Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Reinjection Effect Study of Different Geothermal well Completion in Porous Sandstone Reservoir in Tianjin, China

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Keywords: Neogene, Geothermal reinjection, Perforation, Filter, Well completion

ABSTRACT

Despite Neogene injection typically has very low efficiency in the world; this article describes two successful geothermal reinjection examples in sandstone aquifer. Different well completion such as filter and perforation are adopted in the projects. The reinjection test data indicates that well completion is the key factor that influences the reinjection effect. Perforation is found to increase the effect of reinjection after reviewing the result of applying two well completions in same place. The reinjection rate of wells perforated is 100-130 m^3/h, which is triple to fivefold more than the well which installed the filter instead. Now the well completion of perforation is widely used in Tanggu and Wuqing district which is the high production area of sandstone reservoir in Tianjin

1. INTRODUCTION

Poor injection effect in sandstone geothermal reservoir has become an issue for many countries in the world (Liu J R,2003, Gudni Axelsson,2008). During China's past geothermal exploitation and utilization, it also greatly restricted the development of Neogene geothermal resources. Tianjin is one of the largest and earliest city in geothermal exploration and production in China. The pressure of geothermal reservoir has been dropdown sharply due to the historical issue of serious imbalance between mining and injection (Zeng M X, 2007, LIN J W, 2010). These problems took place since the late 1970s. The injection rate of Guantao group, which is one of Neogene reservoirs in Tianjin is only 20 ~ 50 m^3 / h. However, the production rate has reached 60 ~ 130 m^3 / h, causing the imbalance of production and injection. Consequently, Neogene injection study has launched in Tianjin since 1982. By the end of October in 2012, 87 injection wells had been built and the injection volume was 1087.33 $\times$ 10^4 m^3 per year. It was only about a third of the geothermal resources production of 3156.8 $\times 10^4$ m^3 and the main production reservoir was the bedrock thermal reservoir. The production in Neogene (1131 $\times 10^4$ $m^{3)}$ accounts for 36% of the total production but its recharge amount of 35.26 $\times$ 104 m^3 was just about 3% of the injection quantity. The reinjection problem in sandstone reservoirs still occur at low reinjection rates and short duration times. Poor injection effect has become a bottleneck problem that limits sustainable development of geothermal resources. The completion technology of reinjection wells focused on porous sandstone reservoirs in the last five years and has made some achievements. This article describes two successful geothermal reinjection examples in sandstone aquifer reinjection in two different places.

2. TRADITIONAL FILTER COMPLETION PROCESS

1.1 Principle

Function of filter is to support shaft lining, hold sand, and allow water to seep. For geothermal wells in the actual production process, the selection of filter in Neogene formation is mainly determined by the geothermal reservoir characteristic as lithology, cementation, particle size, permeability and other factors (ZHU J L, 2008).

1.1 Species of Traditional Filter

Typical application of filter include screen pipe and steel wire wrapped monolayer filter. Screen pipe is commonly applied to dense cementation sandstone which lithology is not sand flushing and not stable as carbonate formation. For unconsolidated sandstone which is easily sanding, pipe wrapped monolayer filter should be used instead. The application of pipe wrapped monolayer filter can create a nature filter layer such that large particles cannot pass through the well filter while fine particles go through between the large particles. More particles can be washed away and sand flushing can occur in a relatively shorter time when there are more nature filter layer appeared surrounding the well filter.

3 PERFORATING TECHNOLOGY

3.1 Principle

A device called perforating gun is lowered into the hole at certain depth. After the gun is lined up properly, powerful shaped explosive charges are fired from the control panel. These explosives blast a hole in the steel casing and cement, up to several feet far into the rock. This technology can build a connection between wellbore and aquifer. The shaped jet is in contact with the rocks as soon as rocks are formed at high temperature, high pressure and high strain rate region and quickly act on the surface of rock formation to tear apart the rocks. Subsequently, jet intrudes the broken rocks and lead to the formation of a channel. According to the structure of bullet and rock nature of perforating, the length of perforating channel is about a few centimeters to dozens of millimeters. Perforation technology is already viewed as a relatively mature technology in the oil and gas well development (LI Y Z, 2002, YI J, 2012) in recent years. It has an outstanding performance when applied to geothermal reservoir in Neogene well as a trial.

