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# A FEASIBILITY STUDY OF GEOTHERMAL SPACE HEATING SYSTEM IN TIANJIN PORT RESIDENTIAL DISTRICT

Yang Hongxing    Wang Wanda

Tianjin Geothermal Research and Training Center
Tianjin University, Tianjin, P.R. China

## ABSTRACT

The building area of Tianjin Port Residential District is about 600,000 square metres, which has been heated using fuel oil in winter for the past ten years and 13000 tons of fuel oil is used in every winter. But, the price of fuel oil is high in China. The heating system is not economical.

Since the area is rich in geothermal resources, this paper analyses the existing heating systems and proposes reasonable geothermal space heating parameters when it is used in place of fuel oil. Proper peaking scheme must be chosen in order to raise the utilization efficiency of geothermal energy. So,this paper also describes the technical-economic analysis among four kinds of peaking schemes—fuel oil boiler, electric heat pump, the combination of fuel oil with heat pump and turbin-driven heat pump. The results show that under the present technical-economic conditions the system using part of the existing fuel oil boilers as peaking equipment will be the least in investment, simple and reliable in operation. The alterative peaking scheme is the combination of electric heat pump and fuel oil boiler. This scheme is also superior to that of using fuel oil alone.

Now. a geothermal space heating system is under construction in accordance with this study on the area.

## INTRODUCTION

The Tianjin Port Residential District is situated on the Bohai Bay. The heating building area in winter is 600,000 square metres and will come to 900,000 square metres in the year 2000. Fuel oil boilers are now the heating source. The circulating water in the heating system is heated to 85°C and then sent to the users. Such heating systems have been put to operation for years. With the expansion of the building area these systems have not been able to meet the increasing need. This is reflected in the high consumption of oil, low capacity of boilers and poor quality of heating. Besides, air pollution is very serious in that district.

Fuel oil is not plentiful and its price is high in China. It is an export commodity which can be sold to gain foreign exchange. Besides, consuming large amounts of oil is contrary to our state energy policy. It is therefore an urgent matter to find substitute for the heating energy.

There is abundant low temperature geothermal water resourses under the Bohai Bay. The information from the two completed wells shows that the temperature of the water at the depth of 800 metres is about 80°C. It is a good heating energy source. To study the feasibility of tapping geothermal resources for heating, it is necessary first to analyse the operating conditions of the existing heating system and then examine the four schemes of geothermal heating systems with peaking load and make technico-economic analysis and comparisons so as to provide design engineers with information.

## THE EXISTING HEATING SYSTEMS

The residential district consists of three sub-districts. In Table 1 are the heating building area, the capacity of boilers in each sub-district. The saturated steam (800 kPa) generated by fuel oil boilers, heats the circulating water to 85°C through heat exchangers. The return water temperature is 62°C and the room temperature is usually 20°C or so.

Table 1 The heating data of the existing, systems

| District | Heating Area ($m^2$) | The Capacity of Boilor (kW) | Oil Used (Tons/yr) |
|---|---|---|---|
| Gangqu | 85500 | 16700 | 2238.7 |
| Binhai | 156900 | 20900 | 4108.3 |
| Dongqu | 248700 | 34800 | 6512.0 |
| Total | 491100 | 72400 | 12859.0 |

Such heating systems consume large amounts of oil. The heating cost is high, about 518.8 yuan/$10^6$KJ, which is three times higher than that of coal boiler heating systems.

According to the measured data the average water temperature going in and out of the radiators in heating rooms is 73.5 °C. The heating load per unit heating building area is 81.4 W/$m^2$ . The geothermal heating system must satisfy these requirements.

## THE GEOTHERMAL SPACE HEATING SYSTEM

The utilization of geothermal energy for heating depends mainly on its economy. Considering the local conditions, we use direct geothermal space heating mode for the feasibility study. Once the geothermal well is completed, the factor affecting the feasibility of the geothermal heating system is the feasibility of the heating system on the ground. Here the four schemes of geothermal heating systems with peaking load will be examined one by one.

