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

The Reinjection Technology Research and Demonstration of Neogene Porous Guantao Reservoir in Binhai New Area, Tianjin

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Keywords: Reinjection, Blocking, Porous Reservoir, Ground equipment, Pressure and Temperature Predication

ABSTRACT

The author analyzes the reasons to reduce reinjection rate through reservoir sensitivity analysis, blocking reasons analysis, the reinjection well completion technology and ground equipment and techniques.

The physical blocking is the main question of reinjection blocking. The well completion technology is pivotal to keep sustainable reinjection, and the standard ground reinjection system can avoid physical and chemical due to geothermal fluids reinjection. Using successful well completion technology and standard ground reinjection system, the reinjection quantity is 100-120 m^3/h which is a big reinjection breakthrough of porous reservoir in Binhai New Area, Tianjin.

1. INTRODUCTION

Neogene Guantao Group is the main development and utilization reservoir in Binhai New Area, Tianjin. The development has increased, and the reservoir pressure has drop in recent years. Now the static water level is 90-114m. The maximum of dynamic water level is more than 146m, and the largest fall is 6.5m/a. It is pivotal to achieve sustainable utilization of geothermal resources through carrying out geothermal resources reinjection and keeping water level from dropping too fast.

According to reservoir conditions, research results and geothermal geological condition of Neogene Guantao group in Binhai New Area, the demonstration projects has been set up on the basis of confirming reinjection technology scheme. The reinjection rate of single well is up to 100-120 m^3/h which is new breakthrough of porous reservoir reinjection.

2. THE SANDSTONE CONSTRUCT CHARACTERISTICS OF NEOGENE GUANTAO GROUP IN BINHAI NEW AREA

Most part of Binhai New Area lies in the Huanghua depression and small part of the area lies in the Cangxian uplift, which is third tectonic. Except missed in the Xiaohanzhuang convex, the Guantao reservoir generally distributes in this area (Figure 1). The depth to the top of roof is 1129-1806m, and the total thickness is 100-500m. In the Cangxian uplift the thickness is 100-200m, and in the Huanghua depression is 200-500m.

According to research data, this reservoir is the red continental deposit. During the period of the Guantao reservoir deposition, in the northern there was piedmont alluvial plain of Yanshan mountain which developed into braided river deposit. Without the effect of Yanshan Mountain, the southern part developed into low sinuosity river deposits. This stratum shows high sedimentary cyclicity. From the top to the bottom, it shows coarse-fine-coarse lithology, and is divided into three parts: Guantao Ⅰ, Guantao Ⅱ, Guantao Ⅲ.

Guantao Ⅰ stratum is composed of thin layer lark sandstone of shallow grey, sage green, grayish yellow and celadon argillaceous siltstone with unequal thick mudstone of dark red brown and dark purple. The mineral component mainly includes loose quartz and feldspar.

Guantao Ⅱ stratum is composed of shallow grey and dark sage green mudstone with dark sage green and offwhite mud fine sandstone. The mudstone generally contains charcoal crumbs, charcoal stick and net grid calcite strip.

Guantao Ⅲ stratum is composed of varied sand gravel with thin layer gray mudstone and dark saga green mudstone and sandstone. The motley glutenite on the bottom which is signal stratum, the depth to the top is 1600-1680m, the thickness of west stratum is thin, which gradually becomes thicker toward the east and the thickness is 100-150m including 45-100m-thickness glutenite. The glutenite are accounts for 60%-90% of total thickness and its average porosity is 20%. The upper stratum of this stage is mainly composed of middle fine sandstone and the bottom is 30-80m basal conglomerate. The basal conglomerate is the best growth and its thickness is more than 80m in Tanggu. Its lithology is better in Tanggu, because the basal conglomerateis filled by mud in Dagang influencing on water yield. The mineral component includes quartz and feldspar and the basal conglomerate component is quartz, feldspar and firestone. The basal conglomerate radius is general 4-6mm belong to middle to fine grains. There are a few pyrite crystals and the tubercle of iron and manganese.

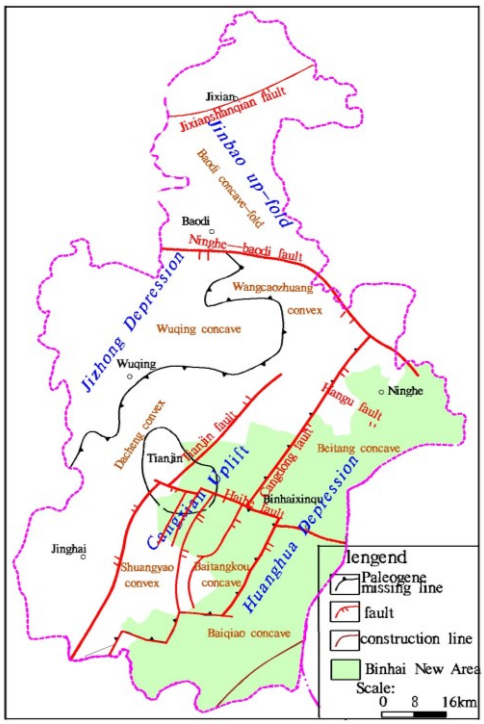

Figure 1: the Construct Location Map

3. THE ANALYSIS OF CRITICAL INFLUENCE OF REINJECTION IN GUANTAO RESERVOIR

3.1Reservoir Sensitivity Analysis

Sensitive analysis mainly contains the mineral combination, cementation type and cementation matter of reservoir rock, porous structure, physical parameter and the type, quantity, attitude of clay mineral, rock dilatability and cation exchange ability, we can find the latent factors to damage stratum and provide basis for rock sensitive test.

