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Performance Analysis on Heating Conditions of Large Sewage Source Heat Pump System

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ABSTRACT: This paper obtained the changing range of sewage temperature, the inlet and outlet temperatures of the sewage heat exchanger, evaporator and condenser in winter by monitoring the large sewage source heat pump system in Shi Jia-zhuang. By the testing data, the operating performance of the heat pump system was studied. During the heating test, the heat pump system operated steadily and the coefficient of heat transfer of the sewage heat exchanger was 740 W/ (m2 •?), and the average coefficient of performance of the heat pump was 3.76. These can be taken as references for the design and engineering application of the sewage source heat pump systems.
Key words: sewage; heat pump; sewage heat exchanger; coefficient of heat transfer; coefficient of performance

I. INTRODUCTION

Urban sewage source heat pump (USSHP) has significant performance advantages and energy saving effect, and has quickly developed and be widely applied in our country and the world [1~5]. As t the proportion that the building energy consumption accounts for the total energy consumption increases day after day, energy saving and the development of new energy attracts people more and more attention [6]. Adopting sewage source heat pump system and extracting part of thermal energy from urban sewage for building heating, can improve urban energy efficiency of effective use and reduce the correspondingly reduction the emission of CO2, NOx, Sox and other pollutants accordingly by reducing use of coal and the other energy [8~9], it has a very important economic and social significance. With the engineering application of this system in Beijing, Tianjin and other cities, the reports of the system performance status also have been published one after the other, but the existing reports all concentrates in small projects with simple structure and relatively easy performance adjustment, ranging from thousands to tens of thousands m2. But the project description of large sewage source heat pump systems lacks, and operating conditions are unknown. In this paper, it carried out system monitoring for about 12 days of the urban sewage source heat pump project with 520,000 m2 in Shi Jia-zhuang City. Data came from the actual project and served the project, with good authenticity and reliability, providing reference for the design and promotion of large sewage source heat pump systems.

II. SYSTEM SUMMARIZATION AND ENGINEERING OVERVIEW

A. System summarization

The schematic of urban sewage source heat pump system is shown as Fig. 1. The sewage clog-proof machine is the patent of HIT [10], whose model is determined by the flux of the sewage. The sewage-mediwater heat exchangers are shell-and-tube exchangers, the sewage flows in the tube and mediwater flows in the shell, the sewage and the intermediate water flow reversely, and its model is determined by the designed heat exchange quantity. According to the loop independence theory, the models of the first and secondary sewage pumps, mediwater pumps and terminal circulating pumps are determined by the flux and resistance of each loop. The heat pump system takes heat from the sewage in winter and releases heat to the sewage in summer by the heat exchanger. It will achieve the switch of the cooling and heating by turning on or off different valves.

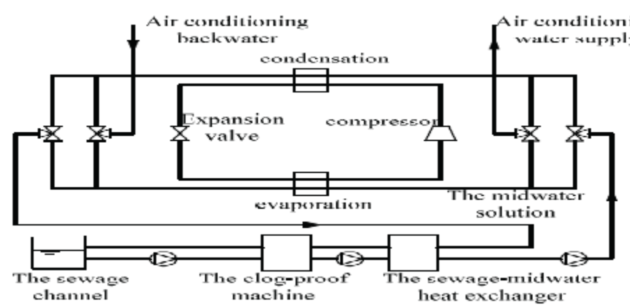

Fig. 1. Schematic diagram of sewage source heat pump system.

B. Engineering overview

The total building area of this engineering is 800,000 m2, and the first phase project with the area of 520,000 m2 adopted the urban sewage source heat pump system providing floor radiant heating and fan-coil heating in for the commercial area in winter, cold water for commercial buildings in summer and hot water supply for buildings without domestic hot water. The project is divided into high and low section independent systems, the design heat load of the high section is 7596kW and adopted 4 sewage heat pump units; the design heat load of the low section is 11372kW and adopted 3 sewage heat pump units, the total design heat load is 18968kW, air-conditioning cooling load is 7316kW in summer. There is a urban channel about 400 m away from the community, it measured the sewage temperature 16 ~ 18 c in winter and 22 ~ 24 c in summer, the flow meets the requirement of the project, the sewage is suitable as the low heat and cold source of the project.

III. ANALYSIS ON SYSTEM PERFORMANCE DATA

The project achieved computer control on all the equipment of the machine room, including start and stop control and the test and record of all the loop temperature. The experiment collected the condenser and evaporator temperature of the heat pump units of high zone 1 #, and low zone 3 # and all the loop flow, the sampling interval is 30 minutes. Sampling time was January 28, 2009 to February 8, lasting 12 days. The equipment selection of high1# and low 3# is shown inTable.1.

