Feasibility of Groundwater-source Heat Pump System Used as Heating System in Northeast China

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ABSTRACT

Ground-source heat pump systems have developed rapidly recently in China. This paper studies the feasibility of the Groundwater-source heat pump system used as heating system on the basis of an intended application on a university campus in Northeast China. The technical problems are discussed and it is found that all the technical matters can be solved. But the heating cost of heat pump system is doubled with comparison to the traditional heating system, i.e. district boiler plus radiators. Therefore, We believe groundwater-source heat pump system is not economical when it is used only or mainly for heating in Northeast China.

INTRODUCTION

Although ground-source heat pump system has been introduced to China for only more than one decade, it is greatly expanded by the promotion of the authorities and HVAC engineers because of its environment-friendly and energy-saving characters. In North China, all the residential and other buildings are obliged to install heating system. The energy consumption for building heating was 1.27×10^8 tons standard coal in 1995, which was 10.7 percent of total national energy output and 21.4 percent of total energy consumption of heating area. If the heating energy can substitute underground energy for coal, which is the most widely used energy for heating system in China, it will bring big profit to the environment.

The authors studied the feasibility of Groundwater-source heat pump system used as heating system on the basis of an intended application on a university campus in Northeast China. The concerned university campus is planed to be about 600 thousand square meters and carry out on two stages. What we discussed here is the first stage, which is about 350 thousand square meters. The buildings waiting to construct include classrooms, laboratories, library and offices etc. The place where the campus located is the primary heating area in China, where there have long cold winters and short warm summers. The buildings are located where they must equipped heating system and the cooling systems are often luxurious additions. For the sake of protecting environment, reducing Operating cost and developing new technology, the administrative board of the university intended to use the groundwater heat pump system as the heating system instead of the Chinese traditional heating system, i.e. district boiler plus radiators. The authors are entrusted to supply a professional report to help the supervisors to make the decision.

THE HYDRO-GEOLOGICAL STATUS AND AVAILABLE ENERGY STATUS

The Hydro-geological Status

The region of Northeast China has abundant ground water source. The owner has commissioned local hydro-geologists for the site survey. The hydro-geological report shows that the average temperature of the ground water is about 9.2-10℃,which is a bit higher than local annual average temperature. The average effective aquifer is 34 meters deep and the groundwater level average drop rate is 0.18m/a. Water quality report indicates that the water quality is quite good and completely meets the requirements of the open-loop groundwater heat pump system. Also, after some well testing, the hydro-geologists suggest a scheme to arrange the well group. According to this scheme, if the diameter of well hole is 500mm and the well depth is 50m, the groundwater production rate is $5000m^3/d$ and the injection rate is $1800m^3/d$.

The Available Energy Status

The place where the campus located is a developing district in that city. The civic establishment is not finished in the vicinity of the campus. The heating networks and gas networks have not reach the campus. Apart from the underground energy, the available energy can only be chosen from coal and electric power. It is considered as a wasteful method to supply space heating completely depending on electric power. Therefore, the practical and available heating energies are coal and underground energy.

The local electric power cost is relatively high, which is RMB0.69yuan/degree. The coal cost is RMB250yuan/ton, which is the national average cost. The discount for electric power valley is not counted.

TECHNICAL DISCUSSION

Groundwater temperature

As mentioned above, the local groundwater average temperature is just 9.2-10℃. Generally, the temperature difference for the heat pump is about 5℃. If close-loop heat pump system is applied, we should separate the circulating water from the ground water by heat exchangers. The reasonable logarithmic average temperature difference should be 2℃ or so. Therefore the temperature of output water of heat pump will be close to the freezing point. If hydraulic unbalance happens, there will be a risk of icing in the heat pump. As a result, when the close-loop heat pump systems are used, it is necessary to add some antifreeze to the circulating water although the usage of antifreeze will produce a lot of problems for design, operation and maintenance.

To avoid above matters, the open-loop heat pump system is an alternative choice when the quality of groundwater can fully accord with the requirements of the system. Because open-loop heat pump systems are always accompanied with great risks of rust and corrosion, it is recommended to do careful investigation and water quality analysis before the plan determined.

Regarding the project discussed, we incline to the latter mode. The low cost is the major reason.

Groundwater level

In China, along with the usage and exploitation of groundwater, the groundwater level is falling day by day. To ensure that the groundwater level is above the required limit along the system life cycle is a key factor to the groundwater heat pump system to operate effectively. If we find the production of Groundwater will decrease too rapidly to supply enough energy to the system, we should prepare some space for the standby equipment, such as electric boilers.

As for the project we discussed here, according to the regulations of China the life of campus buildings is 70 years. The groundwater level average drop rate is 0.18m/a and when the submarine pump works the groundwater level will be 3.4m lower than normal level. So after 70 years, the groundwater level will be 12.6m lower. When the submarine pumps work, the groundwater level will be 16m lower at that time. As described above, the average effective aquifer is 34 meters deep. So the average effective aquifer will be 18 meters deep 70 years later. As the hydro-geological report suggests, it will be feasible as long as the aquifer depth is big than the half of the original depth. Therefore, the heat pump system can operate well along the buildings life.

