obtain geothermal water through the development of geothermal resources, extract the heat of geothermal water for heating through cascade utilization technology, and return the tail water after heat extraction to the same stratum. The whole process only takes heat without water, the system operates in a closed manner, and the water quality does not change [3]. The hot water is extracted from the heat source well, and then enters the plate heat exchanger in the station building after the impurities in the water are removed by the cyclone desander. The softened water in the secondary pipe network is heat exchanged by the plate heat exchanger, so that the heated circulating water is sent to the residential room for heating. The second to fourth stage plate heat exchanger is connected to the second to fourth stage heat pump host, and the heat pump host is started step by step according to the end use load. The temperature of the reinjection water is reduced from 40 ℃ to 10 ℃ at the maximum load, so that the utilization rate of geothermal resources can be increased by 250% at the maximum. After the heat exchange, the well water will be filtered by the coarse efficiency filter and the precision filter for the second time, and then returned to the same thermal reservoir underground, so as to achieve the sustainable renewable utilization of geothermal resources, and truly realize the heat without water. The system mainly includes production well, reinjection well, heat pump host, plate heat exchanger, cyclone desander, coarse precision filter, intermediate circulating pump, end circulating pump and other equipment.The working principle is shown in Figure 1.



1-Primary board replacement，2-Secondary board replacement，3-Three-stage plate replacement，4-Four-stage plate replacement，5-Secondary heat pump，6-Three-stage heat pump，7-Four-stage heat pump，8-Intermediate circulating pump，9-End circulating pump,10-Cyclone desander，11-Coarse filter，12-Precision filter

Figure 1: Schematic diagram of geothermal heating cascade utilization system

2.1 Heat pump host

The heat pump host includes four core components: compressor, condenser, expansion valve and evaporator. The system diagram is shown in Figure 2. The configuration of ordinary heat pump unit and high temperature heat pump unit is different. The relevant configuration of heat pump host used in this data analysis is as follows: the ordinary heat pump host uses Carrier 06TX series compressor, the evaporator heat exchange area is 22 ㎡, the condenser heat exchange area is 34 ㎡, the maximum allowable water inlet temperature at the heat source side is 20 ℃, and the maximum water outlet temperature at the condensation side is 55 ℃; Hanzhong RC2 series compressor is selected as the high temperature heat pump unit. The heat exchange area of the evaporator is 26 ㎡, the heat exchange area of the condenser is 40 ㎡, the maximum allowable water inlet temperature at the heat source side is 39 ℃, and the maximum water outlet temperature at the condensation side is 65 ℃.

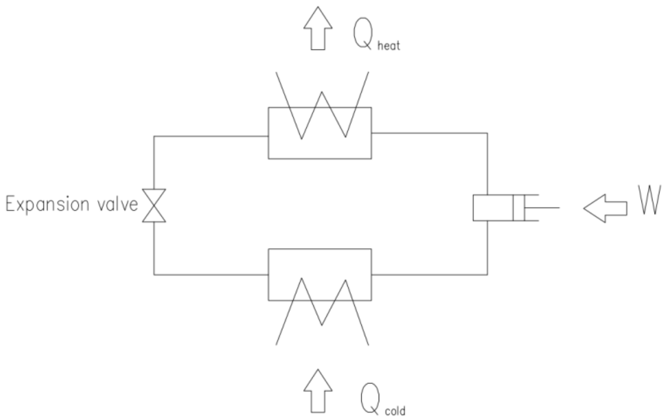


Figure 2: **Schemtic heat pump system**

3. HEAT PUMP PERFORMANCE AND SYSTEM PERFORMANCE ANALYSIS

3.1Heat pump performance

This paper compares the heating capacity of the heat pump and the COP of the equipment from the inlet temperature of the evaporator and the outlet temperature of the condenser. First of all, the general heat pump and the high temperature heat pump are calculated by using the FUEDA low temperature central air conditioning selection software and the FUEDA high temperature central air conditioning selection software, and the specific parameters are detailed in Table 1.