The heat pump is technically possible in China, but not economically competitive in many cases on application. Whether the heat pump can be used in geothermal space heating systems, and whether it is superior to oil boiler heating systrms remain to be studied. The following analysis is an attempt.

For the sake of convenience, the geothermal water with flow rate of 80 Tpns/hr and temperature of 78 °C serves as the basis for discussions.

1. **The Heating** Scheme with Boiler-peaking Load

The geothermal space heating system with boiler-peaking load is shown in Fig.l. The existing oil boilers can be used as peaking boilers. The saturated steam produced by boilers enters the heat exchanger and provides peaking load to raise the temperature of circulating water. The circulating water first flows through the original indoor heating system and then enters the reconstructed indoor heating system which has more radiators. Such an arrangement can reduce the temperature of the discharged geothermal water without refitting all the indoor heating system.

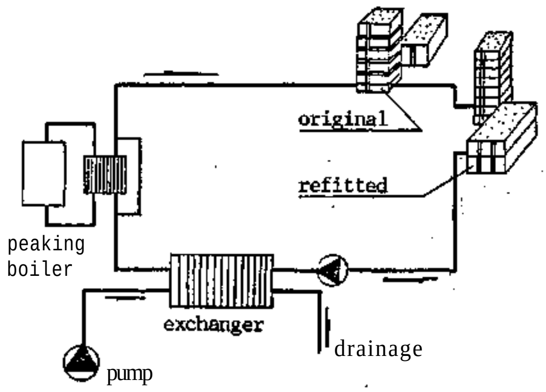


Fig.l The heating system with oil boiler peaking load

According to reference the geothermal space heating parameters with oil boiler peaking load can be got by the mathematical model of the optimum parameters of geothermal space heating system, i.e.

| | |
|---|---|
| peaking temperature | 95 °C |
| discharged water temperature | 43 °C |
| transition temperature | 1 °C |
| peaking days | 98 days |
| heating building area | 65,000 $m^2$ |
| the increment of radiators | 1.5 times |

Table 2 includes the design heating load and I.he proportions of peaking load and geothermal load upon the total heating load under design condit.ions.

Table 2 The calculating results under design heating conditions

| | | |
|---|---|---|
| total heating load (kW) | | 53000 |
| heating building area ($m^2$) | | 65000 |
| peaking load (kW) | | .27000 |
| geothermal load (kW) | | 26000 |
| proportions | geothermal | 49% |
| | Speaking | 51% |

The calculation shows that under the design conditions the proportion of geothermal load to peaking load is about 1:1, while the proportion of the accumulated load is 4.8:1. The geothermal well supplies much of the heating load. The accumulated load diagram is shown in Fig.2.

2. The Heating Scheme with Electric Heat Pumjo Peaking Load

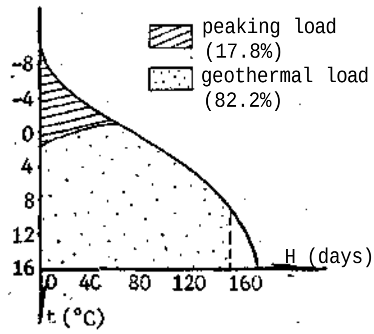


Fig.2 The accumulated heating load

The geothermal heating system with electric heat pump peaking load is shown in Fig.3. Because of the use of heat pumps the temperature of the discharged geothermal water can be reduced without refitting the indoor heating system. The results of calculation of the geothermal heating parameters are shown in Table 3.

