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# Geothermal Reinjection Research and Progress into Sandstone Reservoirs in Tianjin, China

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**ABSTRACT**

As a renewable resource, geothermal energy is very important to the development of the economy of China. Reinjection of the geothermal fluids after use is an effective means for maintaining reservoir pressure which is the key to sustainable utilization of geothermal resources. Reinjection of geothermal fluid is also effective in preventing surface disposal and the pollution of surface waters. In the Tianjin area, several reinjection tests and research regarding reinjection into sandstone reservoirs have been carried out during 1980 to 2008. Four tests, each lasting a couple of years was carried out. Due to chemical scaling in wells and formation, plugging of aquifers and corrosion of casings, the reinjection rates into the sandstone reservoirs decreased dramatically with time. The biggest reinjection rate during the tests was 44.6 m3/h, accompanying the water level increase in the reinjection well to the wellhead very quickly.

During the reinjection tests, we focused on the evaluation and research of the drilling techniques, filtering techniques and reinjection regulations. Up to the recent years, we have made a great progress in reinjecting geothermal water into sandstone reservoirs in two different areas. Three demonstration projects were set up and the high reinjection rates were obtained, up to 100-120m3/h into a single sandstone reinjection well.

In this report, we describes reinjection issues from different perspectives including: reservoir configuration, aquifer characteristics, drilling techniques, filtering techniques as well as re-pumping at the interval of reinjection. We also describe the reinjection experience during the past decades in Tianjin China.

## 1. INTRODUCTION

As a clean energy source, geothermal energy has important implications in improving the social energy framework and protecting the environment. Tianjin has is abundant in low-medium temperature geothermal resources, which covers about 8700 $km^2$. Resources exist in two geological environments, tertiary and base-rock (or basement) reservoirs. The tertiary reservoirs are closed clastic rock subsurface systems which belong to low enthalpy geothermal systems. The geothermal fluids are good quality, low rigidity and temperature of 40～80℃. Geothermal energy has been utilized directly in Tianjin for space heating, bathing, swimming pool, greenhouses, industry, physiotherapy spa. Furthermore, geothermal exploitation is making an important progress throughout the whole country. From the monitor data, 218 geothermal wells in Tianjin drilled into tertiary reservoirs, out of which 85 wells were drilled into Minghuazhen formation. The annual exploitation quantity in 2013 was about $410\times10^4$ m3: Wells drilled into Guantao formation are 133, and the annual exploitation quantity in 2013 was about $950\times10^4$ $m^3$.

With the rapid economic development in Tianjin, geothermal utilization increased very quickly. The increased production from the geothermal resources have only been followed by limited reinjection. Lowering of water level in the geothermal reservoirs is therefore pronounced and reinjection, the water level sinks deeper and deeper at rates ranging from 1.8 to 5.5m/a. Up to now, the water level is found 70 m or deeper.

## 2. GEOTHERMAL REINJECTION EXPERIENCE INTO SANDSTONE RESERVIORS IN TIANJIN

Geothermal reinjection is injecting the produced geothermal fluids after utilization back into the reservoir by gravity (natural free flow) or by pumping (pressured mode). Reinjection is the best method to stop the continuous draw down of the water level in the reservoir and also to avoid surface disposal and pollution of surface water. Reinjection is therefore both important in pursuing sustainable utilization and also important environmental management. (By this way, ensuring geothermal resource sustainable utilization, it's the best method for solving continuous draw down of water level and the environment pollution by the vehicle of returned geothermal water.)

In the Tianjin area, the geothermal reinjection testing and research has been ongoing since 1980s. It has therefore history for more than 30 years. In recent years the, Tianjin government has paid increasing attention on the sustainable development of the geothermal resource. Since 1980, 345 geothermal wells were drilled, including 108 reinjection wells, of which 89 were basement reinjection wells and 19 were sandstone reinjection wells (Table 1). Reinjection quantity was about $562\times10^4$ $m^3$，occupied 12.36% of production, while reinjection quantity in tertiary (sandstone) was about $12.8\times10^4$ $m^3$, or only 0.45% of the production. There is therefore a large gap between production and reinjection volumes. The reason for the clogging have not resolved at the time, especially in porous sandstone geothermal reinjection.

