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DESIGN OF GEOTHERMAL HEATING SYSTEM IN TIANJIN, CHINA

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ABSTRACT

Tianjin is the lead city, with regards to geothermal direct utilization of medium-low temperature geothermal in China. In this paper, the general situation of geothermal heating in Tianjin is presented, and detailed analysis on design of geothermal heating systems is given, including optimizing utilization, piping and radiators. Furthermore the future of geothermal development of geothermal heating system in Tianjin will be discussed.

1. GENERAL SITUATION OF THE GEOTHERMAL HEATING IN TIANJIN

In October of 2007, there were 333 geothermal wells in Tianjin, with a total production of 2,583.8×10^4 m^3. The main geothermal fluid for heating is discharged from the Wumishanzu Group (Jxw) of Jixian System and the Tertiary Guantao Group (NG). The average temperature is between 86.71°C and 62.8°C. By the end of 2007, the geothermal heating area was nearly 1,000x10^4 m^2, heated by a total of 116 companies, accounting for is almost half of total heated area by medium-low temperature geothermal of China.

2. HISTORY AND DEVELOPMENT OF THE GEOTHERMAL HEATING IN TIANJIN

During early geothermal exploitation, due to the simply technology and equipment, the geothermal utilization system was single use, simple and involved extensive exploitation. Most of the heating systems were by direct heating or simple indirect heating. Due to their simplicity the systems were disposing waste fluid at higher temperature, and were working at a lower utilization ratio. With an increasing geothermal utilization domain and the technology of heat pumps and floor radiation heating maturing, the utilization ratio is rapidly improving leading to a more sustainable use of the geothermal resources by step wise utilization and reinjection.

3. DESIGN OF HEATING SYSTEM

Because of the temperature and capacity condition of the Wumishan Group (Jxw) it is the main reservoir utilized for heating in Tianjin. At present, the heating system is being optimized. In the following a typical example of a heating system will be introduced, which fluid produced from the Wumishan Group (Jxw) reservoir at a temperature is 85°C. The flowrate of the well is 105m^3/h, supplying heat for an area of about $20\times10^4 m^2$ of high buildings. The temperature of the back-water is 35 to 45°C, and the heating elements are floor radiators.

3.1 Designed heating load

According to the "standard of building economies" on energy, the unit of heating load is 40 W/m^2, and thus, the heating load is 8,000kW.

3.2 Condition of geothermal fluid and geothermal capacity

The geothermal fluid exploited from the Wumishan Group (Jxw) has a temperature above 85°C and the flow rate is $105m^3/h$, the TDS (Total Dissolved Solids) of the fluid is about 2g/l, which causes only low corrosion damage.

Based on experiments, the exchange coefficient can be estimated at 95％, and the heat exchanger loss at 2°C.

The geothermal capacity can be calculated by following formula:

$$Q_d = 1.163 \times G \times (t_d - t_{w1}) \times 0.95 \qquad (1)$$

Where, G is the flow rate of the well (m^3/h), t_d is temperature of the geothermal fluid (85°C), and t_{w1} is temperature of the geothermal fluid after heat exchange (37°C).

From equation 1, the thermal capacity of the geothermal well is 5,568kW; which is insufficient for heating, and a heat pump is, therefore, necessary. When the temperature of last geothermal fluid has decreased to 13°C (by heat pump) then the total heat capacity is 8,120 kW.

3.3 Design of heat pump peak load

Based on the calculation above, the heat capacity does not fulfil the heat load of 5,568kW - 8,000kW, accounting for a peak load of 2,432 kW, accounting for 30.4% of the total heat load. According to the peak load, the temperature of the circular water is calculated to 42°C, increasing to 43°C after heated by heat pump. The temperature of waste fluid is 15°C, with a utilization ratio, for the heating system, of 95.9%.

Figure 1 shows that when the outdoor temperature is under -0.79°C, the heat pump should be turned on, and the accumulative load and cost of electricity ca calculated automatically.

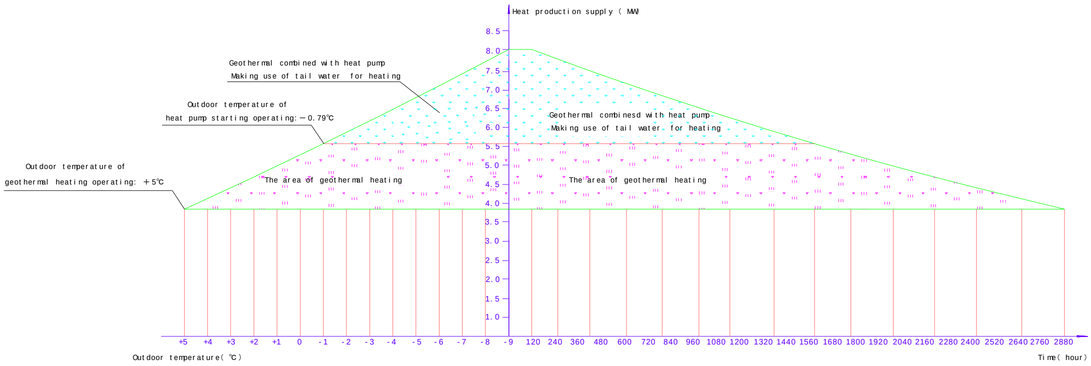

FIGURE 1: Heat load with time of the heating system

3.4 Flow of utilization system

Base on the heat load and condition of the building, the design is follows:

