The Status of Geothermal Utilization in Tianjin and Prospect of International cooperation

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ABSTRACT

There are 151 geothermal wells in Tianjin, where the output of hot water is 26 million m^3 per year, including 12 geothermal wells used in industry with an output of 20,000 t each day. The area of geothermal space heating is 2 315 million m^2, and geothermal winter fry-pond is 80000 m^2 Two large scale geothermal chicken farms have an egg output of 200000 t per year. The fields needed for international cooperation are. reinjection exploitation, reservoir simulating investigation, durable and cheap equipment and scientific management of geothermal wells.

Keywords: Geothermal Energy, Direct Utilization, Intermediate-low Temperature Water, International Cooperation

1. The geothermal resources in Tianjin and its exploitation

1.1 Geothermal resources in Tianjin city

Tianjin is situated northeast of the Huabei plain of China, 135 km from Beijing. Tianjin City consists of urban district, 4 suburban districts and 5 counties, with 11305 km^2 area and 8.4 million population, which is the third municipality directly under the central government and an important industrial and commercial city Tianjin has abundant geothermal resources, with 9 geothermal anomalous regions as designated by isopleth of geotemperature gradient 3.5 °C/100m (Table 1 and Fig.1), and with a total area of 2500 km^2, which is one-fourth of the integral city approximately.

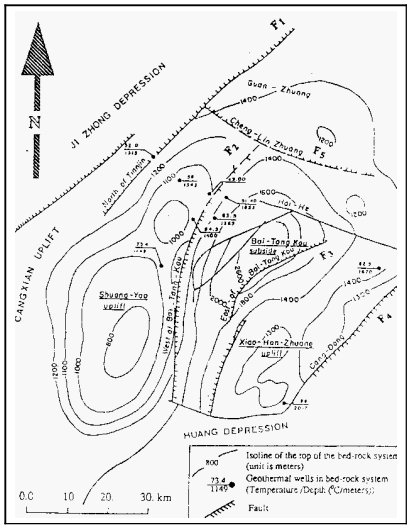

Fig.1. The distribution of geothermal anomalous regions in Tianjin

According to the geological condition, the geothermal field in Tianjin can be divided into two categories, i e the Tertiary System reservoir and the bedrock reservoir The reserve of hot water is 787500 million m^3 for the Tertiary System and 48000 million m^3 for the bedrock (up to 3000m deep) Among others, the geothermal field of Wanglanzhuang, Shanlinzi, Wanjiamatou and the tertiary geothermal hot water of the harbor area have better conditions for development, especially the geothermal field of Wanglanzhuang which is near the urban area and was developed early and is now fully utilized

Table 1. General survey of geothermal anomalous regions in Tianjin

No.	Field Name	Depth of theBed-rock Roof(m)	Control Area (km^2)	Temp. Gradient (°C/100m)
1	Zhuo Liangzhuang	880	200	5.5
2	PanZhuang	1300	600	6.9
3	Qiao Zhuang	1700	90	5.5
4	Shan Lingzi	1200	340	8.3
5	Wang Qingtuo	1400	130	5.0
6	Wang Lanzhuang	1000	640	8.0
7	Wanjia Matuo	1000	260	8.8
8	Sha Jingzi	1500	300	4.5
9	Tang Guantun	1200	60	7.6

1.2 Current developing situation of geothermal resources

The first geothermal well was exploited in 1936 in Tianjin. During the early 70's mass exploration of geothermal wells was carried out inside the urban area, and the development and utilization of the Tertiary System low temperature hot water also on a large scale. Until 1985, over 200 low temperature geothermal wells inside the urban district of 960 km^2, extracted 22 million m^3 of hot water(>25 °C) per year In addition, there were several hundred cold water wells in the shallow layer which were heavily produced, causing large area of surface subsidence of the city; 82.6 mm each year on an average. Therefore, the municipal government has taken on a project to control the surface subsidence: 678 wells were closed including 154 Tertiary System hot water wells and 524 cold water wells, decreasing the output of groundwater by 60 million m^3 per year (including 12 million m^3 of low temperature geothermal water). Consequently the subsidence rate of the urban district decreased to 12 mm in 1992 Until 1992, there are 81 geothermal wells of the Tertiary System(Minghuazhen Group), distribute over the urban district of 460 km^2, with an output of 4.24 million m^3 each year, in addition, there are also 6 bedrock wells with an output of 1.35 million m^3 per year. In the harbor area of Tanggu and Dagang, there are 48 geothermal wells of Tertiary System(Guantao Group), which extract 5.97 million m^3 of water per year The total extraction of a year is 21 56 million m^3

The direct usage of geothermal heat for heating and bathing produced many benefits, therefore the bedrock well increased rapidly during recent years. By June 1994. bedrock wells in the urban district reached 14 (22 including the suburban area), the hot water output from bedrock wells will exceed 6 million m^3, and the heating area from bedrock wells will exceed one million m^2.

