

Application on Sewage-source Heat Pumps

Hong Li, Yunxia Qu

Shandong University of Architecture and Engineering, Jinan, China

Abstract: This paper introduces the features of sewage-source heat pumps and sewage discharge number in China. There are a few practices about the sewage-source heat pump utilized for buildings' heating and air conditioning. The author analyses system economics in different types of heating, such as air-source heat pumps, ground-source heat pumps and sewage-source heat pumps and so on. The result shows the advantages of sewage-source heat pumps in energy conserving and environment protection.

Keywords: sewage-source heat pump; economics; environment protection

1. INTRODUCTION

With the development of modern science and technology, people have deeply realized that the thermal energy contained in sewage is a kind of clean energy source that can be recycled. So utilizing the thermal energy involved in sewage is the renewable energy technology.

Sewage-source heat pump (SSHP) is a kind of air conditioning equipments that extracted heat from sewage. The performance of SSHP is based on a large number of discharged sewage, steady sewage's quality and its temperature always between 13 and 25°C. It has many advantages such as constant heating output, high COP values, good heat exchanging effects and compact unit configuration etc. So it is an efficient way of recycling sewage.

2. DISCHARGE AND TREATMENT CONDITION OF SEWAGE IN CHINA

With the development of civil production, sewage discharge number in China is increasing. By the end of 1996, the sewage discharge number in municipal system has been 20.9 billion cubic meter, we have built 153 treatment plants and the concentrated treatment number has been up to 2.38 billion cubic meter, so the treatment efficiency is 11.4%. It is required by "the 'ninth five years' plan of national environment protection and perspective aim of 2010" that the newly increased sewage treatment quantity is 20 million tons per day in 2002, and the concentrated treatment efficiency is 25%. It is estimated that sewage treatment number is about 20 billion cubic meter this year, the concentrated treatment efficiency is up to 40% in 2010 and we will build another 1000 treatment plants. To 2015, the sewage treatment number will achieve the goal of 36.095 billion cubic meter per year^[1].

Most sewage treatment plants' second effluent meets or is better than the second standard of national sewage discharge, so its quality is basically fit for recycling. Such as Beijing Gao beidian WWTP,

Fangzhuang WWTP and Bei xiaohu WWTP. The details are shown in Table 1^[1].

The above figures show that the sewage treatment efficiency is increasing year by year and the quality of second effluent meets the require of recycling, so all of those create conditions for SSHP technology.

Table 1: the quality of three sewage treatment plants' second effluent

Treatment plant	Gao beidian	Fang zhuang	Bei xiaohu
Treatment quantity per day(10 ⁴ m ³)	100	4	4
BOD ₅ input (mg/L)	124.2	361.8	164.5
BOD ₅ output (mg/L)	8.3	14.8	12.7
COD input (mg/L)	297.7	782.5	276.0
COD output (mg/L)	52.1	71.0	35.1
SS (mg/L) input	284.5	607.7	413.4
SS (mg/L) output	35.0	23.0	12.9

3. THE APPLICATION OF SSHP TECHNOLOGY

As to the development and application of low-phase energy in sewage, soviet, Sweden and some countries in north European which are advanced in heating have done active studies. Because of energy crisis and the increasing environment pollution, many developed countries such as America, Japan and German have allocated a large sum of fund and manpower for research in this field and they have made great progress^[2].

The application of SSHP is just beginning in China. Beijing Gao beidian, Bei xiaohu and Hebei Qin huangdao sewage treatment plants etc have tried using it and all the projects run well. But the heating and cooling areas is small at present and is not proportion to the great deal of energy contained in sewage, so it's potential.

In order to show SSHP advantages in economic and environment protection completely, the paper supplies three different types of heating and cooling for a certain teaching building of Shandong University of Architecture and engineering. The schemes are as follows:

Scheme one: SSHP system. Its main advantage is that it can use the recycled wastewater system to sent second effluent to users, that is to say, it can take a semi-concentrated system for heating and cooling. This project can be finished in short time,

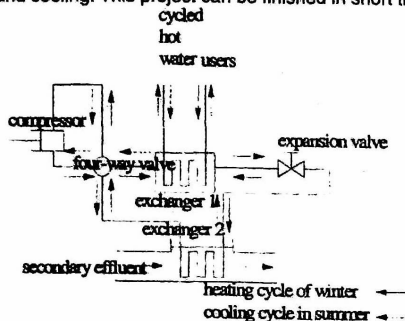


Figure 1: principle of SSHP system

will run steadily, has good performance, and is controlled easily without special administrator. But its shortcoming is that SSHP technology is not mature in China.

Scheme two: gas plus air-source heat pump system. This type of system is easy and has a small first cost, but its efficiency will reduce obviously in sweltering summer and frigid winter. Moreover, its heating quantity is decreasing as the outdoor temperature reducing, and this is opposite to the required building load, and besides, air-source heat pump's evaporator will frost in heating condition, so it needs defrosting periodically.

Scheme three: ground source heat pump system. This system enhances the applied efficiency of primary energy, so it is efficient in energy-saving. So far there have been some obstacles in using the system. Such as its large first cost in burying pipes and it is strange for the government, architecture

The energy that system needs when it supplies the designed loads is called energy consumption. Such as electricity and natural gas etc. In the project, each item's energy consumption of every scheme is calculated by per kilowatt energy, and its formula is as follows:

$$ec = \frac{\text{cooling } ec + \text{heating } ec}{\text{total working load in a year}} (kw/kw)$$

Where, ec — the coefficient of energy consumption'.

Scheme one: in this system, the sewage heat exchanger is a submerged exchanger and the other is a shell-tube exchanger. The principle of the system is shown in Figure 1.