Cooling Buildup

The cooling buildup happens with relations to many factors, such as the layout of groundwater system, the flow rate of groundwater, the depth of groundwater level and the thermal character of the soil etc. It is very difficult to accurately analyze this problem. On the one hand we should prepare some space for the standby equipment lest the entering water temperature of the heat pump is too low to work. On the other hand, the cooling capacity of heat pump system must be fully used although the heat pump system is mostly used as a heating system to ease the thermal unbalance happened below the ground.

To sum up, it is more difficult to use groundwater heat pump system in cold area, such as North China. But there are always some methods to accommodate the groundwater system to the specific circumstances, however the cost will be paid. The experiences of North American and North Europe have also proved that groundwater heat pump systems can be applied in cold area. Therefore, groundwater heat pump system is feasible to be used as heating system in North China on the viewpoint of technology.

ECONOMIC ANALYSIS

China is a developing country. The cost is always the most concerned and decisive factor in a project. Therefore the result of the economic analysis is more important for the feasibility evaluation. There will be a economical comparison between the planned heat pump system and the traditional boiler plus radiators system in the latter part of this paper.

Planned Groundwater Heat Pump System for the Campus

Generally, there are two kinds of water source heat pumps. One is the kind of water-to-air heat pump, which is also named water loop heat pump. This type is usually used in commercial and institutional buildings. The equipment suppliers are almost oversea manufacturers. So this kind of heat pumps is relatively expensive in China. The other is the kind of water-to-water heat pump, which is a popular type in China. This kind of heat pump can be manufactured in China. Hence it can be purchased at a relatively low price. It cannot be used separately but always be used with fan-coil units or air handle units.

To this project, there are some advantages for water-to-water heat pump system:

- The equipment needed to the system are all mature products in China. The prices and technical supports will be more satisfying.
- The campus needs a silent environment. The water-to-water heat pump system superior to water-to-air heat pump system because its terminal equipment works without compressor.
- The water-to-air heat pump unit works with limits on entering air temperature, entering water temperature and ambience temperature. When applied in cold area, the water to air heat pump cannot work unless some measures are carried out. The other way round, water-to-water unit can work without any limit in cold region.
- The campus buildings have unitary work and rest time. And the heat recovery is not needed. The advantages of the water-to –air heat pump system cannot be fully applied.

In conclusion, the planned groundwater heat pump system for the campus should be an open-loop water-to-water heat pump system. The terminal units in the buildings include fan coil units and air handle units.

On the basis of hydro-geological report and the result of heat load calculation, we evaluate that the required groundwater flow rate is 2874m^3/h, the required production wells are 17 holes (3 for standby) and the required injection wells are 43 holes (5 for standby).

Initial investment comparison

Figure 1 shows the comparison of initial investment of district coal boils plus radiators system and groundwater heat pump system. For the traditional radiators system we supposed that there is only one district coal boiler plant for the whole campus and the radiators are made from cast iron. The cost of construction of heating stations and boiler plant is not included. As for the ground water heat pump system, a heating station in which the heat pump units are installed serves for about 50 thousand square meters. The cost of construction of heating stations is not included yet.

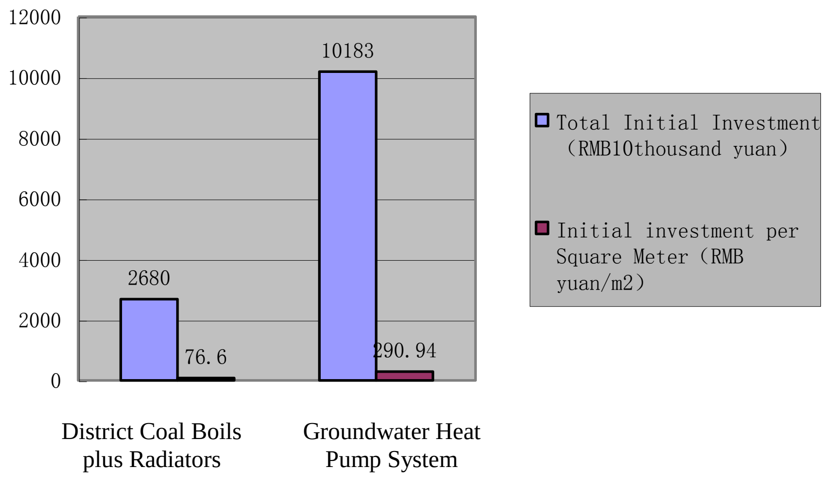

Figure1：Comparison of Initial Investment

Operating cost comparison

Figure 2 indicates the comparison of operating cost of district coal boils plus radiators system and groundwater heat pump system. The cost of latter is mainly composed of electric power fee.

