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Multiple Utilization of Geothermal Resource in Tianjin Olympic Center

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ABSTRACT

This paper describes the geothermal utilization in the Tianjin Olympic Center heating project. The technology in the design of the geothermal pumping station, laying of the piping network, and washing techniques are discussed. The design of water-circle heat pump and ventilation system was analyzed. In addition to being utilized in space heating, geothermal water is designed to provide heat to swimming pools and domestic water. Further, some geothermal water can be used for mineral water production to serve investors, tourists, and the public.

1. INTRODUCTION

The Tianjin Olympic Center is located in the Nankai district in Tianjin. The main stadium was built in 2008 in order to host the football match of the 2008 Olympic Games. Geothermal resources are used in the heating system in this building. The architecture of the stadium is so novel that it gained the name “Shui Di,” which references its location near water and its droplet-like shape. The selection of energy sources for utilization was part of the energy retrenching adopted in this building.

The building is 380 m long from south to north, 270 m long from east to west, and 53 m tall. The total area of the main stadium is about 158,000 m^2, and it can accommodate up to 80,000 spectators and players. There are about 60,000 seats for spectators. The main part of the stadium includes three parts: the football ground, public buildings, and a small swimming pool. Geothermal water will be used for the space heating of the building and the swimming pool. A map showing the location of the Olympic Center and the pump is provided in Figure 1. The total investment is 1.42 billion RMB. The stadium has a huge building with 6 floors and includes an athletes’ room, a judge’s room, a news center, an office, a health center, a shop, a balcony, a show center, a refectory, and a comfort station.

Geothermal energy was used to heat the Tianjin Olympic Center in order to decrease air pollution and save conventional energy. Three geothermal wells were drilled near the Olympic Center for this project. Wells 1 and 3 are directed wells, and Well 2 is a straight well. In this project, Wells 1 and 2 are used for production, and well 3 is used for re-injection. The characteristics of the geothermal wells are shown in Table 1.

Geothermal water is used in a water source heat pump to heat the building in winter, and it is used in a lake to supply a cooling resource in summer, leading to cleaner and retrenched energy utilization.

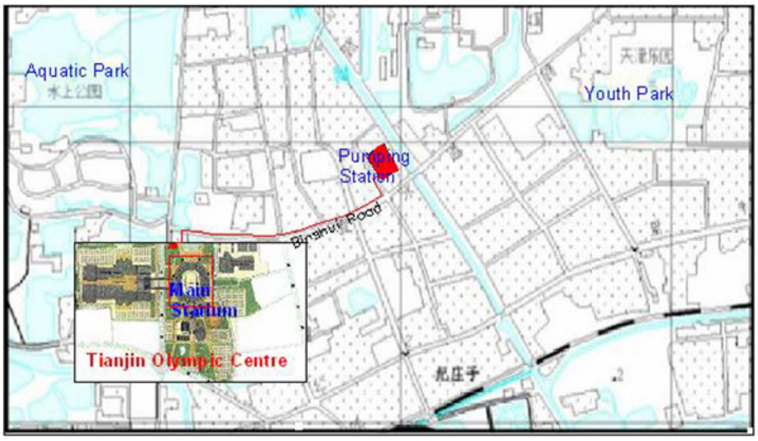

Figure 1: Location map of Tianjin Olympic Center and pump

Table 1: Geothermal well characteristics

Well No.	Finishing time	Well type	Depth (m)	Aquifer thickness (m)	Flow rate (m^3/h)	Temperature (°C)
HX-28	96.07	Directional	2680	570	110	77
HX-32	97.08	Straight	3260	1300	100	76
HX-32B	97.11	Directional	2050	125	82	63

2. GEOTHERMAL POTENTIAL AND WELLS

low operating cost, geothermal resources have been used widely in China as sources for district heating, space heating, greenhouses, fish farming, medicine physiotherapy spas, swimming pools, etc.

Because the chemical content of the water has a great effect on the equipment, tests have been performed on water samples taken from these geothermal wells. This geochemical analysis resulted in a total hardness of 317.8 mg/l, TAS = 2419.9mg/l, and a pH of 7.56. The chemical type of geothermal water was found to be Cl · SO_4 –Na. There is no $CaCO_3$ and silica scaling expected during utilization, but there is a possibility of $CaSO_4$ scaling, which could affect the equipment and pipeline designs.