3.1.1 Sensitivity to Water Damage

Outside liquid of low salinity or salinity sharply changes make clay mineral expansion, fall off, migration and block reservoir pore and throat, the phenomenon of permeability decline.

3.1.2 Sensitivity to Flow Speed Damage

Under the influence of injecting fluids, reservoir clay and other particulates move in the porous medium. As the instances increased, velocity will gradually drop, these deposited particulars block pores and throat paths, which carry out the damage of specific permeability. The damage degree is controlled by the velocity and PH value of reinjection fluids.

3.1.3 Sensitivity to Acid Damage

The acid fluids entering reservoir and reacting with sensitive minerals produce deposits or let out grains which induces reservoir specific permeability dropping.

3.1.4 Sensitivity to Alkaline Damage

The tests attest that the higher PH value of reinjection fluids is, the more damages to Neogene reservoir there will be. The main performance is that , the content of OH^- increases and HCO_3^- may translate into CO_3^{2-} , Alkaline reinjection fluid react with mineral and solid liquid, generate colloidal deposits such as $Si(OH)_4$, alkali scale ($CaCO_3$) and new mineral which will blocking the pore and throat of reservoir .

3.1.5 Sensitivity to Salt Damage

Influenced by low salty, clay minerals engender hydrate and bulge inducing specific permeability dropping. The liquid salty has two stages, first one is the hydro-explosive stage in low dilatability. The second one is permeable explosive stage and the clay crystal space can be increased 120 times.

3.2 Clogging Reasons Analysis

3.2.1 Physical Clogging

(1) The Suspended Sediment of Reinjection Fluids

The most common questions are the suspended sediment grains of reinjection fluids blocking the reservoir pores with the relevant of transferring process, grain size, pore parameters (size, shape, concentration, distortion) and all kinds of action forces in the process of sediment.

When fine grains are adsorbed to well wall to form mass matter, they can be cleared up through returning pumping and acid treatment which will not be influenced a lot. When kinetic fine grains take place blocking in some part of stratum, the pressure and the velocity of suspended sediment cannot keep grains normal move, thus these kind of grains will stay to form annular block area. This block cannot be erasable and bring large influence for reinjection, including sediment, inertia, hydraulic influence, direct prevention, and mess, etc. When the quantity of suspended sediment in reinjection liquids is too high, they will block the porous medium and leads to reduce or lose reinjection ability. Therefore, it is effective to avoid reinjection block through controlling the suspended sediment quantity of reinjection liquids.

(2) Gas clogging
When liquid injecting to the well, they can carry a lot of gas. The dissolving gas will be released by the change of temperature and pressure, or by biologic and chemical reaction. For confined aquifer, in case of injected water carry with bubbles, special method should be made about bubbles caused by gas.

(3) Clay Expansion and Diffusion
Clay expansion and diffusion are the block caused by chemical reaction which is the progress of cation exchanging, which can be resolved through injecting $CaCl_2$.

(4) the Reconstruction of aquifer fine grain
When this well is both reinjection well and pumping well, repeating pumping and reinjection will arose the fine grain reconstruction of around well wall and form block.

3.2.2 Chemical factors

When reinjection geothermal fluids are not consistent with aquifer medium or ground water, some chemical reactions the chemical deposit, clog the reservoir and influence water quality. In addition, the erosion of metal by geothermal fluids will produce insoluble matter to metal, so that direct reinjection will bring block without disposal. The main factors of corrosion are CL^-, soluble oxygen, $SO4^{2-}$, PH, H_2S, CO_2, NH_3 and total solid matter.

3.2.3 Biological factors

Under the adaptive condition the microbe reinjection liquids or local water can rapidly breed around reinjection well to form biological film, which blocks the porous medium and drops the conductive ability of aquifer.

Iron bacteria can also induce reinjection blocking in the progress of accelerating Fe^{2+} into Fe^{3+} to form deposits in the iron pipeline. Feasible water temperature, rich Fe^{2+}, soluble oxygen, fitting PH and symbiotic organic matter can promote Iron bacteria to grow.

In conclusion, the suspended fine grains of reinjection fluids, chemical reaction and gas are main factors of blocking. In order to keep natural reinjection, it is very important to research the well completion technology, reinjection technology and ground equipment.

4. THE REINJECTION WELL COMPLETION TECHNOLOGY, GRGOUND EQUIPMENT AND TECHNIQUES

4.1 The Reinjection Well Completion Technology of Guantao Reservoir

According to geothermal geological condition in Binhai New Area, the structure design of reinjection well of Guantao reservoir includes supd large–diameter-hole gravel packing completion, second supd wire-wrapped screen completion and second supd perforation completion.

4.1.1 Supd Large–diameter-hole Gravel Packing Completion

The supd large–diameter-hole gravel packing technology is to enlarge well hole after well completion, to fill with gravel between screen and well wall. Filling gravel into the well, we should make sure the gravel pack to reach the proper location in order to filtrate water, resist sand and form better screen layer.

4.1.2 Second Supd Wire-wrapped Screen Completion

Adopting the methods of water shut-off with cement, the second supd wire-wrapped screen completion technology is used to the deeper geothermal well which is to t. add blinded-pipe on the screen top, hit hydrocyclonic hole in advance, use hydroclonic hole to inject cement after well pipe reaching the designed location. The hydroclonic hole bottom has higher strength rubber umbrella to prevent cement sinking.

