RESEARCH ON DESIGN OF LARGE SEWAGE SOURCE HEAT PUMP ENERGY STATION

Lingyan Yang,Engineer, China Academy of Building Research,Beijing,China
Qingyu Zhu, Professor, China Academy of Building Research,Beijing,China
Bin Lu, Professor, China Academy of Building Research,Beijing,China

Abstract:The design of a sewage source heat pump energy station is different with a small-scale sewage source heat pump system. The safety, economic and energy-saving must be considered entirely during the designing work. Based on a practical sewage source heat pump energy station project, this paper studied the design of sewage source heat pump energy station, discussed low temperature heat source on the swage, out-net arrangement, unit configuration, user-side settings etc and summarized the design features of the central sewage heat pump energy station. The sewage source heat pump energy station is better in the environmental protection and energy saving than the traditional HVAC methodes using power and boiler.

Key Words:sewage source heat pump (SSHP); heat pump station; design features

1 INSTRODUCTION

With the increasing concern about the energy sources and environment issues, energy-saving and sustainable development are more important challenge in the world. Heat pump, as a mature technology in energy-saving, is an environmental and energy saving technology based on the concept of ecological circulation in heating. It has achieved a lot of economic and environmental benefits after years' development.

Heat pump can use different renewable energy as its low temperature source, such as air, earth, underground water, surface water, solar energy, sewage and so on. Among those, sewage has its advantage for its higher temperature. Especially, the treated sewage temperature could be more than 15°C for its technological requirements. Sewage is superior choices. With the promotion of urbanization, sewage source heat pump got the fast development in recent years.

2 DEVELOPMENT OF SSHP IN CHINA

In china, the researches on SSHP began from 1980s. The earliest SSHP project was built in 2000. The rapid development of SSHP technology created a lot of SSHP projects in recent years.

Water intake and heat transfer are the key technologies of SSHP system which are determined by its essential features. Sewage has different impurities and a large amount of suspend solid. These impurities will block heat exchanger device, decline heat transfer coefficient, and deteriorate its heat transfer. So, solving water intake and heat transfer are the premise to system safety and effective running.

The equipment and technology in anti-blocking are listed as follows: 1) Automatic sieve; 2) Heat pump anti-blocking engine; 3) Self-cleaning filer; 4) Rotating scrap filter device; 5) Water disposal well. These anti-blocking technologies have different limitations and their own mechanism complexity. They all already had practical applications in engineering. Heat pump anti-blocking engine has well appliance, it is a closed sewage intake device using the rotation renewable filter technology. It is simple, steady and no sewage draining. There were several projects operating well in Haerbin and Beijing.

Now, two aspects have been acted to solve heat transfer problem. One is to develop new type of heat exchanger devices and the other is to study on new dirt removal methods. The used heat exchanger in SSHP system have plate heat exchanger, special shell and tube heat exchanger, spray heat exchanger, and dry shell and tube heat exchanger with rapid decontamination etc. Research on new type of heat exchanger devices is still very important. About scale removal methods, we had got automotive sponge ball, spring vibration, automatic disturbed flow, liquid-solid fluidization, etc. These can be divided into mechanic and hydraulic. Mechanic is complex and hydraulic is less reliable. The useful dirt removal should depend on concrete conditions.

The progress on these new technologies promoted the development of large scale sewage source heat pump energy station relying on sewage treatment plant.

3 DESIGN FEATURES OF LARGE SSHP ENERGY STATIONS

Large sewage source heat pump energy station as the energy centre of a district supply heat and cooling energy to the consumers. The design procedure must think entirely about the low-temperature heat source, system configuration, pipe network arrangement, user requirement. Safety, energy saving and economy must be considered comprehensively.

- Safety

Large sewage source heat pump energy station is the energy centre of a district. Its safety is more important. So, the related items of design must be think over at the beginning.
Firstly, the form of SSHP system, there are direct form and indirect form for SSHP. Large heat pump is different with small one in function convertor. Small heat pumps use four-way reversing valve to change refrigerants' flow and from heating to refrigeration while larger one using change of waterway. So, if direct style used, evaporator and condenser must be made of anticorrosion material. Heat exchanger must be as smooth as possible to avoid dirt precipitation. Those will greatly decrease the heat transfer coefficient, and the COP of heat pump. Indirect SSHP has one more heat exchanger. The additional one will increase energy loss, power consumption of water pump and total area of equipment house. For a large SSHP system, the form choice should be made on the basis of analyzing the two forms' advantages and disadvantages.

Secondly, arrangement of pipe network, small SSHP always services a single building. The equipment house is near to the building. So, the simple out net is direct form to supply energy. On the other hand, a large one has more types of users and its load center is uncertain. While arranging its pipe network, it is necessary to reduce transport consumption, reduce influence of user changes to pipe network. So indirect form is more popular for its advantages like against interactions among users, ensuring safety of pipe net. And it is well-known to manage well and clear different responsibilities.