- there are two heat exchanger systems, the temperature of geothermal fluid decreases to 61°C after the first exchange, and to 37°C after the second exchange. When the fluid has been through the heat pump system, the temperature of the waste geothermal fluid is 15°C, and the fluid is injected back into the reservoir.

- the heat load is comprised of two parts: The heat exchange is used for supplying the base load, and the heat pump regulate for peak load.

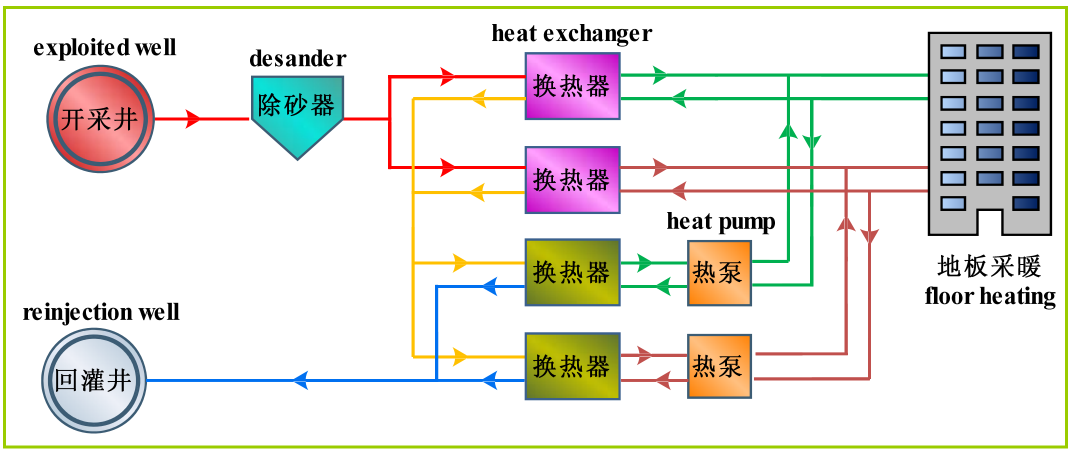

FIGURE 2: Flow chart of heating system

3.5 Heat preservation and anti-corrosion

The surface of outdoor pipes is covered by asbestos to minimize temperature loss. In Tianjin the temperature loss is less than 1~°C/km.

To avoid corrosion the material used for exchangers is Titanium, and the pipes are made of stainless steel or galvanized steel. The inside of the pipes is covered by stucco anti-rust lacquer after cleaning.

4. GEOTHERMAL TRANSPORTATION SYSTEM

The geothermal transportation system is an important part of the geothermal engineering, because the pipe network is a tremendous investment if the water has to be transported for long distances. The type of pipe and material should, therefore, be thoroughly chosen.

4.1 Material of pipe

According to the properties of geothermal fluid, there are different choices of pipes for individual heating systems. The life and the cost of the pipes vary greatly for different materials. Steel, fibreglass and CPVC pipes are some of the common types. What pipe will be used depends on the temperature of geothermal fluid, its chemical property and cost of the pipe. The cost of the pipe is dependent on the durability, temperature and, pressure resistance.

For outdoors pipes with large diameter, the steel and forged iron pipes are still being used, but the trend is to substitute the metal pipes with noncorrosive, non-metal pipes. When comparing technology and economy, reinforced fibreglass (FRP) pipes with a diameter above 300mm have a lower cost than steel pipes, but the duration of the latter is much longer. The experiment with reconstructed polypropylene (PP-R1) pipes has had great success, and they are resistant to high temperatures. It is very complex to apply non-metal pipe indoors. FRP pipes are seldom used due to the small diameter and high cost. The temperature of thermal fluid and cost are the main factors when selecting pipes. For living hot water with a temperature below 50°C many kinds of inexpensive pipes can be applied such as ABS, UPVC, PVC and PP. But for heating purposes it is very complex to choose a pipe suitable for all aspects of geothermal heat production: high temperature, high pressure, heat expansion, wriggling, cost etc. For example, polythene (PEX) and chloridized PVC (CPVC) have been widely used in USA and Europe; they meet the needs of geothermal heating requirements. They are resistant to high temperature and pressure, but their prices are much higher than for steel pipes, so their range is limited. Aluminium moulded compound pipes (PEX-A1) are produced domestically at large scale, because of its excellent resistant to high temperature and pressure and low heat expansion. Although its price is still a somewhat higher than that for steel, the prospect is good since its price will become lower with increasing production.