4.1.3 Second Supd Perforation Completion

The perforation technology is generally used for the deeper geothermal well and its depth is more than 1500m. According to logging curve we can analyze the permeability, porosity and thickness of reservoir and well temperature. This completion technology sets up seeping water paths through perforation manner in proper location. The technology is applied in the reservoir of good water yield property, good permeability, good rock and compact cementation.

4.2 the Reinjection Ground Equipment and Techniques of Guantao Reservoir

The ground equipment can effectively avoid producing physical and chemical blocking of reinjection, decreasing reinjection quantity to attenuate, so that it will keep the sustainable effective use of reinjection well.

The ground equipment need water standard won't be affected by the operation of clear, bounce-back, etc.

The reinjection systems should be strictly closed to avoid producing deposit generated by blocking, the changes of reinjection temperature and pressure. The ground equipment of reinjection system includes filter equipment, exhaust tube, reinjection pipe, water level monitoring pipe, reinjection tube, etc.

4.2.1 Filter Equipment

The reinjection well head needs two steps filter in order to reduce reinjection blocking. The pressure monitors are used in the import and export of two steps filters. According to pressure changes, the period of reverse cleanout are regulated to keep filter effect.

4.2.2 Exhaust Can

On account of the changes of pipe resistance, movement state and hydrodynamic state, part of the gas in the fluid separate out and produce air bubble, which will produce air blocking when they lie in the rock pore. Before reinjection, t exhaust equipment must be set up. When geothermal waste water flow into reinjection tank, the pipe radius changing, flow rate rapidly reducing and pressure dropping will results in pressure difference between tank pressure and the pressure inside the bubble.

4.2.3 Reinjection Pipe Material

Considering the reinjection fluid temperature is generally low, the nonmetal pipe (glass steel or PP-R) is preferred as reinjection pumping water pipe that can prevent corrosion and all kinds of block because.

4.2.4 Well Head Equipment

The well head of reinjection well should be sealing, level, firm, etc. Sealing leakage will leads to minus pressure and inhales atmosphere. Lots of oxygen concentrates among the well of well head to water level surface that brings oxidation reaction and accelerates corrosion. Dissolved oxygen will accelerate corrosion contacted with water surface.

4.2.5 Dynamic Monitoring Equipment

In order to monitor the variation trend of reservoir pressure, temperature and hydrochemistry and keep the sustainable utilization of geothermal resources, we developed the online dynamic monitoring equipment to realize the real-time data transmission of water level, temperature and water quality.

5. THE REINJECTION INFLUENCES ON THE PRESSURE AND TEMPERATURE OF RESERVOIR

We use the model to analyze the reservoir temperature and pressure change of reinjection-exploration system in Tanggu area.

5.1 The Pressure Predication of Stable Reinjection Quantity

The TG17 and TG23 are choosed as the main model fitting caculation. If the current production mode and intension are keep in the future 5 years, the dubble system forms through adding reinjection well to production well (the 2 wells distance is 1000), the predication is done when the reinjection rate is 60%, the reinjection temperature is 35℃. Compared with simple production mode, the drop velocity of reservoir pressure will be relaxed. According to figure 2 and figure 3, the TG17 well bottom pressure rises from 14.93Mpa to 15.03Mpa, correspond average water level drawdown reduces from 3.8 to 1.8 m. the TG23 well bottom pressure rises from 14.12Mpa to 14.22Mpa, correspond average water level drawdown reduces from 3.3 to 1.3 m. Compared with simple mode, the average water drop can recover 10.6 m in the future 5 years.

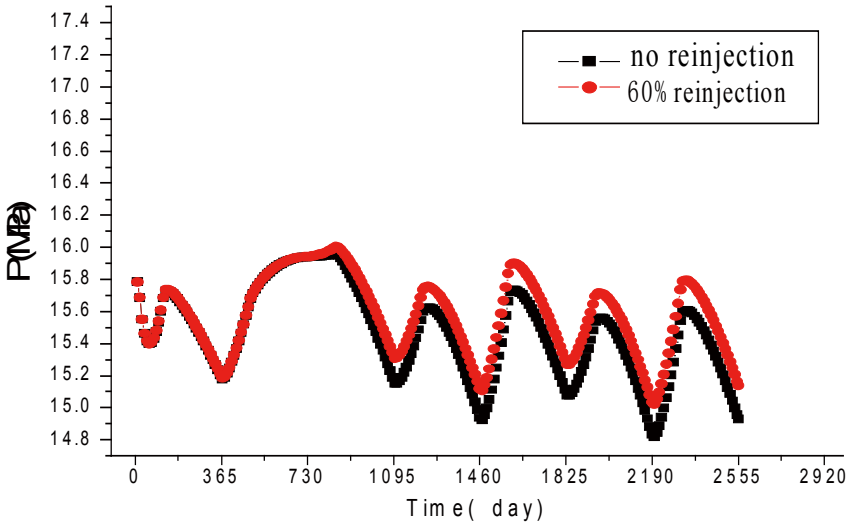

Figure 2: the predication curve of TG17 well bottom pressure in 60% reinjection rate