In the heating cycle, exchanger 1 is condenser. The refrigerant is compressed by the compressor and becomes hot steam of high temperature and pressure. Then it comes into exchanger 1 and exchanges heat with the cycled water. so the water is heated and be offered to users. At the same time, the refrigerant is inverted from hot steam into liquid state. After decreasing pressure in the expansion valve, it turns into liquid with low temperature and pressure. Then it absorbs heat of second effluent in exchanger 2 and is evaporated into as of low temperature and pressure. The gas returns to the compressor again, so the next cycle is beginning. Through such a cycle, the system is able to invert low-phase energy in sewage into high-phase energy.

In the cooling cycle, the refrigerant reverses its flowing direction through the four-way valve and the single-way valve. so exchanger 2 works as condenser while exchanger 1 is as evaporator. Through the similar cycle to the one in winter, the refrigerant absorbs indoor heat, releases it into the sewage and achieves the goal of cooling.

Scheme 2: the air source heat pump system uses SA-30CDH air cooling heat pump with two compressors produced by certain factory in Shanghai. Its cooling performance coefficient is 2.56 and the heating is 2.96.

Scheme 3: this system uses vertical borehole plus water-to-water heat pump. The total length of the borehole is 1600 meter. The heat pump is FWRM030 water-to-water heat pump unit produced by a factory in Zhejiang^[8].

items		SSHP system	Gas + ASHP system	GSPH system
electric power	vertical borehole pump			69.11
	heat pump unit	276.53	192.34	208.37
$\times 10^3$	cycled water pump	66.83	32.24	66.83
(kw)	sum	343.36	224.58	344.31
	gas consumption		0.141m ³ /h	

designers and the public.

The air conditioning area of the project is 1000 square meter. In the compare process, it is assumed that the cooling season is 90 days and the heating season is 120 days.

3.1 energy consumption comparison of three different schemes

Statistical numbers of energy consumption are shown in table 2.

3.2 the first costs of major equipments of different systems

The first cost is the sum of each equipment expenditure of the system, including the construction expenditure, cost in equipment and the spending in

installing etc. The cost is calculated by per. unit load, and the formula is as follows:

$$\frac{\text{the first cost (RMB / kw)}}{\text{the designed load}} = \frac{\text{expenditure in equipment}}{\text{the designed load}}$$

The first costs of major equipments of different systems is shown in table 3.

item of cost(RMB/kW)	SSHP system	Gas + ASHP system	GSHP system
vertical borehole			47.78
heat pump system	913.33	399.34	432.62
Geothermal heat exchanger			1028.57
heat exchanger	256.82	109.20	118.3
cycled water pump	13.66	13.66	13.66
electrical increased cost	259.36		259.36
gas increased cost		1349.99	
sum	1443.17/1183.81	1872.19/522.2	1900.29/1640.93

3.3 comparison of operating costs

According to an economic analysis of different heating/cooling styles done by certain Japanese company, SSHP system retrenches 40% operating cost compared with the conventional cooling plus boiler system, and achieves 30% smaller than ASHP system.

The experimental results of SSHP system of Beijing Gao Beidian WWTP show SSHP system's operating cost is the smallest than gas plus ASHP system and underground WWHP system. During the period of validity(assumed 20 years), the total operating cost is about 70% of underground WWHP and 45% of gas plus ASHP system.

Some literature shows the operating cost of SSHP and GSHP system is 50%~60% of the common central air conditioning system.

3.4 the quantity of CO₂ and NO_x released to environment

According to some literature, the sum of CO₂ released by SSHP system is reduced by 40%~51% in central system and by 13% in separate system, while the sum of NO_x is decreased by 36%~49% in central system and 13% in separate system.

4. CONCLUSIONS

Through above comparisons, conclusions are as follows:

As to the energy consumption, gas plus ASHP system is the smallest, while SSHP system and

- ① GSHP system is larger. But considering the comprehensive economic benefit, it is estimated heat pump compelled by electricity is better than heat pump compelled by gas when its power is below 250kW^[4].
- ② Assuming the electricity and gas increased costs are not included in the first cost, the first cost of SSHP system is 1183.81RMB/kW, the gas plus ASHP system's is the smallest, i.e. 522.2 RMB/kW, while the GSHP system's is the largest, up to 1640.93 RMB/kW. So SSHP system's first cost is three times as that of gas plus ASHP system and is just 70% of GSHP system.

- ③ When the electricity and gas increased costs are counted, the first cost of SSHP system is 1443.17 RMB/kW, is the smallest of three styles and is about 76% of the others.

As for the designed scheme of the system, its first cost is an important factor for the investor. But a scheme with a smaller cost is not meant an economic and suitable one. When criticizing an operating system's economic, its operational cost is an important element too. The paper considers the first cost and the operating cost comprehensively, analyzes three styles in details and gets concluded that SSHP system is the best in economic and environment protection, then is the GSHP system, while the gas plus ASHP system has the largest cost of all.

REFERENCES

- [1] Feng yangang. Study on the reclaim of sewage water: [master dissertation] Beijing: Beijing university of technology, 2001. China
- [2] Zhou Wenzhong, Li Jianxing, Tu Guangbei. Prospect of sewage source heat pump systems and cooling energy utilization of sewage. Heating Ventilation And Air Conditioning, 34(8): 25-29. China
- [3] Xu Wei, et al. Ground source heat pump engineering manual. Beijing: China architecture and building press, 2001. China
- [4] Jiang Nengzhao. Technology and application on heat pumps of air conditioning. Beijing: China machine press, September, 1997. China