4.2 Pipe structure

For the outer protection of the pipe PE or FRP is always used. For heat insulation polyurethane is used, and the inner pipe is made of Q235B such as low carbon steel or other non-metallic pipe.

In order to increase the surface area of steel pipes with polyurethane foam and bond strengthening between the inner walls to reduce corrosion risks, a PE inner corona treatment and rust removal should be performed before heat insulation. The foaming technology is fluorine-free and it is not polluting to environment. During foaming, the density of polyurethane foam is automatically controlled to be within 60 to 80 kg/m^3. Immersion in boiling water for 90 minutes under 1 bar is carried out, to ensure that the water

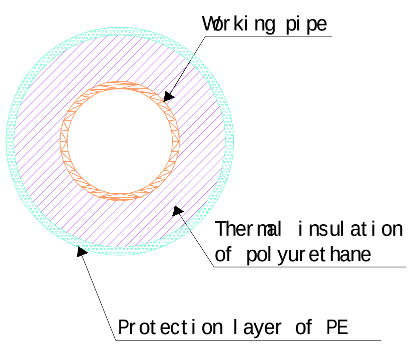

FIGURE 3: The section structure of pipeline

absorption ratio is below 10%. After foam moulding, steel working, insulating with polyurethane, high-density polyethylene is made to trinity.

This structure of a pipe has been proved effective by engineering examples in China and abroad, due to the polyurethane foam insulation material, with an obdurate rate of 88% according to national standards. This means that it has good waterproofing performance (see the Figure3).

4.3 Strength analysis of pipe

To ensure the safe operation of a system at reasonable economic investments, the heating pipe needs with regards to material and strength is analyses and double-check.

4.3.1 Straight pipe thickness calculation

Working pipe thickness is calculated by formula 2：

$$\delta_t = P_d D_o / (2[\sigma]\Phi + P_d) + B \qquad (2)$$

where:

δt=Theoretical calculated of pipe thickness, m
Pd=Calculated of pressure pipeline, Mpa
Do=External diameter of pipe, m
[σ]= Basic allowable stress under calculated temperature, Mpa
Φ= Basic allowable stress correction
B= Additional pipe wall thickness, m

4.3.2 Thickness of outer steel pipe for protection calculation

Based on experiences from previous projects and referring to the relevant norms, to ensure the stability of a buried straight pipeline, to prevent bending, and guaranty a safe and reliable heating, the pipe wall thickness should be calculated.

σ and T on high-point state in the anchor part of the straight pipe:

When rm/δ≤28.7, σ≤334Mpa
When rm/δ≥28.7, σ≤（9250δ/rm+11.7）Mpa
When rm/δ≤28.7, T≤130
When rm/δ≥28.7, T≤（3500δ/rm+8）
Where: rm= the average radius of exterior pipe, m
δ= Average outer pipe wall thickness, m;
σ= Stress changes in the scope, Mpa;
T= Temperature change between inside and outside of pipe,

4.4 Heat preservation of pipe

Materials for heat preservation commonly include rigid foam products, Rockwool and asbestos etc. The types of cellular plastic are abundant. At present, polyurethane foam is widely applied. Its main components are esserbetol and PAPI l. With regards to insulation, anti-corrosion, and waterproofing on pipes for medium-low temperature geothermal water, the prefabricated heat insulating pipe is used

in particular. Rockwool is felted by using phenolic resin, the resistant temperature is 400 °C. Rockwool products generally have Rockwool panels, pipe unit and pipe shell.
Heat insulation of pipelines has significance for reducing heat loss. For the straight-buried pipeline, the currently used domestic material is polyurethane foam, which, not only, has a good thermal insulation property but also a good waterproofing performance. The thickness of the insulation layer has to be calculated for optimal thermal insulation. The Polyurethane thickness, generally, is 25 to 50 mm.

5. RADIATION SYSTEM INDOOR

At present, the heating radiation system includes heating radiators, floor radiation, and centre air-conditioning. The temperature of the supply water for the heating radiators is over 65°C. The floor radiation system covers the entire indoor floor area, and the temperature of the supply water is 45°C. The centre air-condition system is fitted for heating and cooling, the temperature of the cycle water is 55°C in general, which is higher than for the floor radiation and lower than for the radiators. Therefore, in order to save energy, we suggest making use of more floor radiation and centre air-conditioning.

6 CONCLUSIONS

- The utilization ratio of geothermal heating systems can be increased enormously, more than 90%, by utilizing geothermal heat pumps to fall lower the temperature of the tail water.
- The material of the transport system should be selected according to the chemical composition of the geothermal fluid.
- Economizing on energy should be emphasized with regards to indoor radiation.

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