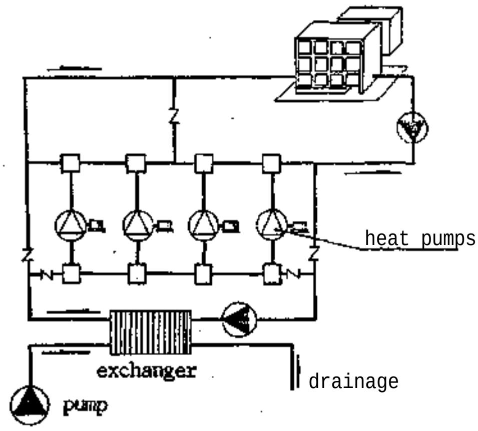


Fig.3 The heating system with heat pump peaking load

Table 3 The calculating results of the heating system with electric heat pump peaking load

| No. of heat pumps | 1 | 2 | 3 | 4 | total |
|---|---|---|---|---|---|
| condensation temp. | 72 | 78 | 84 | 90 | |
| evaperating temp. | 20 | 30 | 40 | 50 | |
| COP | 3.28 | 3.47 | 3.53 | 3.81 | |
| power (kW) | 369 | 345 | 336 | 314 | 1360 |
| heating load (kW) | 1210 | 1190 | 1180 | 1160 | 4740 |
| heating buiding area ($m^2$) | | | | | 58400 |
| heating load per year (kJ/yr) | | | | | 6.26x10 |

The unit of temperature is centigrade.

3. The Heating Scheme with Combination Peaking Load of Oil Boilers and Electric Heat Pumps

The peaking load by combining heat pumps with boilers can not only save electric pov-jer, but also reduce the temperature of discharged geothermal water below 30°C during most of the time in heating period to satisfy the requirement for the discharged water temperature.

The system is shown in Fig.4. During the non-frigid weather in heating period only geothermal water supplies the heating load; during colder weather heat pumps are started ; and during frigid weather oil boilers are added jointly. The heating parameters are listed in Table 4.

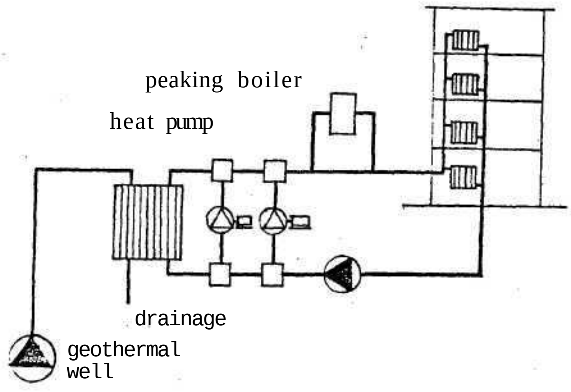


Fig.4 The geothermal heating system with combination peaking load

Table 4 The calculating results of the conbination peaking scheme

| | | |
|---|---|---|
| condensation temperature (°C) | | 78.0 |
| evaporating temperature (°C) | | 30.0 |
| COP | | 3.53 |
| heat pump power (kW) | | 1016.27 |
| accumulated heating load (kJ/yr) | | 8.58x10 |
| geothermal load (kJ/yr) | | 6.32x10 |
| peaking load | boiler (kJ/yr) | 1.45x10 |
| | heat pump (kJ/yr) | 0.81x10 |
| heavy oil consumed (tons/yr) | | 442.6 |

Fig. 5 shows the proportions of the two kinds of peaking load upon the total heating load. It can be seen from the figure that the use of combining heat pumps with boilers can avoid bearing the maximum design heating load by heat pump and reduce greatly its capacity and the consumption of electric power. The design of the system can be more reasonable, and the geothermal utilization efficiency is raised.