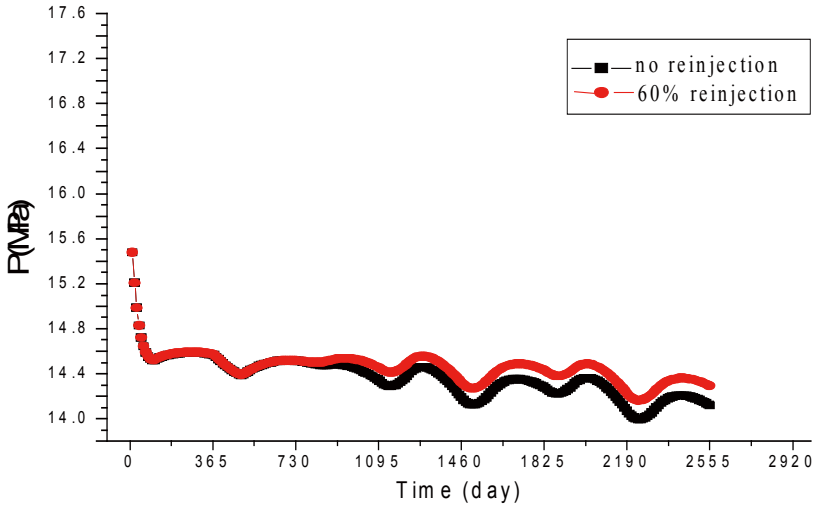

Figure 3: the predication curve of TG23 well bottom pressure in 60% reinjection rate

5.2 the Reservoir Temperature Analysis in Different Reinjection Temperature

The reinjection heat breakthrough is important factors that influence temperature field. Figure 4 and figure 5show the predication results of well bottom pressure and temperature in the different reinjection temperature.

When the distance is about 1000m between reinjection well and production well, changing reinjection temperature has no influences on geothermal well bottom pressure. When reinjection temperature drops from 35℃ to 10℃, the reservoir temperature hardly changes.

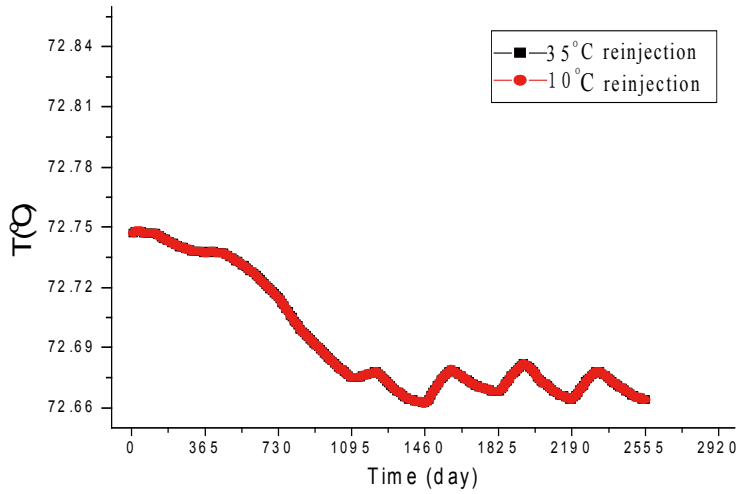

Figure 4: the predication result of TG-17 well bottom temperature in different reinjection temperature

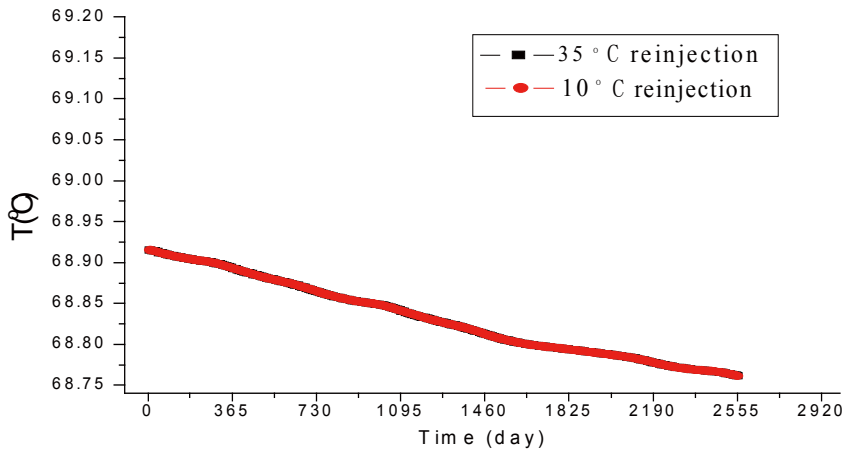

Figure 5: the predication result of TG-23 well bottom temperature in different reinjection temperature

5.3 The Pressure and Temperature Analysis in the Different Well Distance

The reasonable distance is the important factors that keep reservoir temperature and avoid rapid heat breakthrough between reinjection well and production well.

The well bottom pressure and temperature change is predicated when the 2 wells distance is 1000m, 800m, 700m and 500m in order to make sure the most favorable distance under the condition of the lest interference, the heat breakthrough time and the best distance between reinjection well and production well. The results are figure 6 and figure7.

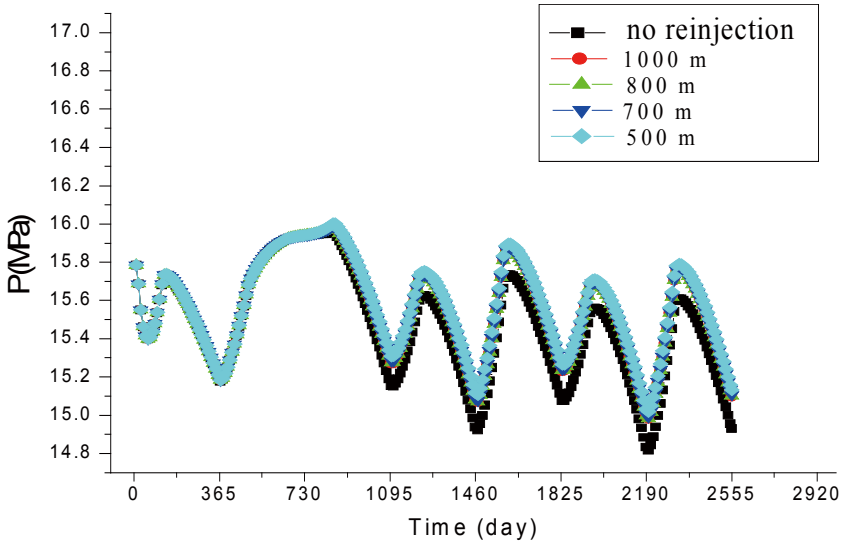

Figure 6: The TG17 well bottom pressure predication in the different well distance