2. The utilization of geothermal heat in Tianjin

2 1 Geothermal space heating(2)

According to Tianjin municipal government plan to the year 2000, the centralized heating area will reach 40-60% of the total building area, consisting of 3.37 million m^2 by geothermal space heating. For this reason, over the last few years the new exploited geothermal wells are deeper, and they are mainly bedrock and Tertiary System(Guantao Group) wells. By the end of 1992, there were 87 geothermal wells (including 6 bedrock wells) in the urban district. The water extraction per year is approximately 16 million m^3 , and the geothermal space heating area **is** 0 465 million m^2 There are 17 Guantao Group geothermal wells in the Tanggu district. The water extraction per year is 2 64 million m^3 and the geothermal heating area is 0 70 million m^2. There are 31 Guantao Group geothermal wells in the Tagang district. The water extraction per year is 3.33 million m^3, and the geothermal space heating area is 1 15 million m^2 The geothermal space heating area of Tianjin city already reaches 2.315 million m^2 Table 2 shows the circumstances of the bedrock geothermal well for space heating in the urban and near suburban regions in Tianjin.

The geothermal space heating system can be divided into direct heating system and indirect heating system in Tianjin. The direct heating system uses the water which has better quality and **less** corrosion tendency, whereas the indirect heating system uses the water which has lower quality and heavy corrosion tendency and thus has to use a heat exchanger. Owing to the corrosion, the plate heat exchanger made of Titanium is used, which is rather expensive and is a key point of discussion whether to choose a direct system or indirect system during design for a light corrosive geothermal system For example, the geothermal water of the Tertiary System(Guantao Group) in Tanggu is light corrosive with the Larson corrosion index of 1.5-1.8, is directly fed into heating system. The average corrosion rate is 0.12-0.18mm per year, i.e. the total corrosion amount is 0.6-0.9mm during the five years period. However, for most bedrock wells, with light corrosive water and the Larson corrosion index of 2.0-3.5, the corrosion rate **is** rather high if no exchanger used. For example, the Ordovician System geothermal well in Tianjin Geothermal Research and Training Centre of Tianjin University containing 91**1.1** mg/l of chloride ion, caused corrosion perforation of stainless steel plate heat exchanger during one Winter period (4 months).

The space heating reinjection doublet well system is one of the exemplary engineering designs for resources protection in Zijinxinli where is belong to the Wanglanzhuang district.(6) A reservoir model has been established (Fig.2) and numerical simulation conducted.(1) When the cycle extraction **is** 216 t/h, over 180 day continuous exploitation per year, the distance between the two wells **is** 1000 m, and the thickness of effective fault **is** 60 m, it indicates that the temperature of the production well will decrease 3-4 °C after 30 years exploitation, i.e. the doublet well system is economical and rational. Based **on** this model, the first production well of the doublet well system was exploited in 1993, using an inclined well with inclined depth **of** 2010 m and vertical depth of 1800 m. The water temperature is 92.5 °C and the flow rate is 156 t/h, and two hot water boilers (each 6 t/h) were provided for peak adjustment. In the winter of 1993, the building area with geothermal space heating using a single well had already reached 120000 m^2. If heating area used peak adjustment, the area would be over 200000 m^2. The operation parameters of the equipment was identical with the design value and it worked smoothly, with part of the water after heating used for bathing. The second reinjection well of the doublet well system is going to be exploited in 1995. Figure **3** shows the heating technological flow chart of this system.