3. DESIGN OF PUMPING STATIONS

In this project, the pumping station is located near the In this project, the pumping station is located near the geothermal well. The heat resource for the main stadium is the 76°C geothermal water pumped from the 1500 m deep well to the Olympic Center. During the design phase, the sustainable development of the resource was considered. Thus, after flowing through the heat exchanger, the tail geothermal water is re-injected into the same reservoir, as shown in Figure 2.

4. PIPELINE AND SYSTEM

4.1 Piping Network

Piping network calculations involve finding the optimal system parameters with respect to a predefined cost function (i.e. minimizing cost). The pipes have a resistance defined by the Darcy-Weisbach equation，given in Equation 1:

$$h = \frac{v^2}{2g}\frac{L}{D} f = \frac{8m^2 Lf}{D^2\rho^2\pi^2 g} \tag{1}$$

The friction factor can be calculated directly from Colebrook-White equation:

$$\frac{1}{\sqrt{f}} = \left(\frac{a}{\mathrm{Re}\sqrt{f}} + \frac{b}{kD} \right)^2 \tag{2}$$

The TPL was selected to be 5 mm/m in the main pipe and 10 mm/m in the branch pipe. This paper focuses on the network with a total pipe length of about 1 km that serves the 8 districts of the building and the swimming pool. The various diameters of the decentralized heating system piping network are shown in Figure 3.