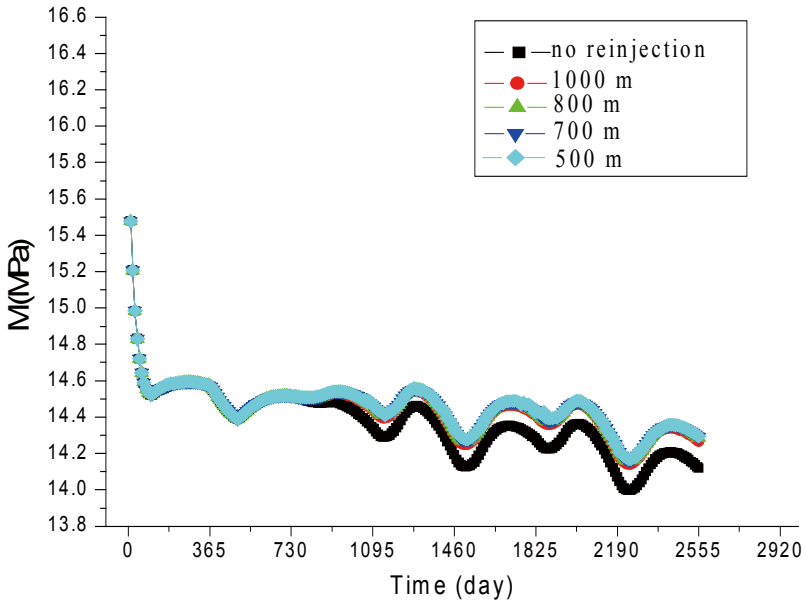

Figure 7: The TG-23 well bottom pressure predication in the different well distance

According the predication results, the well bottom pressure of production well lightly rise when the well distance changes from the far to the close. The drawdown funnel effect is more obvious, the hydraulic gradient increases and recharge effect is obvious when the wells distance is closer.

When the wells distance shortens from 800m to 500m, the reservoir temperature has no obvious change. The energy of reservoir framework accounts for more than 90% total energy, reinjection fluids and rock frame continue heat exchange, fluids temperature gradually increases with fluids movement after waste water is reinjected reservoir, which reduces reinjection fluids influences on reservoir temperature. According the characteristics of porous reservoir, the movement mode of geothermal fluids is main dispersion without pipe movement in the pore medium and greatly reduces the movement velocity which supply enough time for cold-heat exchange. The movement speed of temperature is low than pressure movement velocity, the temperature has no obvious changes in the short time. The cold water is heated in the reservoir during no spacing heat period because of the intermission reinjection mode. So reinjection temperature has no obvious influences on reservoir temperature. The shortest distance can be about 500m between two wells distances in the porous reservoir which has no obvious influences on the reservoir pressure and temperature in the short period.

6. SECTIONS THAT FOLLOW <HEADING 1 STYLE> THE CONSTRUCTION OF DEMONSTRATION PROJECTS

Based on the above research results, we use successful reinjection techniques and set up demonstration projects in Binhai New Area. The integration techniques are used for the well structure designing, geothermal well drilling, the construction of ground reinjection systems and the operation of reinjection systems in the demonstration projects. Each of the reinjection rate of DL-25H, TGR-26D, TGR-28 is up to 101.9 m^3/h, 114.5 m^3/h, and 114.5 m^3/h, which are the reinjection new breakthrough of porous reservoir and gain the remarkable economic, social and environmental benefits.

6.1 DL-25H reinjection demonstration project

6.1.1 Well Structure and Completion

The DL-25H well was drilled on December 25th, 2009 with the depth of 1362.39m. The well completion technology of the DL-25H well is supd large–diameter-hole gravel packing completion in order to avoid attenuating and increasing reinjection according to the geological characteristics of shallower reservoir depth, incompact rock construct, worse cementation and higher penetrability (Figure8).

This technology can increase the crossing sectional area, improves reinjection ability, and guarantees sustainable reinjection.

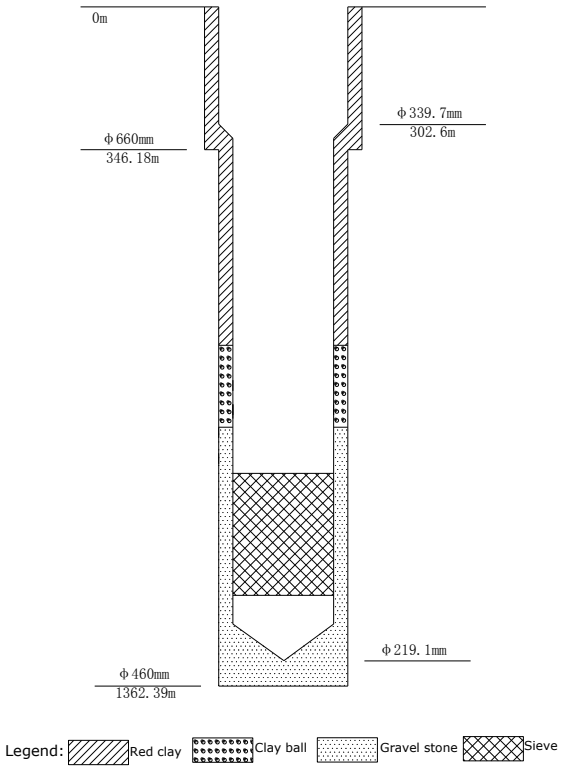

Figure 8: the DL-25H well construction

6.1.2 Flushing Well

Air compressor and cement pump gas is used to flushing well until water are clear. The quantity of pumping test is 107 m^3/h after well completion，the stable dynamic water level is 137.9m, and the water temperature is 76 ℃. The results of water sample analyzing show that hydrochemistry type is Cl•HCO_3•Na，the degree of mineralization is 1726.2 mg/L，and the PH value is 7.57.