3.2 Advantage of perforation

Shaped charges with wire casing is the most popular method during the completion of a geothermal well in Neogene. It has the following advantages: (1) A variety of perforating gun and bullet; large diameter perforating gun and large quantity explosive can be used for high-density, deep penetration, large aperture perforation. (2) The perforation can be positioned rapidly and accurately. (3) High detonating reliability of electric detonator. (4) Convenient operation for continuous multi-layer perforation.

Perforation of a geothermal reinjection well usually chooses 89mm to 127mm gun. It has a length between 2 and 4 m, density of 15 ~ 20 holes/m and aperture of 9.5 ~ 12 mm. Perforating way has a spiral arrangement while the perforating depth can generally reach more than 50 cm.

4. EXAMPLES OF APPLICATION

4.1 The Binhai New Area Reinjection Wells

In order to study the reinjection effect of different geothermal well completion in Neogene recharge, three geothermal wells in Neogene reservoir in Binhai New Area have been drilled for the research.

4.1.1The Geological Structure and Formation Characteristics

All of three geothermal reinjection wells are located in Huanghua depression. Yanshan uplift area was as the main provenance in Miocene epoch, with braided river transportation and formed sedimentation, Guantao group clastic rock of fluvial facies with sedimentary cycle. Guantao group is the main exploitation reservoir in Binhai new area. The basic structure of Guantao group has three layers: thick sand as the top layer, conglomeratic sandstone as the bottom layer and mudstone in between. Thickness of sandstone layer is much higher than others, generally about 10 ~ 20 m while the total thickness of those layers is 80 ~ 120 m, permeability is 500 ~ 1600 × 10-3μm ^{2} with porosity of 27 ~ 35%.

4.1.2 Introduction of Geothermal Well

Those three geothermal reinjection wells are not far apart, its relative position can be seen in figure 1, the specific conditions of those geothermal wells are shown in table 1, well bore structures are shown in figure 2.TG-20 with TGR–29D and TGR30 has a single production -double reinjection system, while TG - 22 and TGR28 has a double production-single reinjection system.

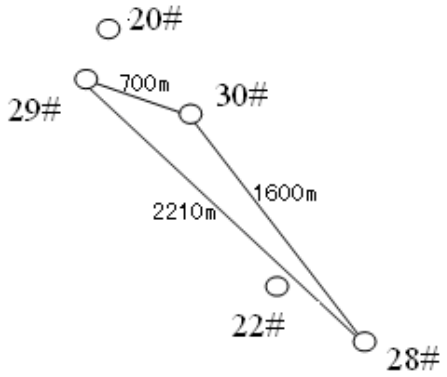

Figure 1: The distribution of geothermal well

Table 1: Basic data of geothermal well

Borehole no.	Drilled depth	Casing program		Completion Technology	Flow ratet (m^3/h)	Temperature (℃)
28#	1891	two section	Vertical well	Perforation	118	63
29#	1995.11	two section	directional well	Perforation	106	63
30#	1930	two section	Vertical well	Filter	100	63

4.1.3 Geothermal well completion technology

Different well completion technologies are used in Borehole 28#, 29#, 30#. Well perforation is employed in borehole 28# and 29#. Shaped charges with wire casing are adopted for well perforation, with 102mm gun and 12.7mm bullet. The density of perforation hole is 15 per meter. The perforation length of Borehole 28# and 29# is 87m and 92.3m respectively. On the other hand, filter is used in well 30#, which has a Φ177.8mm well pipe with Φ14 mm hole punched and porosity of 12%, the wired trapezoidal carbon galvanized anti-corrosion wire has a distance of 0.5～0.7mm.

