ANALYSIS OF A SURFACE-WATER HEAT PUMP SYSTEM APPLICATION

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ABSTRACT

This paper analyses the application of a surface-water heat pump system in a R&D base in Beijing, China. The conditions such as surface-water area, volume, water temperature, ambient temperature etc. are studied firstly, then the system selected program is discussed. Through comparing several system types, a suitable system is determined, the technical and economic analysis is made, and the energy and financial saving is calculated.

Key Words: ***surface water, temperature difference, economic analysis.***

1 INTRODUCTION

The R&D base is located at Beijing of northern China, which floor area is about 100,000 square meters. There is a lake in this base, with area of about 100,000 square meters and average depth of 3.5 meters. To meet the heating and cooling load demand, the temperature rise is 0.33℃ in summer at the design condition defined in the National HVAC design code, and 0.22 ℃ decrease in winter. On the assumption that the earth's temperature is constant, heat exchanging happens among lake, ambient and earth. So the lake's area and volume is enough for the load. Because the water is corrosive, the indirect system with a coil heat exchanger is better than the direct system. Considering the building usages in this base, the fan coil unit system is appropriate. Compared with the traditional HVAC system, the energy saving is obvious in winter.

2 PROJECT INTRODUCTION

This R&D base is located at Beijing, the capital city of China, with a floor area at about 100,000 square meters. There is a lake in this base. The area of this lake is about 100,000 square meters, and the average depth about 3.5 meters. The owner of this base plans to utilize the lake to meet the heating and cooling demand for the office buildings. Annual average ambient temperature of Beijing is about 13 ℃, average ambient temperature in Winter is about 4 ℃ and 26 ℃ in Summer.

3 SELECTION OF SYSTEM

Surface water is liable to be polluted. There is a lot of soil, sand, algae, and other impurities in it. Water surface is exposed to air, so oxygen content is very high and causticity is severe. If surface water is supplied to heat pump unit directly, the life-span of the unit will be badly shorten, the performance of the heat exchanger will go down obviously, and also the piping system will be blocked, so it is not suitable to use a direct system to serve surface water to the heat pump. However, if we use a heat exchanger to separate the surface water from condenser loop, and the heat exchanger is running at a small temperature difference, thus we can use a cheaper heat exchanger to protect the expensive heat pump unit. One disadvantage of using this kind of indirect system is that there is a temperature difference in heat exchanger, which cannot take full advantage of the energy in the surface water. When the volume or temperature of the surface water cannot meet the load demand of the system, an auxiliary heat source is needed. Generally the auxiliary heat source is a cooling tower in summer, or a natural gas boiler in winter.

According to meteorological and hydrological conditions in Beijing, temperature of surface water in summer is about 25~27℃. Suppose the temperature difference between load side and condenser side is 5 ℃, the inlet temperature of the condenser loop will be not higher than 32℃, the temperature difference between then condenser inlet and outlet can fulfill the requirement of the heat pump’s specification which is needed to ensure the heat pump running correctly.

In winter, temperature of surface water is about 4℃. Suppose the temperature difference between load side and heat source side is 2℃, the inlet temperature of the heat source loop will be lower than 2℃, when the temperature difference between the heat source inlet and outlet is more than 2℃, the fluid liquid’s temperature will be below 0℃, antifreeze is necessary for the heat source loop. Heat pump’s COP is in the range of 2 and 3, when temperature of the surface water is lower than 4℃, or there is less volume content in the lake, we should use auxiliary heating equipment, in this project we use a gas boiler to fulfill the load demand of the office building. Compared with normal space heating system which supply hot water to the heating equipment directly, this system has no ascendant, but the auxiliary gas boiler only be used when the water volume is not enough or the temperature is very low. The frequency that this situation happens is not so high, through a whole year; surface water heat pump system can still save energy, which will be discussed later.

From the point of view of the terminal, heat pump system can be classified for two types, one is central water to water heat pump with fan coil units system, and the other one is relative small water to air heat pump system. For the first type, heat pump unit is normally located in a central plant, which supply chilled or heat water to the zone equipment such as fan coil units or air handle units, because several buildings will be built in the base year after year, and the usage for these buildings is not same, if using central plant, we suggested that each building set up a plant to fulfills itself.

Water to air heat pump unit is relative smaller, it can be installed in the ceiling of controlled zones or a small space near their. This system still needs a central plant to install pumps and heat exchangers. The condenser loop normally needs not insulation, condenser water are supplied to the heat pumps in every zones, return air in the controlled zones are handled by the evaporator in cooling mode (condenser, in heating mode).

The characteristics of this two type systems are summarized as following.

Water to water heat pump system

- More centralized;
- Has much more domestic manufactures;
- Low system initial cost;
- Need a relative bigger plant;
- Pipes need insulation;
- Need four pipes system;
- Fan Coil Unit and/or AHU are needed;
- Can not flexibly adjust the heat pump’s output;
- Suitable for buildings where people have same work and rest schedule, because of the part load ratio;
- Low noise level.