**Table 1: Number of Reinjection wells in Tianjin**

| | Sandstone reinjection well | Basement reinjection well | Total |
|---|---|---|---|
| 2006 | 8 | 30 | 38 |
| 2008 | 9 | 43 | 52 |
| 2013 | 19 | 89 | 108 |

## 3. TERTIARY SANDSTONE GEOTHERMAL REINJECTION EXPERIMENTATION IN TIANJIN

Rreinjection into sandstone reservoirs has been the subject of extensive investigations in Tianjin during the last three decades, and four large-scale reinjection tests have been carried out. [2]（Table 2）

**Table 2: Basic Information of the Previous Test**

| Test phase | Time(year) | Test site |
|---|---|---|
| Ⅰ | 1987-1989 | Dagang district water and electricity factory |
| Ⅱ | 1995-1996 | Tanggu district Xinkai Area |
| Ⅲ | 2003-2004 | Dongli district & Wuqing district |
| Ⅳ | 2006-2008 | Dagang district |

In the previous reinjection tests, aquifer parameters and well casings and diameter of the reinjection wells were different, A detail data list is seen in Table 3:

**Table 3: Basic parameters for Reinjection Tests**

| Reinjection well | Da gang district | Tanggu district | Dongli district | Wuqing district |
|---|---|---|---|---|
| Stratigraphy | Ng | Ng | Ng | Ng |
| Lithology granule | Silty sandstone, sandstone | Sandstone, with gravel | Sandstone, with gravel | sandstone, Silty sandstone |
| Cementation grade | Bad-good | bad | bad | good |
| Granule dia.(mm) | 2-4 | 5-10 | 5-10 | 0.5-1 |
| Porosity (%) | 29.9 | 20 | 27-32 | 20.1-31.6 |
| Permeability (md） | 500-600 | 740-1270 | 690-1085 | 171.8-874.5 |
| Depth (m) | 1900 | 2025.26 | 1360.19 | 2346.8 |
| water sieve type | Monolayer sieve | Monolayer sieve | doublet sieve | doublet sieve |
| space between sieve (mm) | 0.4～0.6 | 0.5-0.7 | 1.5(inner); 1.2(outer) | 0.7(inner); 0.5(outer) |
| water sieve dia. (mm） | Φ219 | Φ219 | Φ177.8 | Φ177.8 |
| water sieve total length (m) | 58.58 | 60.99 | 57.52 | 93.87 |
| Fluid temperature (℃) | 69.5 | 69.5 | 81.5（70） | 73℃ |
| Flowrate ($m^3$/h) | 55 | 90～120 | 100 | 94 |

**⑴ Dagang district reinjection test**

In Dagang district, four reinjection tests were carried out where fluid were injected into tertiary Guantao formation through wells R2 & R12， for a total testing time of 4728 hours (197 days)，and a cumulative quantity of 77943 m3 (Table 4).

**Table 4: Basic data for the reinjection tests in Dagang**

| Well No. | Accumulative time(d) | Accumulative Quantity($m^3$) | Reinjection Temperature(℃) | Reinjection mode |
|---|---|---|---|---|
| R2 | 54 | 23000 | 55 | Single well |
| R12 | 16 | 8889 | 38 | Doublet well |
| R12 | 68 | 23819 | 36.8 | Single well |
| | 31 | 9867 | 36.8 | Single well |
| R12 | 6 | 2465 | 36.8 | Doublet well |
| | 15 | 12503 | 36.8 | Doublet well |
| | 7 | 7400 | 32.5 | Doublet well |

During reinjection, the injectivity of injection wells decreased rapidly (Fig.1) Reinjection capacity has positive correlation with reinjection temperature .but even an increase of the wellhead pressure from 0.1 to 0.2 MPs during the 54 days test does not compensate for the decrease of the reinjection capacity (fig. 1).

**⑵ Tanggu district reinjection testing**

In the heating period of 1995-1996, reinjection test was finished in the Guantao group in Tanggu district. The test persisted 79 days, and resulted in three useful data sets. Idiographic data is list in table 5.