Table 2.The circumstances of bedrock geothermal well **for heating** in **urban and near suburban regions of Tianjin**

No.	Well No.	Location	Geological Layer	Depth m	Temp. °C	Flow t/h
1	WR1	district heating company	O	1262.8	57	140
2	WR2	TGRTC, Tianjin Univ.	O	1515.79	50	54
3	WR3	Qingninghou village	ϵ	1149.17	84	20
4	WR4	earthquake station	J_{xw}	1406.13	74	10
5	WR5	grain school	Q	1546.66	72	30
6	WR6	Dasi township	J_{xt}	1610	84	72
7	WR8	Tuanbo village	J_{xw}	986	76	54
8	SR8	east suburban farm	ϵ	1491.6	80	84
9	WR9	Dasi township	J_{xw}	2202.42	85.5	44
10	WR10	spring hotel	J_{xw}	1684.23	84	88
11	WR11	No.4 cotton mill	J_{xw}	1673.3	90.4	300
12	WR28	guest hotel	O	1109.49	62	40
13	WR12	enviroment bureau	J_{xt}	3323.09	84	130
14	WR15 D	Zijinxinli	ϵ	2010	92.5	156
15	WR18	local railway bureau	J_x	12500	76	140
16	WR20	evening news paper	J_x	3654	84	140
17	SR-2	Shanlingzi village	ϵ_f	1760	98	**200**
18	WR17	changing company	Q_{nl}	2670	76.4	140
19	WR19	house trust company	J_{xw}	2710	74	100
20	WR38	Dongfanghong company	J_{xw}	1910	88	80
21	WR39	Jiuchuan house company	J_{xw}			

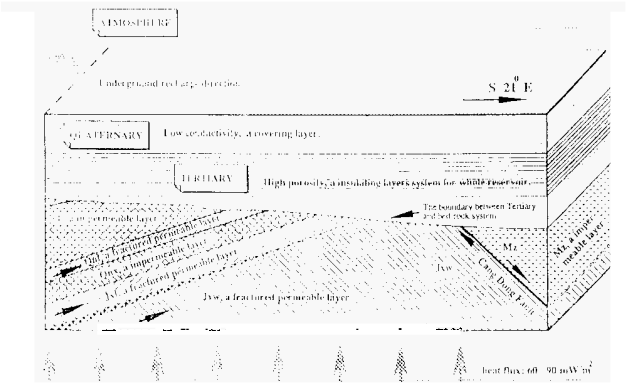

Fig.2 The conceptual model of the geothermal field in Wanglanzhuang

To increase the utilization ratio of the geothermal energy, and to prolong the life of equipment and improve the economy of system, some technical measures have been performed step by step for the space heating system in Tianjin. They are: (1) establish reservoir model and numerical simulation, (2) carry out reinjection exploitation, (3) substitute 100 °C heat-resisting submersible pump for deep well pump (4) use multiple function wellhead assembly and high effective removal system for sand and iron, (5) use straight piping system of anti-corrosion, water-proof and heat preservation, (6) use large titanium plate heat exchanger with changeable passage, (7) develop software optimize the geothermal system, **(8)** adopt high effective and cheap valve for temperature control, (9) comprehensive utilization of drain water, and (10) adopt dynamic monitor of computer and modernized management. The geothermal equipments mentioned above can be made in Tianjin nowadays by **a** number of companies formed for the geothermal industry.

2.2 Geothermal utilization in industry

The early geothermal well exploited was mainly used in industry in Tianjin, being concentrated on textile and dyeing mill, they were

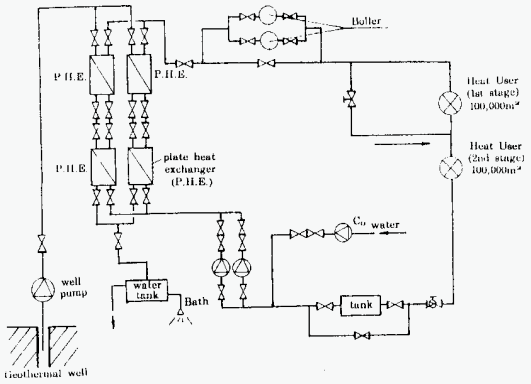

Fig.3 The technological flow chart of geotherma space heating system in Zijinxinli

mostly the wells of Tertiary System(Minghuazhen Group), which provided high quality and low temperature hot water for operation of dyeing and washing or used as boiler's water Some industrial utilization cases of geothermal wells in Tianjin are illustrated in Table 3. One example of geothermal water utilization is Tianjin Fourth Cotton Spinning Mill,(5) with one geothermal well exploited in 1988. The water temperature was 91.5 °C, flow rate 298 t/h, and flowing pressure 0 24 MPa The geothermal water was used for space heating of different buildings of 45000 m^2 area, for air conditioning of workshop of 130000 m^2 area, for bathing of staff and workers Fig4 shows the schematic diagram of the geothermal utilization system.