6.1.3 Reinjection System

The reinjection systems of DL-25H well include filter equipment, exhaust gas equipment, reinjection pipe, water level test pipe, reinjection pipe, etc. The technological process of reinjection system is figure 9.

According to water quality analysis results, the reinjection treatment systems include cyclone desander, coarse filter, precision filter and exhaust tank.

(1) Desander: according to the characteristics of geothermal fluids, the ground reinjection systems add the cyclone desander equipment.

(2) Coarse filter: the coarse filter systems are parallel composed of four filters, each filter rate is 20 t/h, and total filter rate is up to 80 t/h.

(3) The precision filter: the precision filter systems are parallel composed of four filters, each filter rate is 20 t/h, and total filter rate is up to 80 t/h. It can not only preventing the physical block, but also intercepting or absorbing microbe and bacteria due to higher filter precision.

(4) Exhaust tank: the velocity, pressure and hydrochemistry of geothermal fluids will change after waste water flowing through pipes and two steps filters. The changes of velocity and pressure release gas.

(5) The choice of reinjection pipe: To avoid physical blocking the reinjection systems has been improved on reinjection pipe and water level test pipe which used stainless steel pipes to further improve the performance of resisting chlorination and erosion.

PPR pipes are totally used to be delivery way in order to avoid erosion and to keep the quality of reinjection water, which has the characteristics of heat resisting, pressure resisting, erosion resisting and no scaling. The test report of PPR pipe shows that it can bear 95 ℃, 1.11 Mpa, and more than 1000h test.

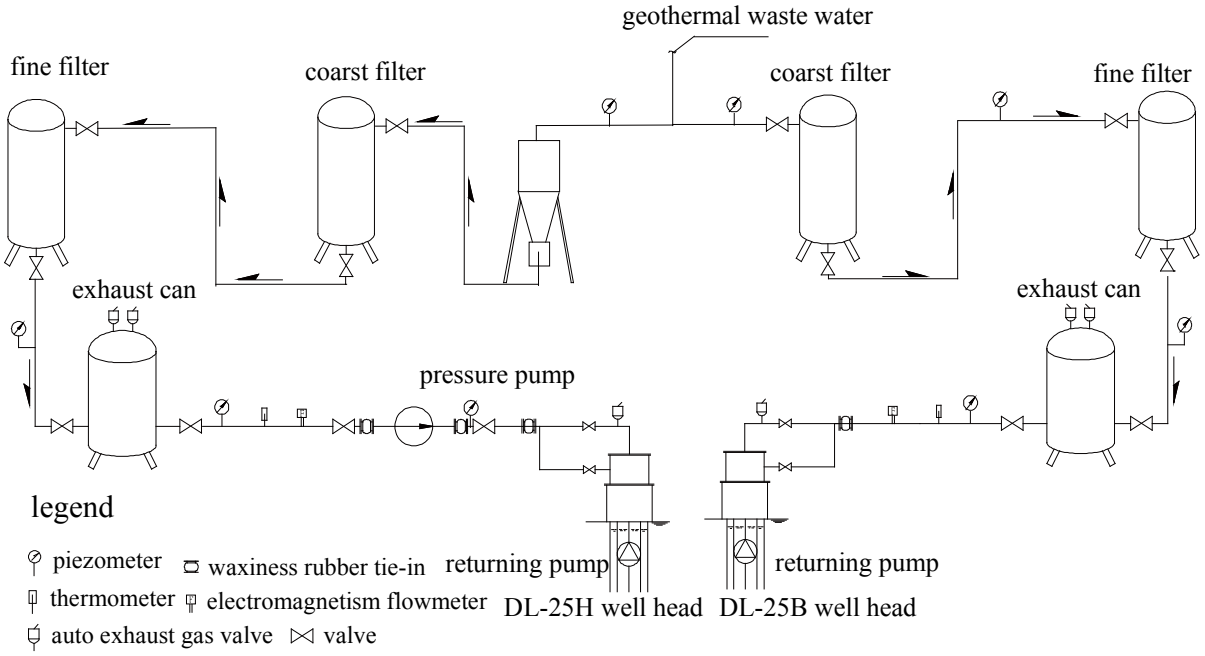

Figure 9: the technological process of DL-25H reinjection system

6.1.4 Reinjection Testl

Using gravity reinjection, the reinjection rate is gradually increased. Before reinjection, based on the reinjection scheme we cleaned the pipe of reinjection system and equipment and connect the equipment. According to the data of reinjection test, we draw the curve of water level, temperature and reinjection rate in DL-25H well (Figure 10). The results show that the most reinjection rate is 101.9 m^3/h.