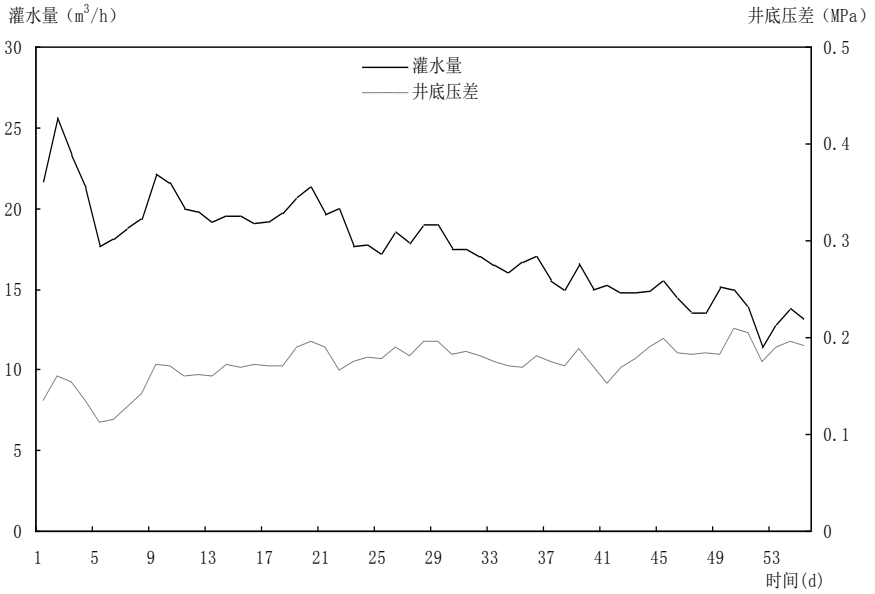


**Figure 1: Relationship curves of reinjection capacity and pressure**

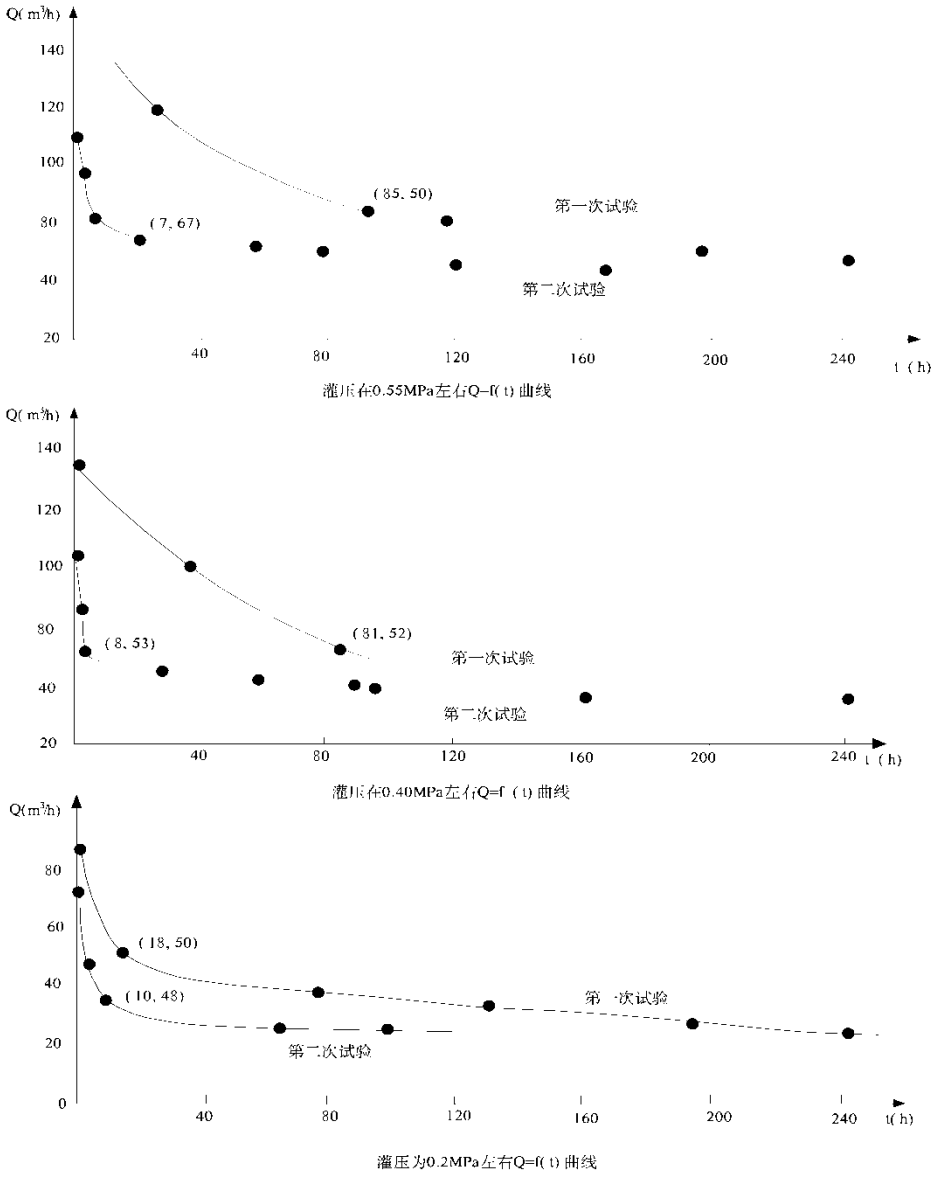


**Figure 2: Relationship curves of water level and temperature in Tanggu**

From this test, we can see a positive correlation between injectivity and pressure, and at a given reinjection pressure reinjection capacity decreases with the time. (Figure 2)

**(3) Doli & Wuqing district reinjection tests**

In 2004, two reinjection wells were drilled in Doli district, in agricultural science and technology section and Wuqing Guohuan Inc, to finish the reinjection tests. In order to prevent physical and chemical clogging of aquifers and wells, secondary filtrating equipment were installed in the system, the primary filtration was to filter particles larger than 50μm, but the secondary filtration was extensive, with a precision of 3-5μm. The test lasted 138 days. The basic information of the tests is listed in Table 6.

**Table 6: Basic Information of the Reinjection Test in Doli**

| Sequence No. | Test No. | Quantity ($m^3$/h) | Temperature(℃) | **Accumulative Quantity($m^3$)** |
|---|---|---|---|---|
| 1 | 1st | 49 | 45 | 863.4 |
| 2 | 2nd | 48 | 46 | 4167.1 |
| 3 | 3rd | 41 | 47 | 1795.9 |
| 4 | 4th | 43 | 48 | 10163.6 |
| 5 | 5th | 41 | 48 | 5087.2 |
| | total | | | 22077.2 |

## 4. ANALYSIS ON THE REINJECTION IMPACT FACTOR IN SANDSTONE

Analysis of the results of different tests and the factors impacting the reinjection capacity:

(1) Stratum lithology, hydrogeology condition

The lithology，bulk of rock granule, interstice between the granule, porosity and permeabilities of the stratum impact reinjection. In Tanggu and Dongli district, the lithology is sandstone with gravel, granularity is bigger (5-10mm), osmosis is better (permeability 690-1270 md), the reinjection capability is much better than other areas.

(2) Reinjection fluids temperature

During the previous decades, Reinjection capacity has positive correlation with reinjection temperature.

(3) Reinjection pressure

Commonly, the capability reinjection in porosity stratum is about 20-30m3/h, subjoin pressure can increase the capability in a certain extent.

(4) Casing program of porous reinjection well

5. Reinjection water characteristics

## 5. CONCLUSIONS

Geothermal reinjection is very important practically. From the reinjection test research of the Casing program, the main factors affecting geothermal reinjection includes: hydro-geologic characteristics, distance between the production and reinjection well, and reinjection mode. Reinjection in sandstone is a very complicated, thus systems engineering and advanced studies is an important and necessary part to achieve sustainable exploration & development.

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