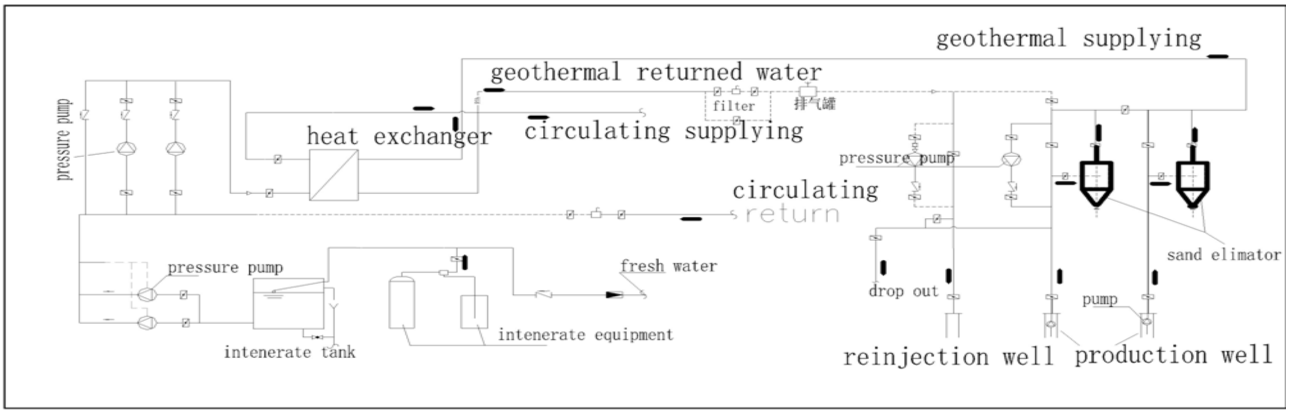

Figure 2: Schematic diagram of geothermal space heating system

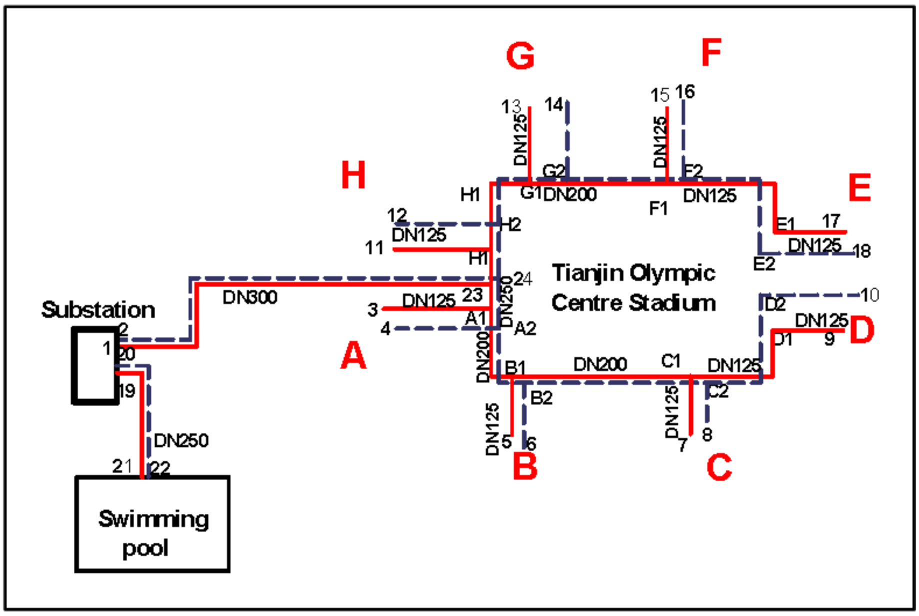

Figure 3: Parameters in the decentralized heating system piping network

4.2 Heat Exchangers

Due to the corrosive nature of geothermal water, it cannot be used directly in space heating systems. Thus, heat exchangers are used to transfer heat from the geothermal water to the system fluid without mixing the fluids. Typically, a heat exchanger has four connection points, as shown in the sketch in Figure 4. The quantity of heat exchanged can be calculated using the following equations:

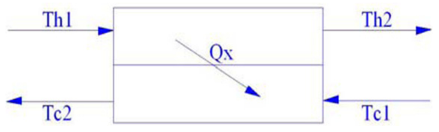

Figure 4: Sketch of heat exchanger

$$Q = m_c C_P \left(T_{c1} - T_{c2}\right) \tag{3}$$

$$Q = m_c C_P \left(T_{h1} - T_{h2}\right) \tag{4}$$

In order to model the heat exchanger within the network, an equivalent model with two connection points was introduced. The equivalent heat transfer coefficient is associated with this simplification. This coefficient is non-linear and dependent on the fluid temperatures, so iteration is necessary to obtain an exact thermal solution. The heat flow for the heat exchanger elements is then calculated by equation 5:

$$Q = UA\left(\mathrm{T_{h1}} - \mathrm{T_{c2}}\right) = UA\left(\mathrm{T_{h2}} - \mathrm{T_{c1}}\right) \tag{5}$$

The total heat capacity of the geothermal wells was calculated with Equation 5 to be 5.5 MW. It was assumed that there was a temperature difference of 5°C, U = 3000 W/m2, Q = 5.6 MW, Th1 = 75°C, Th2= 35°C, Tc1 = 70°C, and Th2 = 30°C. Hence, the area A of the heat exchanger was calculated to be 373 m^2.

5. INDOOR AIR CONDITIONING SYSTEM DESIGN

The total area of " Shui Di" is about 158,000 m^2, the total cold load is 7900 kW, and the designed heat load in winter is 5600 kW. The air conditioning system consists of a water system and a wind system.

5.1 Indoor and Outdoor Design Parameters

Air temperature affects the indoor temperature through heat conduction in the external walls and windows and through free and forced convection, so the load of heating systems is closely related to the temperature of the outdoor climate. Tianjin is located in the north temperature zone with an annual mean temperature of 12.3°C, and the average temperature during the heating period is about -0.5°C. The wind speed is 3.1 m/s in winter and 2.6 m/s in summer. The Olympic Center contains many rooms designed for different functions, the parameters of which are listed in Table 2.

The air conditioning system was designed to be a fan-coil system with supply, return, and indoor temperatures of 60°C, 30°C, and 20°C, respectively. Hot tap water will be distributed to consumers from the substation. The swimming pool is designed according to the most common standards regarding the requirements of dimensions and sanitary equipment.