Sewage volume is also an important factor for safety. While designing small SSHP system, especially systems using untreated sewage, the most important is sewage flow and temperature for its large fluctuations. Sewage flow's variation with time must be clearly researched forecasted. The top flow should be 25% larger than demand of heat pump

system. But for a large SSHP system built in sewage treatment plant, the flow is steady and this is very important to system. So excessive coefficient of sewage safety flow is on practical load and changes of sewage flow, and is smaller than that of small SSHP system.

- Economic

Large sewage heat pumu energy station services larger district. Its users can be developed in different stages. So the initial design should think of its stage planning. Which means factory built by stages, devices installed by stages. Then the energy station can satisfy users' requirements, declines investment of each stage and better affords user's requirement after stages meanwhile.

Pipe network reservation is necessary. It is on the relative position of energy centre, arrangement form of pipe net and expanding of it.

Small SSHP must afford user's requirement in the lowest sewage volume. so, the volume of balancing reservoir should afford several hours' flow during the low sewage volume period. But for large sewage heat pump energy station, the large sewage flow is steady without obvious change. It is ok to settle for changes in short time. It can even be canceled if long-term data of sewage flow is stable. That means less civil construction cost and better economic.

- Energy-saving

Because of the relationship between outlet water temperature and unit efficiency, the lower outlet water temperature is, the higher efficiency is in winter. So, in the design of user system, low temperature device is recommended, like fan coil and floor radiant heating system. It also needs to increase outlet water temperature properly in summer.

Large sewage heat pump energy station needs a large amount of sewage. Saving energy in sewage delivery has important significance. It will be better to build heat pump eqipment house near the sewage treatment plant.

Frequency operation is another effective means of energy saving, it supplies wider load extension and better adjustable. But actions should take user's requirement into account, adjust whole system and ensure safety.

After analysis about planning and design SSHP energy station theoretically above, we will study these points in the practical project next.

4 PROJECT INTRODUCTION

This project locates in an industriall park in Shandong Province, the SSHP energy station is in the sewage treatment plant. As more enterprises plan to settle in, this system would gain more customers in the future. The construction of the energy station involves two phases. Phase 1 supports a region with 125,000m^2 and 500m transport distance, and phase 2 for 290,000m^2 and 2000m. The two regions are respectively located in the south and north side of the energy station. The design of this paper meets the needs of phase 1 and gives the consideration to phase 2 in layout design.

4.1 User's demands

The phase 1 project services new buildings, with SSHP as its heat and cold resource. Fan-coil units and floor radiant heating are adopted in this project. The designed temperature of fan coil are 46/39℃ in winter condition, and floor radiant heating are 45/37℃. Floor radiant heating system contains high and low area, and is separated by plate heat exchanges. In

summer condition, the designed temperature of fan coil is 5/12°C. The temperature difference is 7°C in both summer and winter condition, which reduces the flow and the energy consumption of pumps and improves the EER. The total cooling load and heat load are 6400kw and 5400kw respectively by design. The phase 2 project affords 9300kw and 8000kw in cooling and heat load respectively in prospect. The design of the SSHP energy station is based on the data above.

4.2 Properties of the sewage source

In this sewage treatment plant, over 90% sewage comes from the factories in the high technology park, and the domestic sewage takes a little proportion. Due to the factory's processing procedures, the temperature of sewage water drainage is higher than the temperature of domestic sewage, and the microbe content is lower than ordinary sewage. After the processing procedures, the sewage quality reaches national A level emission standard.

- Sewage temperature

The temperature is an important factor which influences the efficiency of SSHP. In order to estimate whether the sewage can fulfill the needs of SSHP in summer and winter condition, the drainage temperature should be comprehensively monitored during the heating and cooling period. The average temperature of the sewage drainage is between 16°C and 19°C in heating season(November 15 to March 15 the next year), and between 25°C and 28.5°C in cooling season(June 20 to September 30). So we can see that the temperature is very suitable for the application of SSHP, the sewage is an ideal low-grade heat source. As the cooling water, the sewage in summer is better than the cooling tower.

- Sewage volume

The sewage volume of the sewage treatment plant is 7043m^3/h in heating season, and 8814m^3/h in cooling season, which completely satisfies the requirements of energy station (1650 m^3/h in cooling season and 1470 m^3/h in heating season designed in phase 1 project).

- Sewage quality

Even though the quality of sewage drainage reaches level A of the national drainage standard, it still needs further assay to check whether the quality satisfies "the Industrial Water Quality of Urban Wastewater Recycling" (GB/T1992-2005) when it is used in heat pump system. Test result is shown in the table 1.