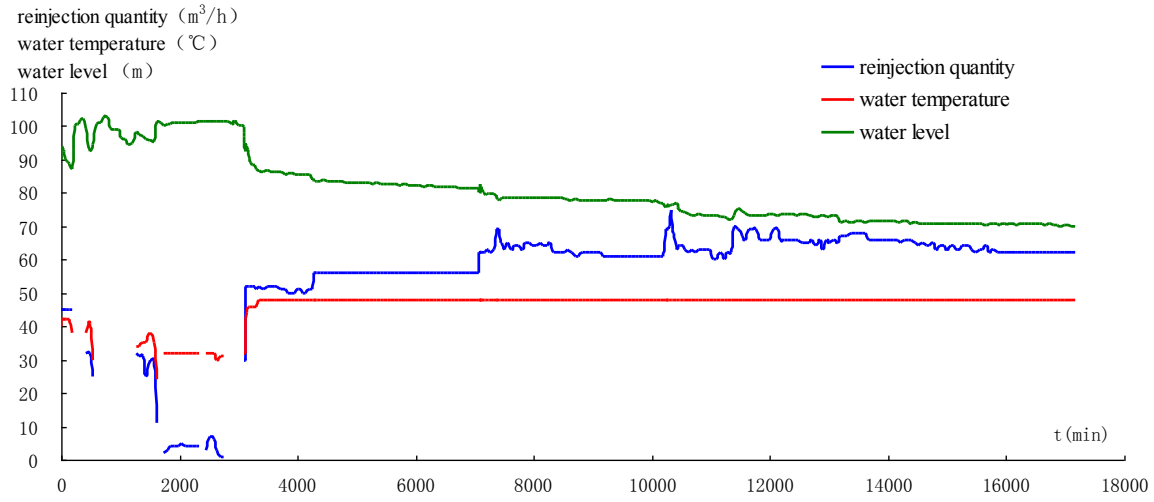

Figure 20: the relation curve of water level, temperature and discharge in the DL-25H reinjection well

6.2 The Reinjection Demonstration Droject of TGR-26D well and TGR-28 well

6.2.1 Well Structure and Completion

According to reinjection results, the reinjection well of Guantao reservoir can use the perforation technology in this region. The TGR-26D well and TGR-28 well are used to be second supd perforation completion according to the reservoir characteristics of

shallower depth, better compact stratum and higher permeability (Figure 11 and Figure 12). The logging curve results show the permeability, porosity and the thickness of reservoir, so the perforation stage are chose to be better cementation stratum.

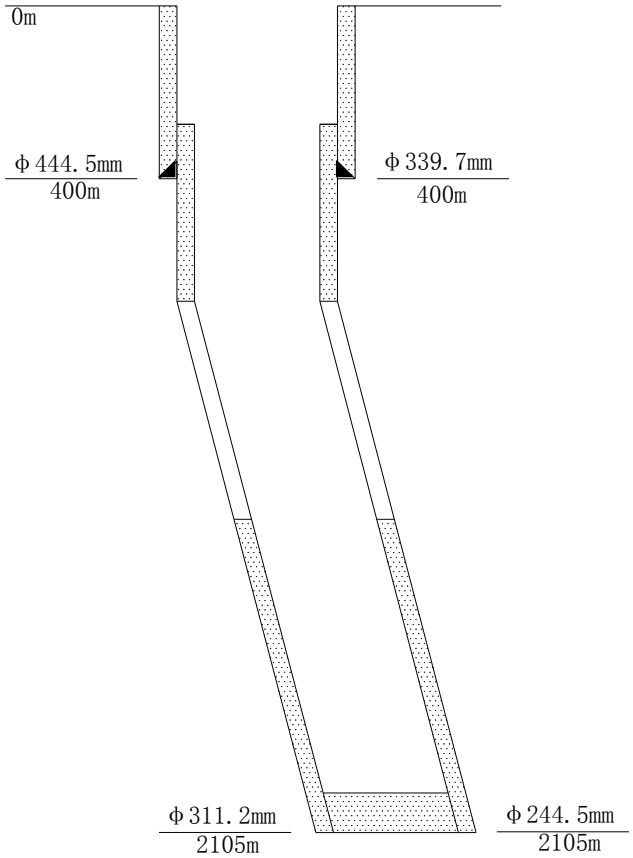

Figure 31: TGR-26D well construction

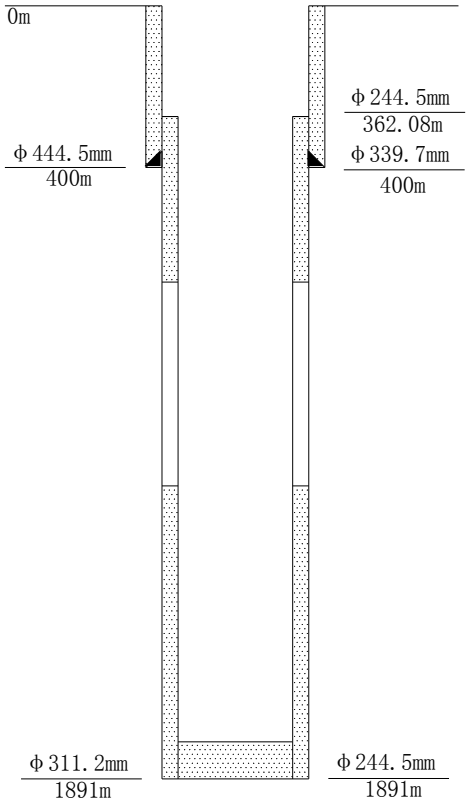

Figure 42: TGR-28 well construction

6.2.2 Reinjection System and Test

The ground reinjection systems of two wells are same with DL-25H. After indirect heat exchange, the geothermal fluids of enter into the reinjection station to add pressure, then to pass through coarse filter, precision filter, exhaust tank and reinjection well at last. The precision of coarse filter is up to 50μm and that of filter precision is up to 3μm. The exhaust equipment separates out gases coming from geothermal resources because of pressure change.