Table 2: Calculated parameters of indoor air

Function	Indoor condition				New wind
	summer		winter		
	DB(□)	RH(%)	DB(□)	RH(%)	m^3/P•h
Athlete room	26	60	20	-	30
Judge room	26	60	20	-	30
News center	26	60	20	-	25
Office	26	60	20	-	20
Health center	26	60	20	-	25
Council chamber	26	60	20	-	25
Shop	26	60	20	-	20
Balcony	26	60	20	-	20
Exhibit	26	60	20	-	20
Dining room	25	60	20	-	25
Latrine	-	-	5	-	-

5.2 Air Conditioning Terminal Design

The former building built in 1992 used centralized air conditioning, which was designed in such a way that as long as one office needed to be cooled, the entire stadium would be cooled, leading to huge operating costs. In order to ensure safe operation and depress the operating cost of the project, water-circulation heat pumps were selected to be applied so that each room can be heated or cooled specifically. A schematic diagram of water-circulation heat pump is shown in Figure 5.

5.3 Mineral Water Design

Furthermore, research has shown that some elements are good for the health. For example, F and H_2SiO_3 have beneficial effects on the bones and teeth. They can also be used to treat some illnesses, including cardiovascular diseases. Due to the health benefits of this geothermal water, it can be used to produce mineral water after passing through the heat exchanger to benefit investors, tourists, and the public. Because the quantity is very small, accounting for about 3% of the total geothermal fluid, it will not greatly affect re-injection.

5.3.1 Mineral Water Appraisement

It is known from analysis of the water samples taken from these wells that there are many healthy elements in the water. Of these, Li, Sr, H_2SiO_3, and soluble solids meet standard levels, but the F content exceeds such limits. Results of this analysis are shown in Table 3 Mineral water can be produced using the geothermal water, but some elements such as F should be dealt with first.

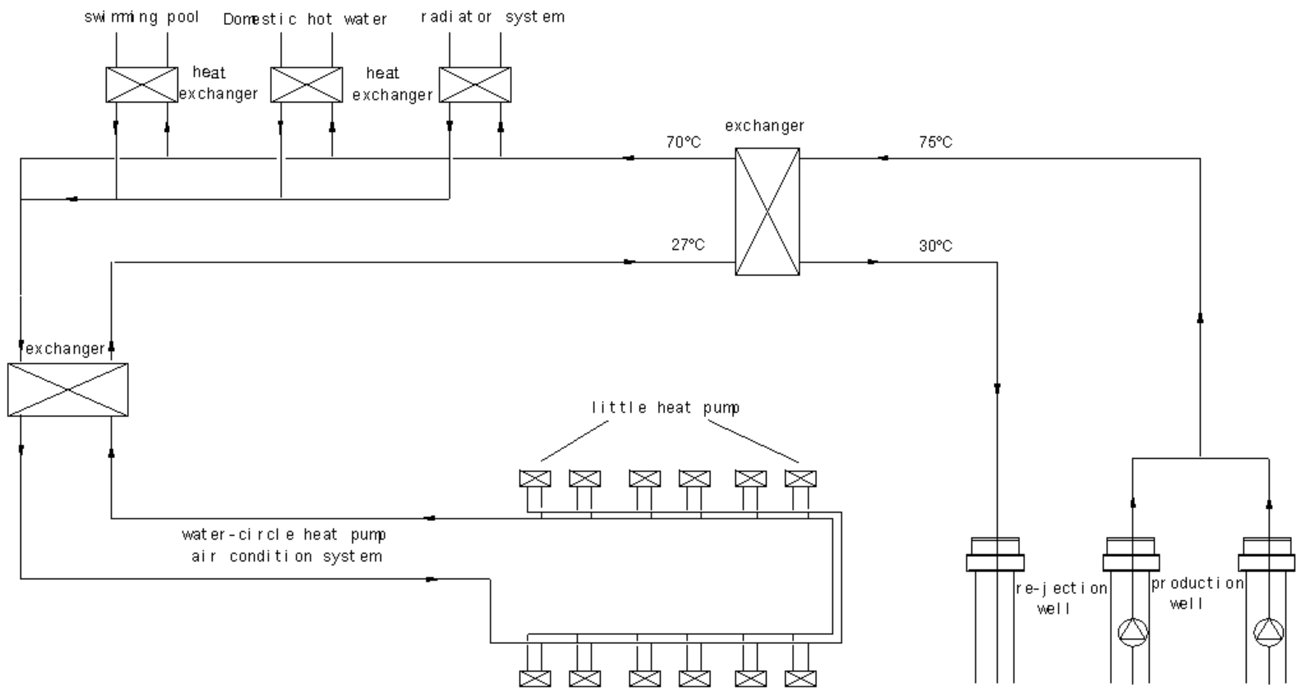

Figure 5: Schematic diagram fof water-circle heat pump

5.3.2 Mineral Water Production System

The geothermal water will be dealt with during the production, as is shown in the diagram in Figure 6.

