GROWTH OF GEOTHERMAL REINJECTION IN BEIJING, CHINA

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ABSTRACT

Geothermal reinjection has experienced for some 30 years in Beijing. Various reinjection tests were stated in small scale at the beginning. At present, geothermal reinjection in productive scale has been carried out in 6 couple of wells. The annual reinjection quantity is 1.322 M m^3. It equals 56.6% annual production yield. Reinjection raises reservoir pressure. There are obvious efficiency on resources, economy and environment aspects. The mechanism of the reinjection has been studied during the progress of the reinjection.

Keywords: Geothermal, reinjection, mechanism of reinjection, Xiaotangshan, Beijing

1, INTRODUCTION

Xiaotangshan warm spring, which located in northern suburb of Beijing, was recorded in historical book in Yuan Dynasty of some 700 years ago. In Qing Dynasty, Emperor Kangxi and Empress Dowager Cixi constructed traveling palace there for their warm spring bath. At the beginning of 1950s, warm spring sanitarium and public bath house were constructed there. Geothermal had been using in small scale bath and medical treatment until 1970s. The first geothermal well was drilled successfully in Beijing Urban area in 1971. This exploration found the Beijing Urban geothermal field and then started geothermal utilization as energy resources. Up to date, 4 geothermal fields of Beijing Urban, Xiaotangshan, Liangxiang and Lisui have completed exploration and resource assessment. Another 6 geothermal fields have carried out detailed survey or reconnaissance. There are total some 300 geothermal wells in Beijing. Well depth ranges 700-3000 m. The main reservoir is fractured karst siliceous dolomite of Pre-Paleozoic. Geothermal water is 37-89 ^oC in temperature. Production yield is 600-3000 m^3/d for single well. Geothermal water is Na-HCO_3 type mainly. The total dissolved solid is 0.4-0.7 g/l usually. Thermal water contains high contains high contents of H_2SiO_3, F and Rn reached the standard of medical mineral water.

Geothermal water was used for winter space heating, bathing and medical care, resort and entertainment, greenhouse planting, and aquaculture breeding etc. aspects. Geothermal resources management started in middle of 1980s in Beijing. Saving resources and planning exploitation are promoted. The annual exploitation is nearly 10 Mm^3 in recent years. The production is larger in winter while smaller in summer. This feature made the thermal water table variation obviously with a general trend of slow decline (Fig.1).

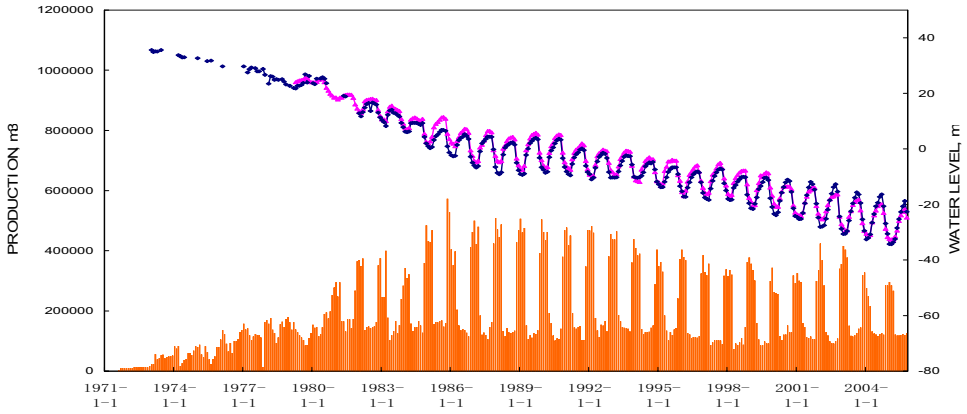

Fig.1 Monthly production and water level in Beijing Urban Geothermal Field

2. EARLY STAGE REINJECTION TESTS

There were some 20 geothermal wells in Beijing in 1970s. Early stage geothermal reinjection test started at that time. The total quantity of geothermal reinjection was some 100,000 m^3 only at that time. The maximum annual reinjection rate was about 1.5 % of annual production. These tests accumulated various relevant data and experience.

2.1 Tap Water Reinjection

The first reinjection test was selected in geothermal well JR-2 located in the Temple of Haven. Test carried out for 12 days from November 27 to December 9, 1974. Tap water in 10^oC which cooling at winter air flows into geothermal well freely. The total quantity of injected tap water is 2,042 m^3. It formed a local increased pressure in reservoir, due to higher specific gravity. It raised water head in surrounding geothermal wells. The down hole temperature recovered basically in 15 days.