Table.1 Equipment selection of sewage source heat pump of high1# and low 3#

Heat pump unit（high section）	heat exchanger amount of 2532kW; input power of 520kW
Heat pump unit（low section）	heat exchanger amount of 2843kW, input power of 670kW
Sewage heat exchanger（high section）	heat exchanger area: 600m^2, heat exchanger of 2576kW
Sewage heat exchanger（low section）	heat exchanger area : 600m^2, heat exchanger of 2893kW
Sewage pump	Flow rate of 300 m^3/h, head of delivery of 16m,power of 22kW
Intermediate water cycle pump	Flow rate of 300 m^3/h, head of delivery of 25m, power of 37kW
Terminal water cycle pump	Flow rate of 240 m^3/h, head of delivery of 38m, power of 45kW

A. Screening of effective data of system running January 28, 2009 ~ February 8, 2009, it conducted on-site testing for 12 consecutive days, when testing, the system was stable, the loop water flow was stable basically, with sewage flow of 290 m3 / h, intermediate water circulation flow rate of 300 m3 / h and the end user circulating water flow rate of 240m3 / h.

Since all the loop flow is large and stable, the temperature measurement errors impact on the data reliability greatly.

Therefore, it needs to find the data for analyzing the heat pump performance from the raw data. Data screening procedures and principles are as follows: (1) According to the import and export water temperature of the heat pump evaporator, it calculates the heat absorption capacity of the heat pump evaporator by the formula $Q = c \cdot m \cdot \Delta t$, excluding the values which are less than or equal to 0, and it can be concluded that the sewage output of heat are equal to the heat absorption capacity by the heat balance of the sewage – intermediate heat exchanger, so the import and export water temperature which is less than or equal to 0 is removed. The reason for this phenomenon is that the heat pump is not running. (2) According to the import and export water temperature of the heat pump evaporator, it calculates the output of heat of the heat pump condenser by the formula$Q=c \cdot m \cdot \Delta t$ excluding the values which are less than the heat absorption capacity of the evaporator, the reason for this phenomenon is temperature testing errors. Conducting the data screening according to the above steps, 570 set of available data were got, including 210 set of the import and export water temperature data. Figure 2 shows the change trend of the urban sewage import and export temperature, it can be seen from the diagram, the sewage temperature is between 13c and 16c, the water temperature drop is 3 ~ 5c. This shows that urban sewage is the ideal cold and heat source for heating and air conditioning of heat pump.

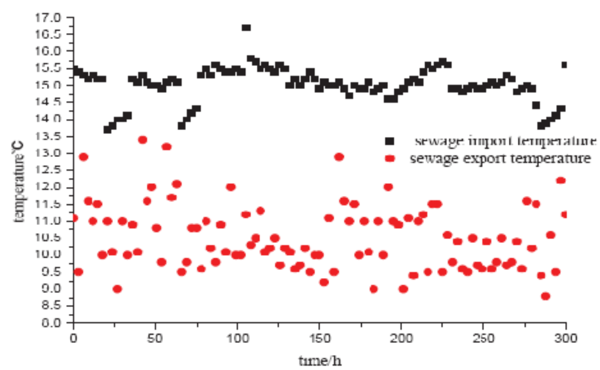

Fig. 2. The variation of sewage import and export temperature with time.

B. Processing methods of effective data

(1) Sewage instantaneous heat release capacity is calculated by the following formula:

$$q_w = \frac{1}{3600} \rho_w c_w V_w (t_{w.i} - t_{w.o})$$

Where: q_w —sewage instantaneous heat release capacity, kW; ρ_w – the sewage average density of Trunk sewers, kg/m^3; c_w —the sewage average specific heat, kJ/kg. ℃; V_w – the sewage flow, m^3/h; $t_{w.i}$, $t_{w.o}$ —the sewage import and export temperature, ℃。

(2) Instantaneous heat absorption capacity of evaporator of Units p the import power when units are heating. C. Heating operation analysis in winter Performance analysis of sewage heat exchanger Sewage heat exchanger is the key equipment of the sewage source heat pump heating system, the level of the heat transfer coefficient is the key issue to the normal operation. In this paper, the import and export temperature of heat exchanger and the flow of the sewage and the intermediate water were measured. During the test, the flow of the sewage and the intermediate water was stable respectively, they were 290 m3 / h and 300 m3 / h. Fig. 3 shows the change of the heat transfer capacity and heat transfer coefficient of sewage heat exchanger with time.

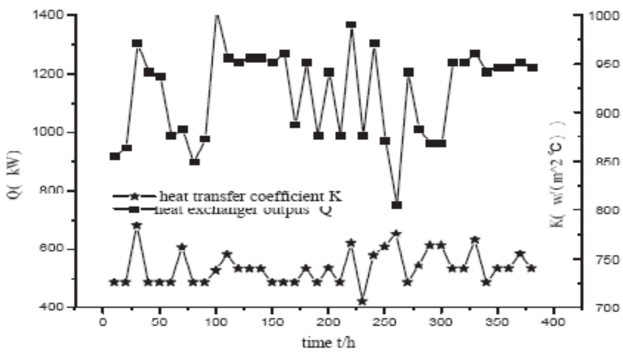

Fig. 3. The variation of the heat transfer capacity and heat transfer coefficient of sewage heat exchanger with time.