Table 1:Table of the sewage quality (mg/l)

ph	7.45	**Sulfate**	719.53	**manganese**	0.34
Turbidity(NTU)	10.11	**COD**	59.46	**Total oil**	0.19
Chroma	22.21	**Potassium**	22.4	**Calcium**	224.03
BOD	3.86	**NH4+**	35.59	**Magnesium**	56.87
Conductivity (ms/s)	234.29	**Total phosphorus**	3.05	**Ammonia nitrogen**	22.8
Chloride	482.09	**TOC**	14.37	**Sodion**	421.95
Silica	8.14	**Hydrogen**	385.03	**Nitrate**	4.57
Total hardness	793.71	**Total dissolved solids**	2253.35	**Fluoride**	0.84
Total alkalinity	315.91	**Ferric ion**	0.15	**Barium**	0.07

The contents of sulfate ion and chloride ion are over standard in the sewage, as well as the hardness of sewage. Therefore, the sewage quality should be full considered in the design and scheme comparison of SSHP energy station.

4.3 Design scheme

Based on the user's requirements and sewage conditions, and the consideration of the safety, economy and energy conservation, we brings forward some pertinence design methodes.

- System form

According to the introduction of water quality above, the sewage corrodes ordinary stainless steel material, so the contact-type equipments should be carefully chosen. Therefore, even though indirect type system could result in 3.8MW energy loss and increase 2°C temperature difference to heat exchange, we still choose the indirect type sewage-source heat pump system to protect the heat pump units and reduce investment.

- Outdoor pipe network arrangement form

The user of the first phase project is a polymer science park. The first phase project and the second phase project, which is a ceramics park, locate in two opposite sides of the sewater heat pump energy station. Since the two phases will be constructed apart for a long time, the pipe network connecting to the polymer science park is independent from the phase 2 project. So the construction of the first pipe network is simple, and the pipe network is very convenient for further expanding.

- Connect form with user side

Compared with indirect connection, direct connection is more energy-saving. But the different demands for pressure of the terminal buildings should be considered in the direct connection. In addition, the water supplement system and constant pressure system are more complex, and the management are relatively hard to take. The indirect connection mode, which adds heat exchanges, makes the management and commissioning easier. Considered the further expanding of the outer net, we choose indirect connection mode. It also makes the responsibilities clearly between the energy station and the users.

- Sewage-taking form

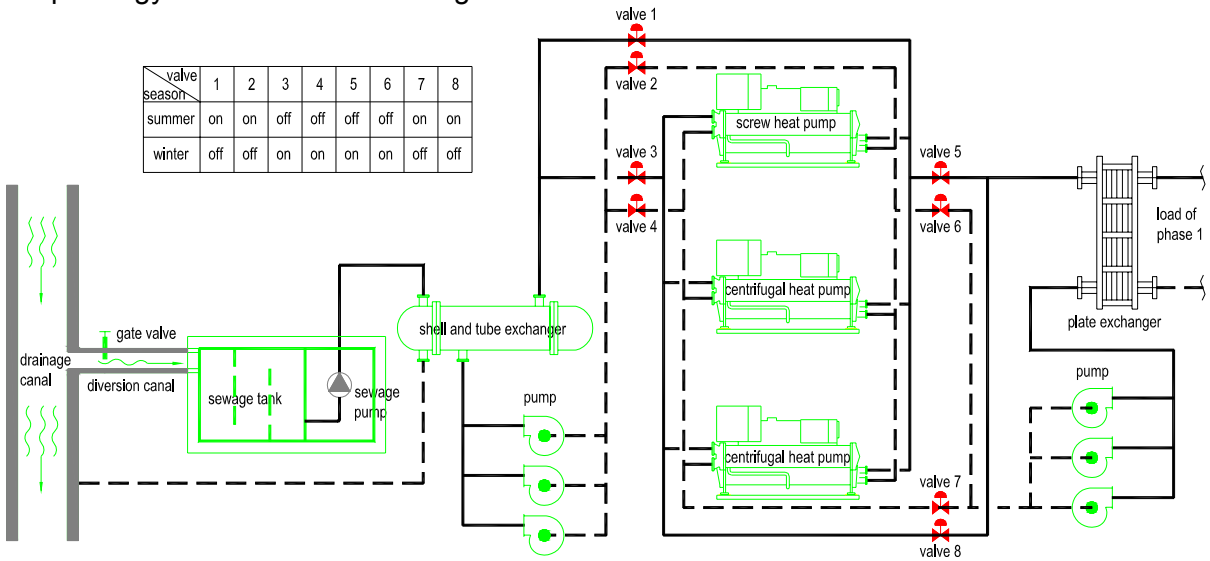
For better taking the sewage, an underground sewage tank with 1700m^3 is built according to the SSHP energy station demand for sewage in one hour. This tank can maintain a basic flow, buffer the peak and valley of the sewage flow, and can be used as a settling pond. The top of drainage canal is in the same level with the ground, and the bottom is 1.3m below the ground. To lead the sewage to the tank, diversion canal and gate valves are adopted instead of the expensive anticorrosive metal material pipes and valves. The water automatically flows into the tank when the water level is lower in the tank. The water flows out of the plant when the tank is full, which makes the overflow pipe unnecessary. In the transition season, the tank can be cleaned after the valves are shut down. Roof insulation and exhaust function are considered in the tank design.