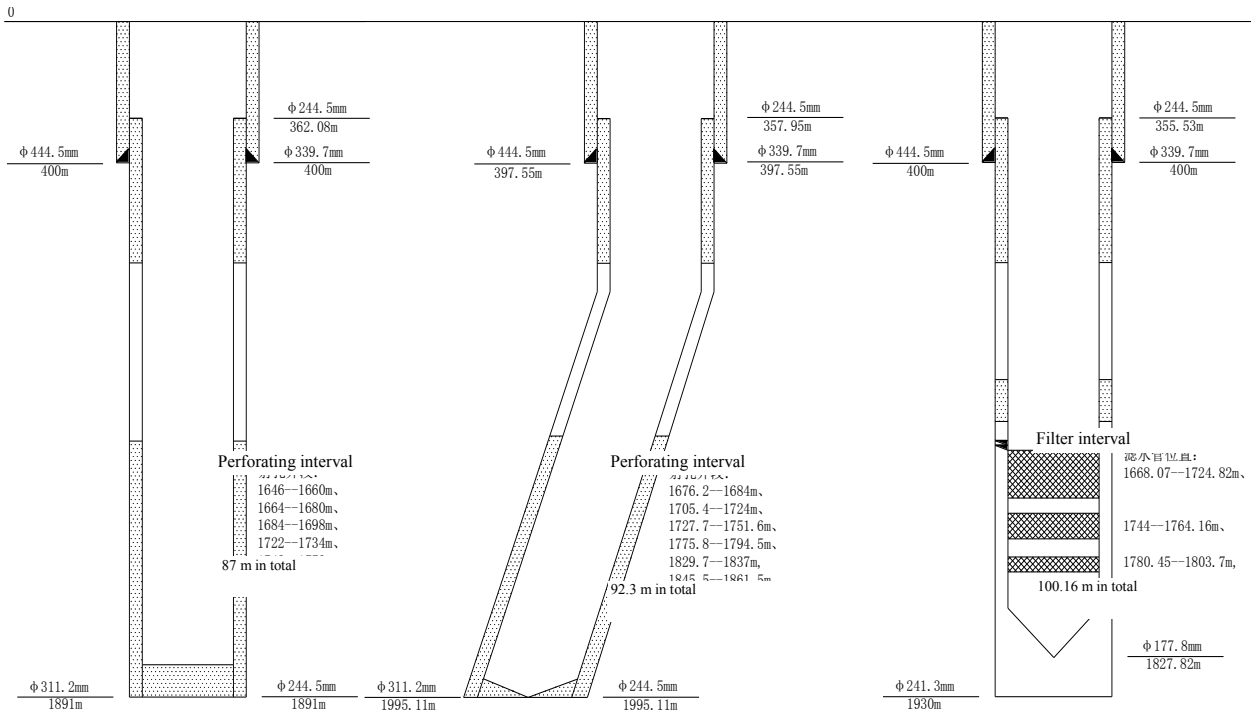

Figure 2: Sketch map of geothermal well 28# (left), 29# (middle), 30# (right)

4.1.4 Reinjection test

Reinjection well test has done once the completion of reinjection well. Reinjection test of 28# is done during heating period; but test of 29#, 30# is not. The entire test is carried out under depressurization condition. Reinjection test data is shown in Table 2, the test curves are shown Fig.3, Fig.4, and Fig.5

Table 2 Reinjection test data

Borehole No.	28#	29#	30#
Reinjection time	2011.6	2012.11	2012.11
Reinjection temperature（℃）	58-67	32-40	36-38
Duration（h）	306	193	233
Static water level（m）	103.18	98.96	102.36
Max reinjection rate（m^3/h）	120	62	22
Stable water level（m）	16	82	36
Stability time（h）	94	37	96