6. CONCLUSIONS

① The total area of the stadium in the Tianjin Olympic Center is about 158,000 m^2, and the heating area is about 50,000 m^2. Geothermal energy will be used in the huge building for space heating, domestic hot water, and a swimming pool, and about 3% geothermal water will be used to make mineral water.

② A production system based on low temperature geothermal energy combined with a water source heat pump for peak load was designed, and supply and return temperatures were specified to be 75°C and 30°C, respectively.

③ The heating system is designed to be a fan-coil system with supply, return, and indoor temperatures of 60°C, 30°C, and 20°C, respectively. Hot tap water will be distributed to consumers from the substation. The swimming pool is designed according to the most common standards regarding the requirements of dimensions and sanitary equipment.

④ Geothermal energy is utilized fully in the Olympic Center, and mineral water can be produced from the geothermal water using some treatment, such as filtering.

In this project, multiple utilizations of geothermal energy have been designed. Geothermal energy use benefits the city because of their promotion of competitive sports activities and other associated socio-economic. This operation can be used as a model for analogous projects all over the country.

REFERENCES

Erlingsson, Th. Jóhannesson, Th. Chatenay, C. and Elíasson, E.T., 2002: Comprehensive use of geothermal energy for large sports complexes, the Icelandic approach. *Proceedings of 2002 Beijing International Geothermal Symposium, Beijing*, 345-353.

Jalili-Nasrabadi S. 2004: Geothermal district heating and swimming pool in the Sabalan area, Iran. Report 7 in: *Geothermal Training in Iceland 2004*. UNU-GTP, Iceland, 99-130.

Lei Haiyan, 2004: Simulation of district heating in Tianjin, China. Report 8 in: *Geothermal Training in Iceland 2004*. UNU-GTP, Iceland, 131-158.

Maharjan, R., 1995: Design of a dryer and a swimming pool using geothermal water. Report 7 in: *Geothermal Training in Iceland 1995*. UNU-GTP, Iceland, 155-184.

Perkins, P.H., 1988: *Swimming pools*. Elsevier Applied Science Publishers Ltd., London, 370 pp.

Svavarsson, G., 1990: *Designing swimming pools*. University of Iceland, B.Sc. thesis (in Icelandic), 52 pp.

Tang Huifen and Fan Jixian, 1992: *Heating system handbook* (in Chinese). 796 pp.

Yin Heng, 2002: A demonstration geothermal project in Beijing-multiple utilization of geothermal energy. Report 19 in: *Geothermal Training in Iceland 2002*. UNU-GTP, Iceland, 395-430.

Table 3: Mineral water appraisal result

Element sort		Test (mg/l)	standard	Appraise result
Health criterion	Li	2.86	≥0.20	Denominate
	Sr	3.44	≥0.20	Denominate
	Zn	0.03	≥0.20	Below standard
	Br	0.8	≥1.0	Below standard
	I	0.09	≥0.20	Below standard
	H_2SiO_3	71.5	≥25.0	Denominate
	Se	<0.001	≥0.010	Below standard
	CO_2	15.4	≥250	Below standard
	Soluble solid	2250.6	≥1000	Denominate
Upper limits	Li	2.86	<5.0	Measure up
	Sr	3.44	<5.0	Measure up
	I	0.09	<0.50	Measure up
	Zn	0.03	<5.0	Measure up
	Cu	<0.02	<1.0	Measure up
	Ba	0.156	<0.70	Measure up
	Cd	<0.001	<0.010	Measure up
	Cr	<0.005	<0.050	Measure up
	Pb	<0.01	<0.010	Measure up
	Hg	<0.0001	<0.0010	Measure up
	Ag	<0.01	<0.050	Measure up
	H_3BO_3	29.6	<30.0	Measure up
	Se	<0.001	<0.050	Measure up
	As	<0.005	<0.050	Measure up
	F	8.1	<2.0	Overstep
	NO_3^-	1.62	<45.0	Measure up