- Units configuration of heat pmup

The terminal buildings are new constructions, the heating and cooling load is increasing with the occupancy rate rasing. Fan coils are adopted for cooling and heating in the business buildings. The floor radiant heating is adopted in residential housings for heating, no cooling demands in need. According to the features of the load in the first phase project, two centrifugal heat pump units are chosen to bear 80% of the total load (40% for each one). One screw heat pump is chosen to bear the rest load (20%). In this way, the energy

conservation and high-efficiency of the system can be made by flexibly controlling the performance of system according to the load variation.

According to the design characteristics above, system schematic diagram of sewage heat pump energy station is shown as Figure 1.



valve / season	1	2	3	4	5	6	7	8
summer	on	on	off	off	off	off	on	on
winter	off	off	on	on	on	on	off	off

Figure 1: System Schematic Diagram of Sewage Heat Pump Energy Station

4.4 Analysis of energy and environment conservation

In the first phase project, the SSHP energy station offers 3584MWh cold energy and 5107.2MWh heat every year. Compared with the traditional boiler heating and water chiller scheme, it can save 208tons standard coal every year and improve the primary energy ratio by 24%. This system brings great environment benefits as well as the improvement of energy utilization. When the phase 1 project is completed, it can save 890tons coal can. Moreover, it can reduce the emmision including 2263tons carbon dioxide, 15.14tons sulfur dioxide, 6.14tons nitride and 12.82tons dust every year. Since there is no cooling tower outside, a big amount of water can be saved, and noise pollution is reduced, also. So the environment benefits of the SSHP energy station are significant.

5 CONCLUSION

The SSHP technology is an important popularized technology of national energy-saving and renewable energy policy. It has positive effect on the strategy for low-carbon economic development, and realizing our nation's target of energy-saving and emission reduction. At present, China's large SSHP energy station is still in the initial stage. The safety, economy and energy-saving properties should be comprehensively considered to determine its own design characteristics. combined the analysis with the practical cases, this paper gets the design characteristics of sewage-source heat pump energy station:

- The SSHP energy station is used as energy center to supply heat and cooling energy. The lower of the terminal system water temperature, the more efficiency of the heat pump system. So, the terminal system of low-temperature hot water heating supply, such as fan coil and floor radiant heating system, is recommended.
- Even though the direct connect mode owns higher efficiency, the indirect connect mode is chosen in consideration of the different requirements of users, to make system safer and more flexible to meet further expanding.

- A well planning is important to the construction of equipment room and outer net. Space for further development should be reserved. Outer net should be optimized and supposed to pass the center of the load.
- The terminal load change should be considered for reasonable selection and configuration the heat pump units. Reasonable units selection enchance the flexibility and the efficiency of the SSHP energy station.

6 REFERENCES

Ma Zuiliang, Yao Yang et al. 2003. “Application of sewage source heat pump systems” China Water& wastewater, Vol. 19, pp. 41-43 (In Chinese).

Wu Huarong, Sun Deixing 2004. “Appliance of Immersion Evaporation technology in Urban Sewage Source Heat Pump System” Heating Ventilating & Air Conditioning, Vol. 34, pp.86-88 (In Chinese).

Wu Huarong, Sun Deixing et al. 2005. “Operating Condition and Parameter Characteristic of Urban Sewage Source Heat Pump System” Fluid Machinery, Vol. 11: 73-76 (In Chinese).

Wu Huarong, Sun Deixing et al. 2006. “A Research and Application of Urban Sewage Source Heat Pump” Journal of Haerbin Institute of Technology, Vol. 38, pp. 1326-1329 (In Chinese).

Yao Yang, Song Yan et al. 2007. “Design and analysis of multistage spray heat exchangers in sewage-source heat pump systems”. Heating Ventilating & Air Conditioning, Vol. 37, pp.63-67 (In Chinese).

Wu Ronghua, Xu Ying et al. 2008. “Research and utilization progress of intake water heat-exchange technique of sewage and surface-water source heat pump systems” Heating Ventilating & Air Conditioning, Vol. 38, pp.25-30 (In Chinese).

Zhang Jili, Ma Liangdong 2009. “Study progress in intaking water,defouling and heat transfer in sewage water source heat pump air conditioning systems” Heating Ventilating & Air Conditioning, Vol. 39, pp.41-47 (In Chinese).