We can see from Fig.3, the heat transfer capacity of the sewage heat exchanger was about 1300kW, the heat transfer coefficient was about 740w/m^2. The heat transfer coefficient was smaller than the design value; the reason was that the load of the user was so small that the heat transfer capacity of the heat exchanger got smaller. Performance analysis of heat pump units

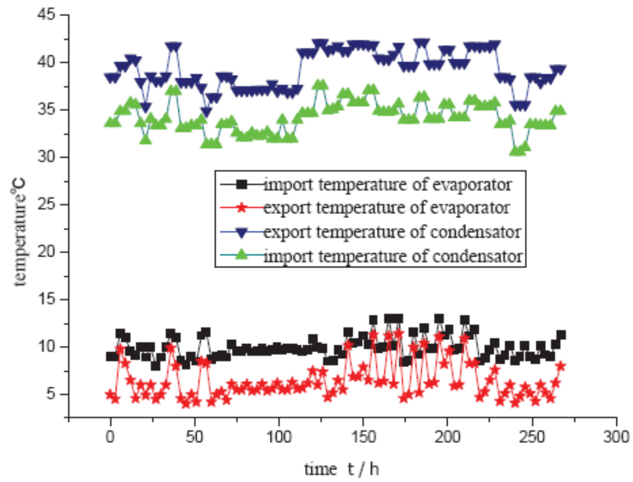

Fig.4. The variation of the import and export temperature of evaporator and condenser with time.

The change of the import and export temperature of evaporator and condenser with time affects the instantaneous heat absorption capacity and heat release capacity of the heat pump units directly. Fig.4 shows the change of the import and export temperature of evaporator and condenser with time. We can see from Fig.4, the average import temperature of the evaporator was about 10c, the average export temperature was about 6.5c, and the temperature difference was about 3.5c. The average import temperature of the condenser was about 34 c, the average export temperature was about 39c, and the temperature difference was about 5c. From (2), (3), and (7), we can know the heat pump power consumption; the instantaneous heat absorption capacity and the instantaneous heating capacity fluctuated with time. By the measured data, it was calculated that the average heat absorption consumption was about 1200kW, the average heating capacity was about 1720 kW, and the average power consumption was 515.5kW. Fig.5 shows the change curve of the instantaneous performance coefficient of the heat pump units with time during the heating test (January 28, 2009 ~ February 8, 2009). The heating performance coefficient of the heat pump units can be calculated by the formula (4).

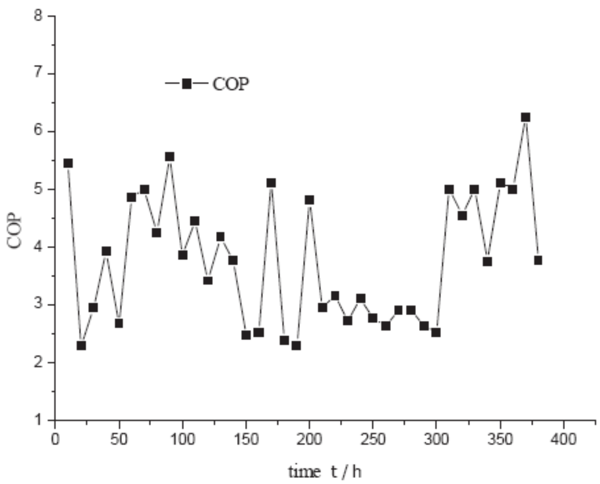

Fig. 5. The variation of the instantaneous performance coefficient of the heat pump units with time.

We can see from Fig.5, the performance coefficient of the heat pump units varied between 2.5 and 5.5, the average heating performance coefficient was about 3.76, considering the power consumption of the sewage pump, the intermediate water pump and the end cycle pump, the energy consumption ratio was about 3.0.

IV. CONCLUSION

By testing and analyzing the actual running data of the sewage source heat pump, we can get the following

(1) Urban sewage temperature is 13~16 c , sewage temperature drop is 3~5 c, it is very suitable as the low heat and cold source of heat pump system;

(2) During the test, the units' instantaneous performance parameters changed little with time, the instantaneous average heat absorption capacity was about 1200kW, the average heating was about 1720kW, the average consumption power was 515.5kW, showing the stable performance of heat pump units, it is suitable for long running;

(3)During the test, the average heating performance coefficient of the units was 3.76, considering the power consumption of the sewage pump, the intermediate water pump and the end cycle pump, the energy consumption ratio was about 3.0.

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