Table 1: Heating capacity of equipment under different working conditions of two heat pumps (KW)

Heat pump type	Inlet water temperature of evaporator	Heating capacity of equipment at different outlet temperatures of condenser (KW)						
		35℃	40℃	45℃	50℃	55℃	60℃	65℃
Ordinary type	18℃	1008.5	972.3	937	902.4	868.7	-	-
High temperature type	18℃	892.5	860.9	829.9	799.9	770.6	742.3	714.8
	23℃	1019	982.2	946.2	910.8	876.1	842	808.9
	28℃	1160	1117.5	1075.7	1034.3	993.5	953.4	913.9
	33℃	1316.7	1268	1219.7	1171.9	1124.5	1077.7	1031.2
	38℃	-	1435	1379.7	1324.8	1270.2	1216.1	1162.2

From the data in Table 1, it can be seen that the heating capacity of the high-temperature heat pump host increases with the increase of the inlet temperature of the evaporator. The heating capacity increases by 14.2% to 12.8% for every 5 ℃ increase from low temperature to high temperature, and the increase slightly decreases for every 5 ℃ increase as the temperature increases. When the inlet temperature of the evaporator is equal to 18 ℃, the heating capacity of the ordinary heat pump is 11.5% higher than that of the high-temperature heat pump. When the inlet temperature of the evaporator is higher than 18 ℃, the heating capacity of the high-temperature heat pump is stronger than that of the ordinary heat pump. The heating capacity of both types of heat pumps decreases as the outlet temperature of the condenser increases. For ordinary heat pumps, the heating capacity decreases by 3.59% to 3.73% for every 5 ℃ increase, and the attenuation becomes more severe as the temperature increases. For high-temperature heat pumps, the heating capacity decreases by 3.54% to 4.43% for every 5 ℃ increase, and the attenuation becomes more severe as the temperature increases.

Table 2: Equipment COP of two heat pumps under different working conditions

Heat pump type	Inlet water temperature of evaporator	COP value of equipment at different outlet temperatures						
		35℃	40℃	45℃	50℃	55℃	60℃	65℃
Ordinary type	18℃	6.379	5.683	4.979	4.309	3.693	-	-
High temperature type	18℃	6.263	5.579	4.893	4.237	3.635	3.099	2.634
	23℃	6.946	6.177	5.410	4.683	4.017	3.426	2.910
	28℃	7.703	6.835	5.976	5.171	4.435	3.782	3.211
	33℃	8.528	7.552	6.597	5.703	4.889	4.169	3.541
	38℃	-	8.333	7.269	6.279	5.384	4.591	3.900

According to the data in Table 2, the COP of the high-temperature heat pump host increases with the increase of the inlet temperature of the evaporator. The COP increases by 10.9% to 10.27% for every 5 ℃ increase from low temperature to high temperature, and slightly decreases for every 5 ℃ increase as the temperature increases. When the inlet temperature of the evaporator is equal to 18 ℃, the COP of the ordinary heat pump is 1.83%~1.57% higher than that of the high-temperature heat pump. When the inlet temperature of the evaporator is higher than 18 ℃, the COP of the high-temperature heat pump is higher than that of the ordinary heat pump. The COP of both types of heat pumps decreases as the outlet temperature of the condenser increases. For ordinary heat pumps, the COP decays by 10.9% to 14.29% for every 5 ℃ increase. The higher the temperature, the more severe the attenuation. For high-temperature heat pumps, the COP decays by 10.92% to 15.05% for every 5 ℃ increase. The higher the temperature, the more severe the attenuation.

3.2 SYSTEM PERFORMANCE

Taking a certain project in Zhoukou as an example, the geothermal water is 90m long ^{3}/ h. After direct heat exchange, the temperature of the geothermal tail water is 40 ℃. It is planned to extract the tail water to 10 ℃ and then recharge it. A comparative analysis of the system performance is conducted according to three schemes. Scheme 1 uses three ordinary heat pumps, Scheme 2 uses one high-temperature heat pump+two ordinary heat pumps, and the high-temperature heat pump is set at the first level. Scheme 3 uses two high-temperature heat pumps+one ordinary heat pump, and the high-temperature heat pump is set at the first and second levels. The relevant parameters for system operation are shown in Table 3.

Table 3：Comprehensive COP of heating system under different combination schemes

Option	Power consumption of heat pump （KW·h）	Power consumption of system circulating pump （KW·h）	System heating capacity （KW）	System COP
Option 1	632.66	52.5	3150	4.60
Option 2	545.40	52.5	3150	5.27
Option 3	509.38	52.5	3150	5.61

From the data in Table 3, it can be seen that using high-temperature heat pumps in Scheme 2 and Scheme 3 can increase the system COP by 14.56% and 21.95%, respectively. In the engineering design process, the geothermal heating system utilizes the tailwater cascade after direct heat exchange, and configuring appropriate hosts according to different temperatures can greatly improve the system COP.

4. CONCLUSION

This paper analyzes the performance parameters of two different types of heat pump host under different working conditions. Combined with the middle-deep geothermal heating tailwater cascade utilization system, the impact of three equipment selection schemes on the system performance. Reasonable equipment selection can improve the COP of the system by 21.95%. It provides a reference scheme for the efficient utilization of high temperature heat source.

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