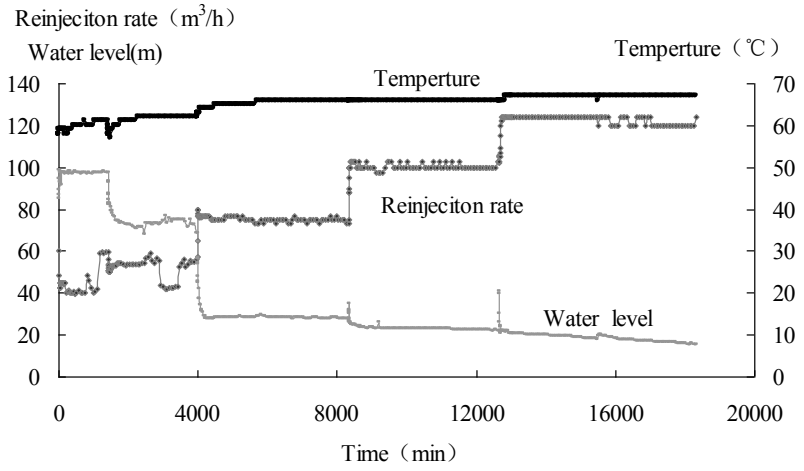

Figure 3: Reinjection test of 28# well

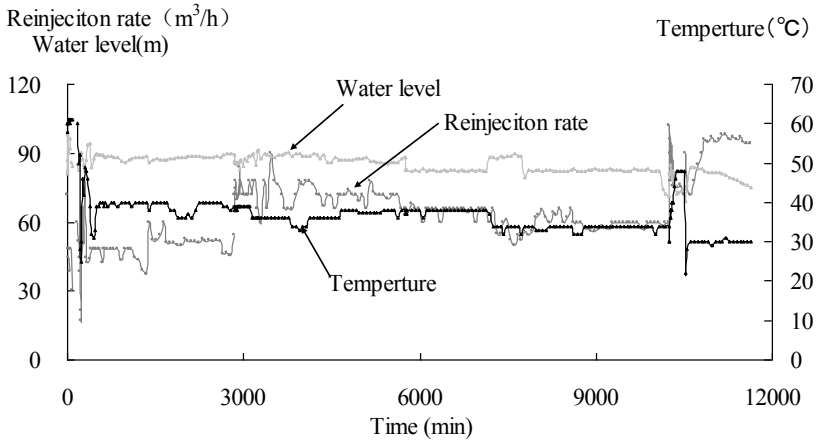

Figure 4: Reinjection test of 29# well

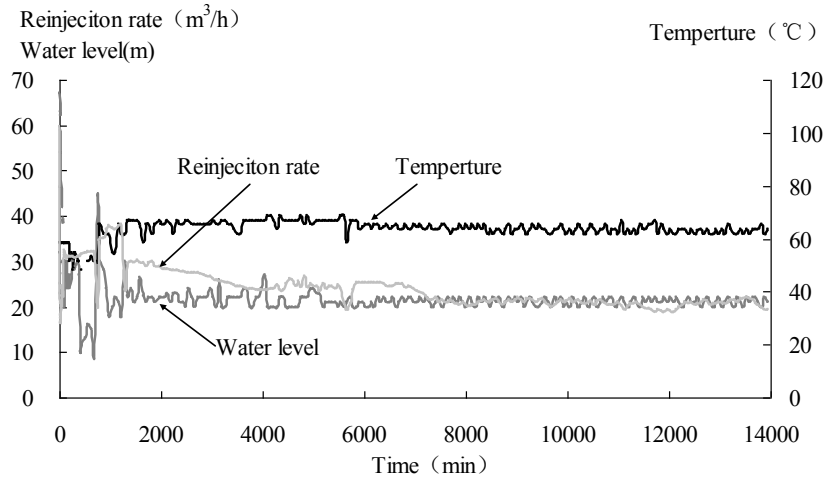

Figure 5: Reinjection test of 30# well

Recharge capacity of every well is evaluated based on the data of reinjection .The maximum injection rate of 28#, 29# and 30# in theory is 121 m^3/h, 114 m^3/h and 35m^3/h, respectively. It indicates that the reinjection effect is influenced by well injection. Wells under completion technology of perforation have better reinjection capacity than the well under completion technology of filter during the reinjection test for the same area, same geothermal reservoir, same ground operation of injection system and injection methods. The reinjection rate of wells perforated is 100-130 m^3/h, which is triple to fivefold more than the well that adopted the

filter. In other words, perforation well completion technology has a great performance on reinjection in Neogene reservoir in Tanggu district in Tianjin.

4.2 Reinjection well in Wuqing

After the success of Neogene geothermal injection in Binhai new area, perforation has also been applied to Wuqing depression which belongs to Jidong depression. Since Mesozoic, this depression continued to sag in sedimentation condition for a long time, and eventually formed thick Cenozoic sediments. Guantao is also the main exploration geothermal reservoir in this area. Considering the poor injection effect in the region before, it is decided to carry out Wuqing reinjection studies gradually after the successful reinjection in the Binhai new area. A new geothermal reinjection well which also used peroration are drilled and that is a new attempt in Wuqing. The depth of this well is 1978m (along hole depth). Geothermal reservoir is consisted of seven water layers that are about 4.4～23.8m, resulting in 80.7m in total. Permeability is 554.44～1714.7×10^{-3}μm^2 with porosity of 29.42～36.70%. The casing program is as long as the length of perforation in 28#, which is 81m. Reinjection test was conducted in Dec.2013under depressurization. Reinjection effect is very promising.(Figure 6)