Table 3. Industrial utilization of geothermal wells in Tianjin

No.	Well No.	Factory	Depth (m)	Temp. °C	Flow Rate t/h	Utilization
1	196155	wool mill	1001.0	53	23.6	cloth dyeing
2	WR11	No.4 cotton mill	1673.3	91.5	298	air condition
3	156120	No.2 bus factory	820	52	30	parts cleaning
4	156106	knitting mill	929	47	34	dyeing, washing
5	096181	No.1 knitting mill	966	44	100	dyeing
6	196162	photpfilm factory	690	42	40	operation
7	146100	Renli wool mill	851	41	60	cloth washing
8	026008	polymer textile mill	671	40	101.8	washing
9	116069	sports cloths factory	828	38	70	dyeing
10	166131	wool stripe mill	691	38	36	wool washing
11	146099	East Asia wool mill	880	38	10	wool dyeing,wash ing
12	116184	string mill	860	38	45	string dyeing

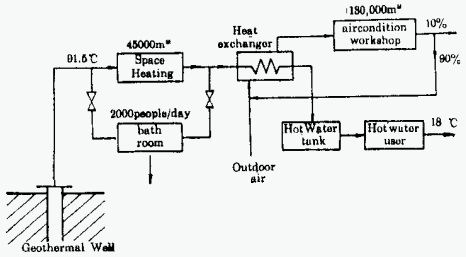

Fig.4 The schematic diagram of the geothermal utilization system of No.4 cotton mill

The geothermal water was cascaded through many steps, firstly used for space heating and air condition, afterwards the water was purified, then used for production operation and daily life Concerning the air condition system, a mixture of 10% fresh air and 90% workshop draft was used, after cyclical spraying (temperature and moisture adjustment) of the geothermal water, the treated air was sent into workshop In this way a large amount of coal and electrical power were saved which was necessary for the steam supply Through calculation of Enthalpy-Percentage Saturation diagram, an air condition system with a flow rate of 100000 m^3/h needs 902 kg/h of 60 °C geothermal water, or 601 kg/h of 80 °C geothermal water During 1988-1991, a 3 years period, the system saved 17400 t of standard coal and 1 13 million Yuan of investment, and decreased by 6 9 t the discharge of smoking dust, 11 7t of SO_2 and 455 t of cinder every winter

2.3 Geothermal utilization in agriculture

Geothermal utilization in agriculture in Tianjin is mainly in the fields of winter fry-pond and hatching. There are 17 geothermal winter bases for fry-breeding with the fry-ponds covering an area of 80000 m^2, suppling the market each year with 20 million African crucian fry and 10 million carp fry. In addition, there are precious aquatic products such as: breeding prawn, soft-shelled turtle and bullfrog. Meanwhile two large-scale geothermal chicken farm provide 60 million breeding chicken and 200000 t of fresh eggs each year

There are several fair-sized comprehensive geothermal utilization system in the suburban districts of Tianjin, which make remarkable benefits both in economy and to society. Especially the villages, which are just breaking away from poverty due to the usage of geothermal energy, are most interesting in geothermal utilization in agriculture. There are three different kinds of geothermal utilization bases in agriculture in Tianjin as follows:

(1) Geothermal comprehensive utilization system for agriculture in Tuanbo village(3)

One geothermal well was exploited in Spring 1985, the depth of the well was 980 m and the temperature of the water was 76 °C. In the following years, a complete set of geothermal engineering designs were implemented, including. 1.3 hectare of geothermal winter fish-pond, 10 greenhouses, one workshop for edible fungus, 8 factories with geothermal space heating, 2 geothermal bathrooms, 867 hectare of reed-fish-ponds combine engineering, and one administration building of 4 storeys. The output value produced during 5 years is 44.422 million Yuan, making a profit of 10 839 million Yuan. Also this village supplies the market with 1855 t of fish and 70.5 t of fry during this 5-year period.