Water to air heat pump system

- Relative dispersive;
- Products in the market mainly are overseas;
- High initial cost;
- A small central pump and heat exchanger plant;
- Pipes need not insulation;
- Two-pipe system can realize space heating and cooling simultaneously;
- Very flexible adjustment;
- Suitable for buildings where people have not same work and rest schedule;
- Higher noise level than fan coil units;
- Without electrical preheating coil, low temperature protection will start up when out side air temperature is lower than 5℃.

From the R&D base owner’s, we know that this base is very far from the city center, about 40 km, people working at this base mostly live in the downtown, the base has its own bus to send people to work and back home, so they have same work and rest schedule, for the R&D jobs people prefer low noise, and the most import reason is the initial cost and maintenance, the water to water heat pump system with fan coil unit terminal was selected.

3 ESTIMATION OF LOAD AND WATER VOLUMES

According to national code, climate design data is:

- Annual average temperature 11.4℃
- Outdoor heating dry bulb -12℃
- Outdoor RH 45%
- Outdoor cooling dry bulb 33.2℃

- Outdoor cooling wet bulb 26.4℃

Indoor design data for the base's building is:

- Summer Dry bulb 25-27℃;
- Summer RH <60%;
- Winter Dry bulb 18-20℃;
- Winter RH no requirement

In the phase this analysis was performing, design job did not begun yet, the construction and architecture data were not available, and we could not simulate this building without those data. Refer to normal Chinese office building's data, we suppose the cooling load is 100W/m^2, heating load is 50W/m^2, total area is 100,000 m^2, simultaneity coefficient is 0.9. Total cooling load is 9000 kW; total cooling load is 4,500 kW. Assume the cooling COP is 4.3, and heating COP is 2.6, the condenser loop will release 11,093 kW heat to the lake in summer, and 2,769 kW heat supplied by the surface water in winter.

From the data mentioned above, the total volume of this lake is 350,000 m3, in summer, if the air condition system running 12 hrs, heat released to lake is Q=1,1093 kW×12hr×3,600s= 479,217,600 kJ. the temperature rise is Q/CM=479×106/(4187×3.5×105)=0.33℃. if the temperature difference between inlet and outlet of the heat exchanger is 5℃, the flow rate is G=1908 m^3/h, it will take 175 hours to circulate all the water by the exchanger, about 7days. Also because in summer Beijing has a hot daytime and cool night, the temperature is about 10 to 15℃, the 0.33℃ temperature rise is much smaller.

In winter, space heating is needed every hour, heat supplied by the lake for one day is Q=2769 kW×24hr×3600s=239×106kJ. Ice will not be thicker than 30cm, the average depth will go down to 3.2 m, and total volume is 3.3×105 m^3, temperature declined is Q/CM=239×106/(4187×3.2×105)=0.18℃, if the temperature difference between inlet and outlet of the heat exchanger is 2℃, the flow rate is G=1191 m^3/h, it will take 278 hours to circulate all the water by the exchanger, about 12days. And Beijing has a sunny winter, solar radiation heat gain to the lake is considerable, the 0.18℃ temperature decline can be override by the solar and heat exchange with the riverbed.

Although through the above discuss, it seems the water volume is big enough to meet the energy demand for the air condition system, we still think there should be a auxiliary gas boiler installed to ensure the system performance in case of extreme weathers, and a detailed simulation after scheme design should be carried out using a simulation software.

4 ABOUT THE ENVIRONMENT

Before being supplied to the tubular heat exchanger, surface water is usually treated to lower its impurity content, anticorrosive treatment is also needed. Great attention should be paid to avoid pollution on the lake.

5 ECONOMIC ANALYSIS

5.1 Cooling

Compared with normal chiller, surface water heat pump has a higher COP, but it cannot get obviously energy saving. Although this system doesn't need cooling towers, a heat exchanger is needed, so for cooling mode, there are not so many benefits to the users.

5.2 Heating

To find out the economic benefit from heat pump system, a traditional reference system should be taken into account. The most popular space heating system is composed of gas boiler in plant and radiator at terminal.

The heating load demand schedule in Beijing is: the percentage of average load demand at 90% of peak schedule is about 15% of total running period; percentage of 60% load demand is about 30%; percentage of 30% load demand is about 55%. The space heating demand period is 129 days.

Table 1

Item	Amount	Unit Price (RMB)	Total cost (RMB)
Pump Electric Consumption	500,000 kWh	0.45	300,000
Heat Pump Electric Consumption	2,700,000 kWh	0.45	1,620,000
FCU, AHU Electric Consumption	320,000 kWh	0.45	192,000
Laborage, maintenance, misc.			500,000
Aggregated			2,084,000
Price Per square meter			20.84

From the table, the heat price for heat pump system is 20.84 RMB/m^2, for the traditional reference system, the average price in Beijing is 30 RMB/m^2.

6 CONCLUSIONS

1. This base can apply surface water heat pump system.
2. An auxiliary gas boiler and cooling tower should be taken into account to ensure the system running well in case of extreme weathers.
3. A detailed simulation after scheme design should be carried out using simulation software.
4. Great attention should be paid to avoid water pollution of the lake.
5. The heat price for heat pump system is 20.84 RMB/m^2; traditional reference system's average price is 30 RMB/m^2.