For the traditional radiators system, it is assumed that the system keep running all day long in the heating time, which is 152 days (regulated by the standard). And the heating network works with constant flow rate.

As regards the heat pump system, it is presumed that the ground water flow rate and the circulating water flow rate are all unchanged. The operating regulation of fan coil units is as same as the distribution of the heating load while the heating load changes synchronously with the outdoor temperature. It is also supposed the heat pump units averagely run on 60% total capacities. The average working time of the system is counted as 10 hours a day and the heating time are 152days.

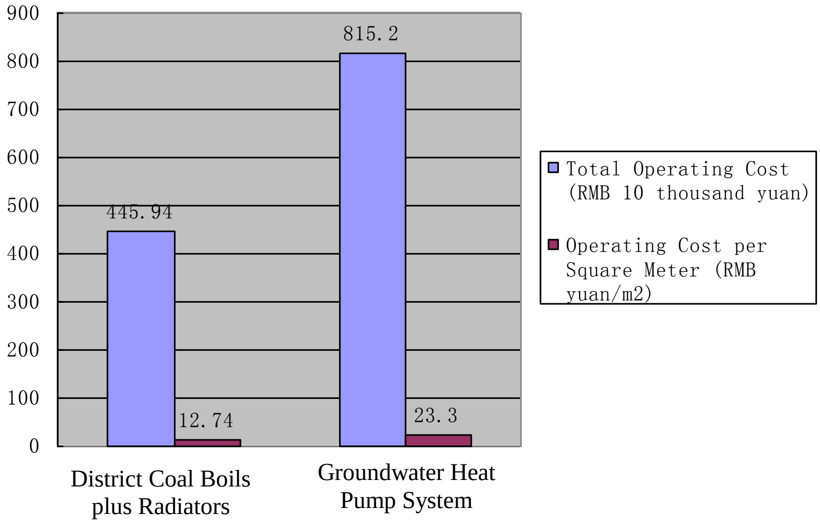

Figure2：Comparison of Operating Cost

Heating cost comparison

Figure 3 describes the comparison of heating cost of district coal boils plus radiators system and groundwater heat pump system. At this part, the lives of both systems are calculated as 15 years. The depreciation rate is regarded as linear with the year.

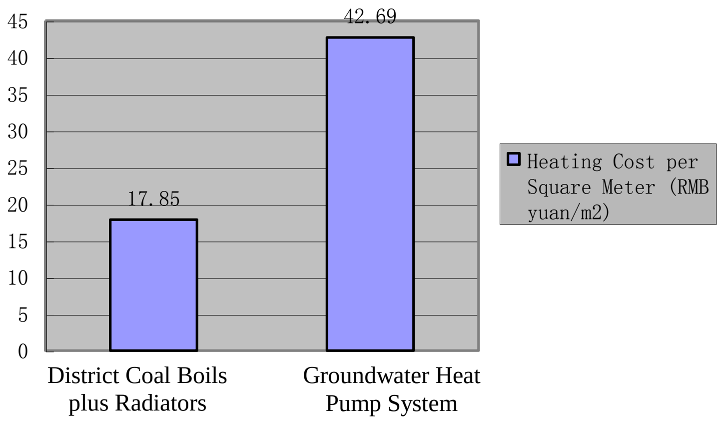

Figure3：Comparison of Heating Cost

As is shown above, the heating cost of district coal boils plus radiators system is only 42% of that of groundwater heat pump system. Some issues listed followed may give the reason:

- The initial investment of groundwater heat pump plus fan coil units system is much higher than that of district coal boils plus radiators system. Because the former has the ability of both cooling and heating while the latter just has the single capacity of heating. If only the heating system is needed, part of the investment of the former must be wasted.
- The groundwater heat pump plus fan coil units system has higher operating cost than the district coal boils plus radiators system. About 1/3 heating energy supplied by the former is transformed from electric power while the quantity of heat supplied by the latter is mainly translated from coal. The price of coal is much less than the price of electric power at the same quantity of energy, which maybe is the leading reason.
- The groundwater heat pump plus fan coil units system and the district coal boils plus radiators system are not on the same grade. The former has great advantages over the latter on both functions and comfort. On the viewpoint of performance and cost ratio, the differences of the costs are not so big as mentioned above.

CONCLUSIONS

- The groundwater heat pump system is applicable to be used as heating system in Northeast China. But some additional expenses will outgo to adapt to the conditions of the cold area.
- On the basis of the circumstances of the project discussed here, the initial investment of district coal boils plus radiators system is only 30% of that of groundwater heat pump plus fan coil units system. The heating cost of the former is also less than a half of that of the latter.
- Although the groundwater heat pump system has distinguished strongpoint on environmental protection and energy-saving, it is not always the economical scheme according with the specific conditions of each project. The local price of electric power is an important factor for the result of economic analysis.
- The groundwater-source heat pump system is not economical when it is used only or mainly for heating in Northeast China.

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