(2) Geothermal chicken farm in Lizigu(4)

In the early 80', a idle geothermal well (98 °C water), which was left unused after oil drilling on the farm, was used to found a geothermal chicken farm, the first and largest one in China at the time The farm owns 4896 m^2 of chicken coops, 2 hatching halls equipped with 33 geothermal incubators, with a total building area of 20236 m^2 Every year the farm raise 36000 breeding chicken, 5 5 million breeding eggs, and hatch 4 million chicks, whcih enables the output of eggs to reach a considerable amount of 90450 t per year in Tianjin Because of the geothermal heat, the economy of the farm developed rapidly, the total output value is 133 million Yuan and the profit is 9 43 million Yuan in the 9-year period.

A large geothermal incubator was invented by the farm, which can hatch 12672 eggs for each run, the temperature difference between top and bottom of the incubator is less than 0.4°C, the hatching ratio is 85% on the average and 95% at the maximum. The incubator is easy to handle, by automatically turning over the eggs and with automatic controls for temperature and alarm. Achieving good results, the incubator is manufactured for supply to the market.

(3) Geothermal fry-pond in Luqian village

This village owns 3 geothermal wells, the flow rate of each is 60-70 t/h, the temperature of the water is 47 °C, 48 °C and 50 °C respectively. There are 4 hectare geothermal winter fish-ponds and 13.3 hectare open air fish-ponds, producing 100 t of fry each year, which have become a important base of fry supply in Tianjin.

2.4 Geothermal utilization in other fields

Almost all of the geothermal wells in Tianjin provide bathrooms which are very convenient, save energy and improve environmental conditions. Many higher institutions such as Tianjin University,

Nankai University and Medical University have built geothermal bathroom for their staffs There are two large-scale hot spring amusement parks and three hot spring swimming pools which have been well received by the masses A big scenery spot is now under construction in Tuanbo village, containing 6 geothermal wells to supply the heat energy to many utilizations such as hot spring swimming pool, amusement park, vacation village, sanatoriums, conference centre, aquatic product breeding, greenhouse for flowers and so on

3. Prospect of international cooperation and problems awaiting solution

The direct utilization of geothermal energy in Tianjin already has achieved a considerable scope, and is developing continuously But there are still some technical questions to be solved, that influences the further usage of intermediate-low temperature geothermal water In order to solve these questions, the goethermal workers in Tianjin should be diligent, but international cooperation is also essential. The main aspects of international cooperation are:

(1) Reinjection exploitation is a scientific way which we must take. How to distribute the reinjection wells? In what layer does it lie? What kinds of reinjection method should be taken? What effect will emerge after reinjection? All these need investigation and testing.

(2) It is necessary to establish an integral reservoir model, which demonstrates the main field and exploitation situation in Tianjin at present, to be carried out by numerical simulation. At the same time develop handy software which is suitable to exploit the intermediate and low temperature water.

(3) For developing the direct usage of intermediate-low temperature water, it demands high quality, anti-corrosion, equipment which is durable and cheap. The resolution of these problems is urgent, and should adress the following:

* Heat-resisting nonmetallic pipe: heat resisting under 120 °C, waterproof, anticorrosive, heat preservation, pressure-bearing and durable. The price should be lower than that of the metal one.

* Cheap and durable heat exchanger: Titanium plate heat exchanger has good performance but is very expensive. Investigation must be taken to find a cheap and durable substitution for it.

* High efficiency and compact equipment for iron separating: After reacting with air, the two-valence iron (Fe^{++}) become three-valence iron(Fe^{+++}), the water become red, which contaminate bathroom, ceramic tile and basin. The iron-separating equipments now available are too large and needs a large amount of capital investment.,

* Technique of highly effective anti-scaling compound: some kinds of geothermal water produces heavy scaling, thus, a highly effective and cheap scouring method is essential, to be applied to system of intermediate-low temperature water.

(4) There are over 100 different kinds of geothermal wells in Tianjin, it is necessary that scientific and modernized management should be realized How to control the resources effectively? How to use the ground reasonably? What kinds of technical specifications are needed? How to make a plan for further development? All these should use the experience of foreign countries for reference.

From the 80's, Tianjin has camed out multi-aspect cooperation with United Nations Development Program(UNDP) and organizations from Italy, France, Iceland and New Zealand They have played very active role for geothermal development in Tianjin We wish to achieve more international cooperation, which will enable the geothermal utilization to reach a new level in Tianjin

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