It is attested that the reinjection rate is up to 114.5 m^3/h and 122.5 m^3/h (Figure 13 and Figure 14). The results show that the new breakthrough of reinjection has realized in the Binhai New Area.

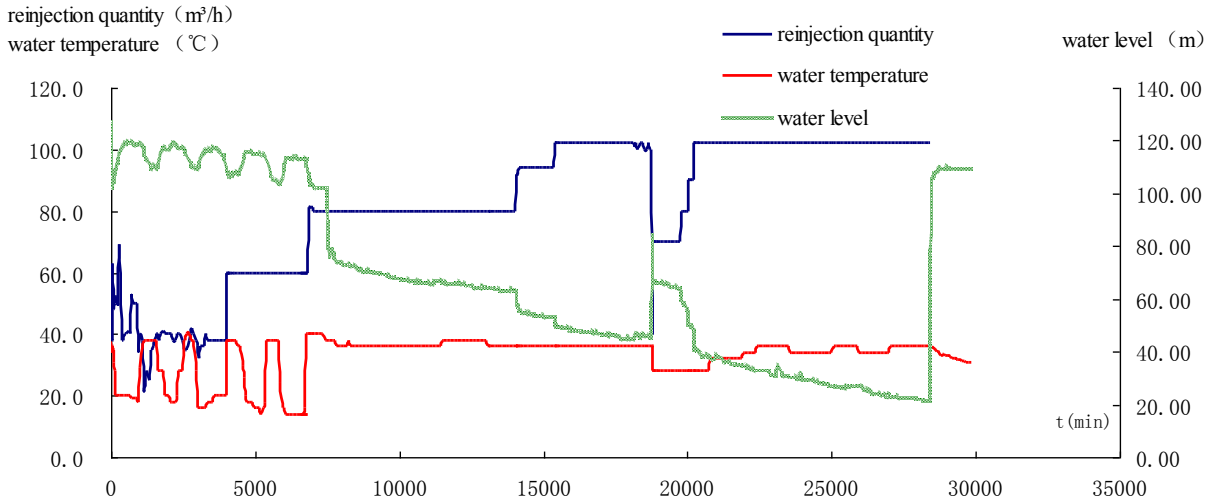

Figure 53: the relation curve of water level, temperature and discharge in the TGR-26D reinjection well

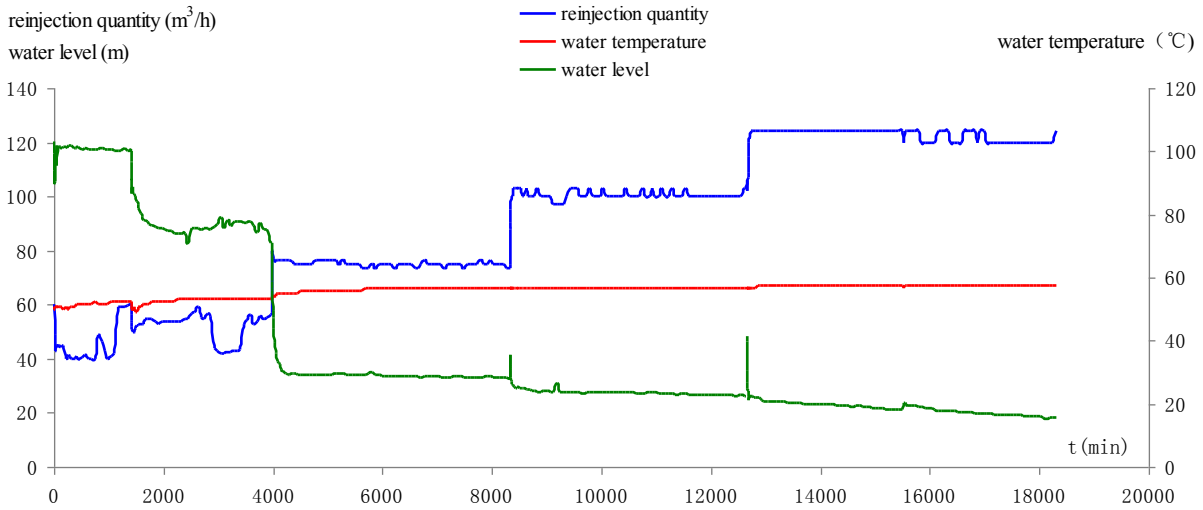

Figure 64: the relation curve of water level, temperature and discharge in the TGR-28 reinjection well

7. CONCLUSION

(1) The suspended fine grains of reinjection fluids, chemical reaction and gas are main reasons of blocking. The physical blocking is the most main question of reinjection block in porous reservoir.

(2) The supd large–diameter-hole gravel packing completion, second supd wire-wrapped screen completion and second perforation completion are perfect to be used for reinjection well of Guantao reservoir in Binhai New Area.

(3) Proper ground reinjection systems and techniques can avoid physical and chemical blocking and reduce reinjection quantity dropping.

(4) The test attests adding reinjection can reduce water level drawdown and pressure, reinjection fluids temperature has on influence on reservoir temperature, and the shortest well distance can be about 500m in porous reservoir without heat breakthrough.

(5) The demonstration projects are set up according to successful well completion technology and standard ground reinjection systems, so the reinjection rate up to 100-123m^3/h that is the biggest reinjection breakthrough of porous reservoir in Binhai New Area, Tianjin.

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