2.2 Waste Hot Water Reinjection

The second test is in the No.3 Cotton Mill. Waste hot water from workshop air-conditioning was injected into geothermal well JR-13. The purpose is storing thermal energy in geothermal reservoir to expect higher efficiency for workshop winter air conditioning using this geothermal well. Test carried out for 123 days from June 17 to October 19, 1975. The total quantity of reinjection is 13,500 m^3. The injected hot water is 56-62 ^oC. Due to a lighter specific weight for injected water, the reinjection formed a reduced pressure in local reservoir. It dropped water head in surrounding geothermal wells. The storied heat made an increase of thermal energy in winter utilization. It equals about one third of injected heat.

2.3 Cold Groundwater Reinjection

When the geothermal well JR-26 was drilled in Harde Gate Hotel, a cold groundwater well was drilled at same site. The purpose is pumping the cold groundwater in large flow rate for reinjection. The test carried out for 89 days from June 4 to September 2, 1980. The total quantity of reinjection is 59,400 m^3. The injected groundwater is 15.5 ^oC. The cold peak didn't effect the nearest geothermal well JR-8 at 250 m away. However, the cold temperature is difficult to be recovered. It recovered about two third at one year later.

2.4 Waste Geothermal Water Reinjection

The second geothermal well JRG-4 drilled in the Metallurgical Industrial Press, is specially for reinjection use. The returned water from well JR-32 after space heating was injected into well JRG-4. Reinjection test was carried out for total 84 days in two springs of 1982 and 1983 respectively. The total quantity of reinjection is 30,200 m^3. It tested different reinjection rate and got corresponding data for water head rising and temperature recovering.

3. COUPLE WELLS REINJECTION IN FRACTURED RESERVIOR

A series of geothermal reinjection has been carrying out in Xiaotangshan geothermal field since 2002. It has been an implementation reached productive scale.

3.1 Reinjection in 2002-2003

Reinjection was carried out in a couple of wells in the Imperial Hot Spring Conference Center. The returned water from geothermal well TR-38 after space heating was injected into well TR-11. Total 100,000 m^3 was injected during the winter heating season. Automatic monitoring of water level in reinjection well and tracer test were carried out.

3.2 Reinjection in 2003-2004

Besides the above implementation, reinjection was carried out in another couple of wells in the Mobile Communication Training Center. The returned water from geothermal well TRG-22 after space heating was injected into well TR-22. Further test was prepared in the third couple of wells in JSW International Exchange Center, but injected small quantity. Total 248,000 m^3 was injected during the winter heating season. Corresponding monitoring was carried out in the reinjection.

3.3 Reinjection in 2004-2005

Reinjection extended in 6 couple of 12 wells in the geothermal field. Increased reinjection was carried out in the Modern Agricultural Science and Technology Garden, the Xiaotangshan Forest Nursery and Xichang Sanitarium. Total reinjection quantity reached 1.027 million m^3 during the winter heating season. It equals 36.5 % of annual production in the field. Automatic monitoring of water level and temperature was recorded once per hour in the reinjection well.

3.4 Reinjection in 2005-2006

Further extension involved 14 well in the 6 couple of reinjection. It included two assemblages of 2-production and 1-reinjection. The quantity of total reinjection and couple reinjection increased than last year. Total 1,322,778 m^3 were injected during the winter heating season. It equals 56.6 % of annual production in the field. The maximum reinjection ratio has reached 99.68 % of production. The minimum reinjection ratio is 56.02 % of production due to neighboring unit (the owner of reinjection well) used their returned water for fish feeding. Many highest records were renewed in this period.

4. BENEFIT OF GEOTHERMAL REINJECTION

4.1 Reservoir Pressure Rising

Figure 2 shows the comparison of water level in past 4 years in Wumishan reservoir in Xiaotangshan geothermal field. It shows the obvious efficiency of the reinjection engineering there. Reinjection water was injected into three reservoirs in the field. Only 58 % of reinjection was injected in the Wumishan reservoir at most. It means that reinjection of 767,200 m^3 had offset initial trend of decline, and even raised 2.2 m than the past year.