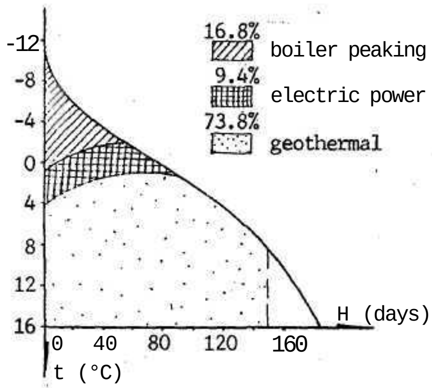


Fig.5 Heating load proportion diagram

4. The Heating Scheme with Turbin-driven Heat Pump. Peaking Load

As electric power is limited in the residential district, it is thought that the steam generated by the existing steam boilers should be used to drive turbins to start the compressive heat pump as the peaking equipment. This scheme may be feasible. The system is the same as Fig.3 except for the replacement of motor driven heat pumps by turbin driven ones. The results of the calculation are listed in Table 5.

Table 5 The calculating results of the turbin-driven heat pump scheme

| No.of heat pumps | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| condensation temp.(°C) | 78 | 78 | 78 | 78 |
| evaperating temp.(°C) | 20 | 30 | 40 | 50 |
| COP | 2.66 | 3.41 | 4.29 | 5.78 |
| heat pump power(kW) | 476 | 351 | 266 | 578 |
| design heating load (kW) | | | | 9340 |
| heating building area ($m^2$) | | | | 114700 |
| acummulated heating load (kJ/yr) | | | | 8.19x10 |

THE ECONOMIC ANALYSIS AND COMPARISONS OF THE FOUR SCHEMES

Table 6 shows the newly increased total investment, cost and heating parameters of the four schemes. Compared with the boiler heating system , the geothermal heating systems will pay more investment but less operating cost. To find which one is feasible, the four geothermal space heating system schemes are compared with the oil boiler heating system so as to carry out the numbers of recovery years. See also Table 6.

CONCLUSIONS AND SUGGESTIONS

1. There is abundant geothermal water underground in Tianjin Port Residential District. The distance to transport the water is short, and the investment in the heating pipe network is small. Compared with the oil boiler heating system, the geothermal heating ststem has advantages of low cost, high economic gains and no air pollution as caused by the smoke emitted from oil boilers.

2. If the indoor heating system is not to be refitted, that is,not to increase the number of radiators, the peaking equipment must be installed. To increase the peaking load is the effective means to raise the geothermal utlization efficiency and expand geothermal space heating building area.

3. If only the existing oil boilers are used as peaking equipment, the cost of geothermal heating system will be the lowest, the number of recovery years smallest, and the operation simple and reliable. This is the best scheme, but the reduction of the discharged geothermal water temperature is limited.

4.For the peaking scheme of combining electric heat pumps with oil boilers the cost and number of recovery year are only second to the unique oil boiler peaking scheme. This scheme is the alternative. It can not only reduce the temperature of the discharged geothermal water

Table 6 Comparative results of the four geothermal space heating schemes

| peaking scheme | boiler | electric heat pump | combination | steam turbin-driven |
|---|---|---|---|---|
| design supply temp.(°C) | 95.0 | 85.0 | 90.0 | 84.0 |
| design drainage temp.fC ) | 43.0 | 30.0 | 30.0 | 30.0 |
| accumulated heating load every year (kJ/yr) | 6.919x10 | 6.262x10 | 8.583x10 | 8.195x10 |
| heating building area ($m^2$) | 65000 | 58400 | 102700 | 114700 |
| net investment (RMB yuan) | 712200 | 1739000 | 2223000 | 2909000 |
| yearly income (RMB yuan/yr) | 990700 | 896700 | 1229200 | 1173500 |
| production cost (RMB yuan/lO^kJ) | 52.5 | 139.8 | 119.3 | 182.6 |
| recovery years (yr) | 1.0 | 5.1 | 3.9 | 12.4 |

but also expand heating building area. It is proposed that this scheme be carried out on a small scale to accumulate experience so as to improve the technique of producing and using heat pumps for geothermal space heating in China.

5. It is suggested that the experiment on reinjection of geothermal water be made to prolong the life of geothermal fields.

## ACKNOWLEDGEMENT

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