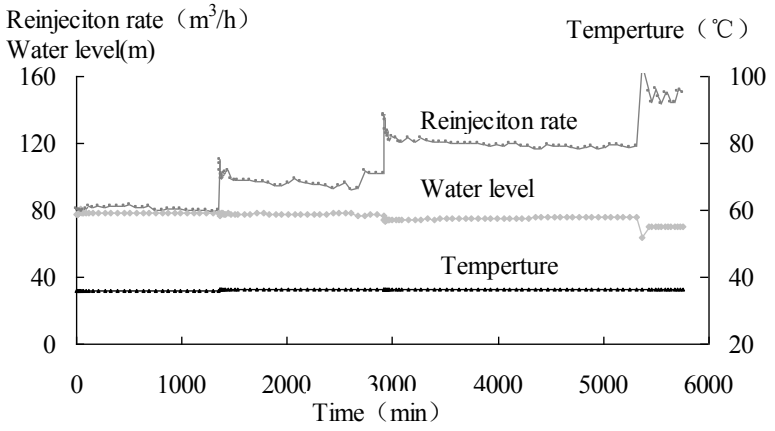

Figure 6: Reinjection test of Wu Qing geothermal well

This well was in good operation condition during the heating period. The average reinjection rate is 128 m^3/h, and the dynamic water level is about 70m.The decay phenomenon of reinjection rate did not take place.

5 ANALYSIS OF THE CAUSES

Some preliminary conclusions could be drawn after comparing the injection test data from two different places. It is concluded that perforation completion technology plays a great role in increasing injection effect in Neogene due to the following reasons:

(1) Perforation is easy to construct and it is unlikely to pollute geothermal reservoir. It allows production capacity to be increased significantly because penetrating a lager depth enabled perforation though the mud damage zone (Figure 7). The connectivity of wellbore and geothermal reservoir is a major factor which can control injection effect. Perforation creates the flow channel for fluid in formation. The inner wall of the hole channel become a flow discharge section for increasing area of flow discharge and increasing the reinjection rate in formation. So it could make the reinjection to occur continuously.

(2) When the wells filter down to the designed point, it could cause disturbance in geothermal reservoir, thus permeability around the filter should be reduced. Meanwhile, the filter may also be blocked by drilling fluid and solid phase material, therefore discharge area should be decreased to control the injection effect.

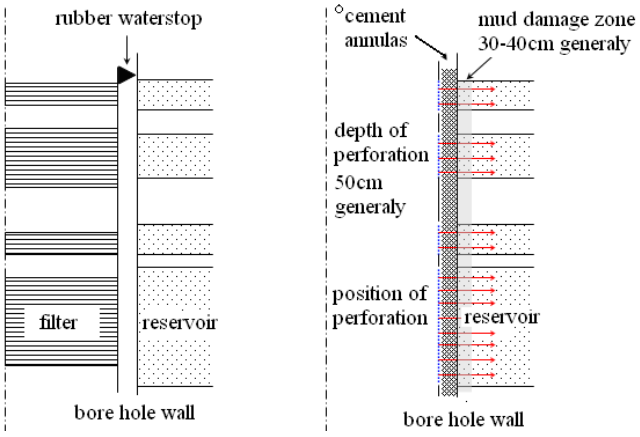

Figure 7: Well completion of filter (left) and perforation (right)

6 CONCLUSION

The successful application of perforating technology in Binhai new area and Wuqing area demonstrates that perforation can increase injection rate and ensure sustainable injection. This is vital for Tianjin geothermal reinjection in Neogene and it is useful for Neogene geothermal injection in surrounding provinces and cities. However, the research has only been applied to thermal reservoir in Guantao formation. Its feasibility among other stratum, such as Dongying group (anther Neogene geothermal reservoir), still need to be further investigated. Meanwhile, for perforating technology in the application of geothermal injection, there are many theory in relevant to the exploration stage, such as injection water infiltration mechanism in the channel, how to optimize parameter during perforating, how to reduce the permeability influence of perforating for inner wall of channel, etc.

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