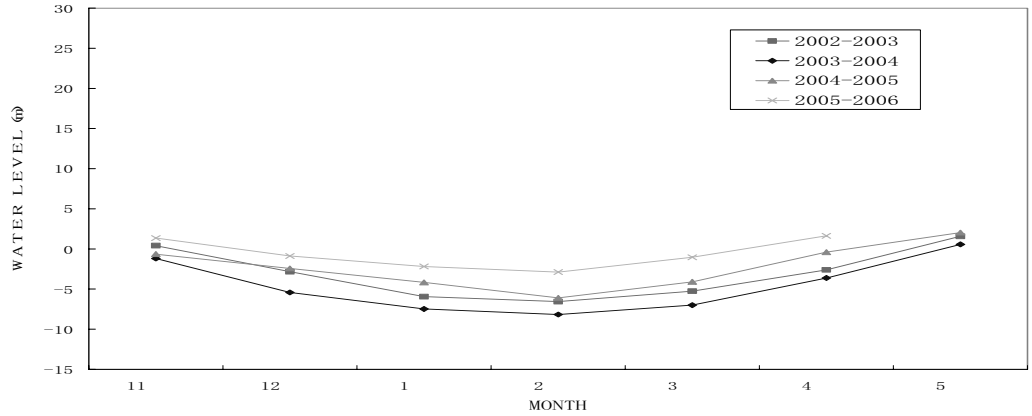

Fig.2 Monthly water level of Wumishan reservoir in Xiaotangshan

4.2 Heat Resources Recovering

The average temperature of exploitative thermal water is about 63 °C. The reinjection water is about 35 °C in average. Total reinjection water of 1.32 million m^3 has been used a heat energy of 155.1 TJ. The used heat gets compensation from the solid framework of reservoir rocks. The average porosity of the reservoir fracture is 0.6% only. So the rock framework of more than 99% heats the injected water easily. Production temperature didn't decrease after reinjection. So heat resources can recover due to reinjection.

4.3 Saving Exploitation Cost

The Beijing Geothermal Administration promotes actively geothermal reinjection at present. The quantity of reinjection can compensate user's production to remit the resource fee correspondingly. The reinjection saved 5.41 million yuan of resource fee in 2005. The past 4 year's reinjection saved total 11.07 million yuan of resource fee.

4.4 Environment Benefit

The geothermal water in Beijing contains high contents of fluoride. Reinjection can avoid the pollution of fluoride and heat.

5. STUDY OF MECHANISM OF REINJECTION

The mechanism of geothermal reinjection can be understood from both aspects in water temperature and water quality respectively.

5.1 Variation of Water Temperature

For total reinjection of 1.322 million m^3 in 2005 winter it had used heat energy of 155.1 TJ. If the reinjection water mixed with 90 times of reservoir water, it would result that production water had a temperature decrease of 0.2 °C. However, we didn't find any decrease of temperature. It means that reinjection water sank down to deep reservoir due to its higher specific gravity, and or there is huge capacity of reservoir at least.

5.2 Variation of Water Chemistry

Table 1 shows a variation of water chemistry in reinjection well. There are highest Na, SO_4 and TDS but lowest Ca and HCO_3 in reinjection well of TR-22 after reinjection. The highest value is higher than its original value and production well. The lowest value is lower than its original value and production well. It means that reinjection is not a simple mixing between both waters. Geothermal water contains high contents of Na, SO_4 and TDS, but low contents of Ca and HCO_3. The above features mean that reinjection water sank down to deep reservoir due to its higher specific gravity, and forced deep hot water rising in the reservoir.

Table 1 Comparison of water chemistry among production and reinjection

Water sample	Date of sampling	Percentage of mg equivalent (mgN %)				TDS (mg/l)
		Na	Ca	HCO_3	SO_4	
TR-22 pumping after reinjection	June 15, 2004	75.36	15.06	51.01	37.98	453
TR-22 pumping before reinjec.	Mar. 15, 2002	67.20	22.30	57.10	30.10	439
TR-22G pumping	Nov. 11, 2003	44.33	30.04	74.90	18.07	331
TR-22G after heating circul.	Nov. 11, 2003	43.27	31.16	74.90	18.01	325

* Reinjection process is that pumping from TR-22G and injecting into TR-22

6. CONCLUSIONS

Geothermal reinjection of production scale has been implemented in 6 couple of wells in Xiaotangshan geothermal field for several years. The injected rate for single well is 90,000-440,000 m^3 per year. The total reinjection quantity has reached 1.322 million m^3 annually. It equals 56.6 % of annual production in the geothermal field. Reinjection didn't cause any temperature decrease for production wells. It reduces the decrease of reservoir pressure obviously. There is significant benefit in economical and environmental aspects for geothermal reinjection. It supports a sustainable development of geothermal resources. Reinjection monitoring confirmed the mechanism of geothermal reinjection. Reinjection water sinks down to deep reservoir due to its higher specific gravity, and forced deep hot water to rise in the reservoir.

REFERENCES

Pan Xiaoping (2005) Enlarging Geothermal Reinjection and Ensuring Sustainable Development. *Proceedings of All China Symposium on Sustainable Development of Geothermal Industrialization*, p.36-40, Chemical Industrial Press.

Pan Xiaoping and Wang Xiaoling (2005) Group Geothermal Reinjection in Xiaotangshan Geothermal Field, Beijing. *100 Examples of Geothermal Exploration and Development in China*, p.101-102, Geological Publishing House.

Zheng Keyan et. al., (1987) Reinjection Test in Fractured Reservoir in Sanlifan Warm Spring Area, Hubei Province, China. *Proceedings of 9th New Zealand Geothermal Workshop*, p.109-112, University of Auckland.