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Experimental study on tail water recharge of sandstone thermal storage geothermal in Zhoukou City

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ABSTRACT：The concentrated exploitation of geothermal resources and the direct discharge of tail water after utilization will cause thermal pollution and water chemical pollution of surface water sources, and even affect hydrogeological problems such as thermal storage pressure and water level drop. Zhoukou City is a concentrated area for the exploitation and utilization of thermal storage geothermal resources in the Guantao Formation. This time, a geothermal recharge experiment was carried out in Zhoukou City, which belongs to the research on the recharge of wells in the same layer. According to the data obtained from the recharge test, the relationship between the recharge amount and the recharge pressure, the influence of the recharge on the water quality of the thermal reservoir, and the effect of the recharge on the temperature of the thermal reservoir were analyzed and studied. The relationship curve calculates the maximum recharge. The analysis results show that the hourly recharge volume increases with the increase of the pressure, and the ability to increase the hourly recharge volume decreases with the increase of the recharge pressure. Therefore, the recharge has little effect on the water quality of the thermal reservoir; in this experiment, the distance between the mining and filling wells is large, so the recharge has no effect on the temperature of the thermal reservoir.

KEY WORDS: geothermal; sandstone recharge; well recharge; Zhoukou

Under the background of "dual carbon", geothermal energy utilization is an important component of the national clean energy strategy, and the problem of increasing the pressure and decreasing recharge amount of sandstone thermal storage in long-term operation seriously restricts the promotion of geothermal energy. With the recent introduction of various policies on the scientific utilization of geothermal energy by the National Energy Administration, the Ministry of Ecology and Environmental Protection and other departments, how to carry out efficient reinjection of geothermal wells has become an important research direction for the majority of scientific researchers and geothermal professionals.

Sandstone thermal storage in Zhoukou area mainly includes thermal storage of Neogene Guan Tao Formation and Minghua Town Formation, geothermal resources are buried deeply, basically in a static state under natural conditions, and the replenishment of geothermal water is weak, which is an unrecoverable consumable resource. Geothermal resources are mainly used for winter heating, and if the heating tailwater is directly discharged into the urban sewer, it will cause a great waste of geothermal resources and put forward higher requirements for urban sewage treatment capacity. The quality of the tailwater after heating basically does not change, only the temperature changes, and the use of reasonable engineering measures to inject the heating tailwater back into the heat reservoir is a fundamental measure to maintain the sustainable development of geothermal resources.

1 GEOTHERMAL GEOLOGICAL CONDITIONS

Huaiyang District of Zhoukou City is located in the middle of Zhoukou City, southeast of Henan Province, with a geographical location of 33°20′N~34°00N, east longitude 114°38′E~115°04′E, with a total area of 1406.6 km2, located in the southern edge of the Yellow River Alluvial Plain, part of the North China Plain, and the Huang-Huai-Hai Plain area. The climate is warm temperate monsoon climate with a mild climate. The territory is rich in surface water and groundwater resources.

Geologically, Huaiyang City is located on the northern boundary of the Luyi Sag, a secondary tectonic unit of the Zhoukou Depression, and the northern margin fault of the Luyi Sag, the Yanghukou-Renji Fault (F6), extends west to the east of Huaiyang City, and ends abruptly. The fault runs north-east, tends south-east, and is a positive fault with a total length of about 58km. The strata on both sides of the fault are Permian and Triassic, which are intra-layer faults.

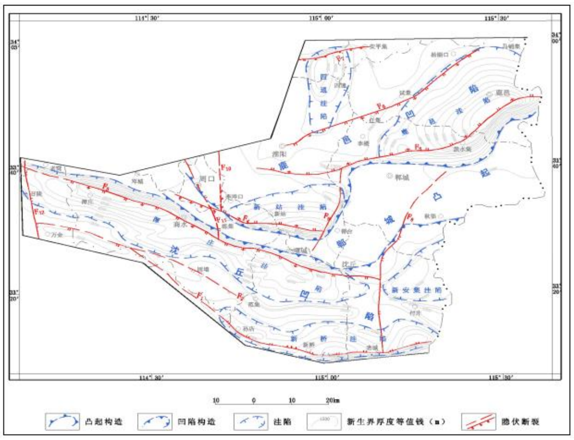

Figure 1 Regional map of secondary tectonic units in Zhoukou Depression

Bailou Town, north of Huaiyang, has built an oil exploration hole - Zhou Shen 8 holes, showing that 1478m drilled through the Neogene system, 2770m into the Permian, 3674m drilled through the Permian, into the Carboniferous Benxi Formation, to 3775.5m drilled through, revealing that the Benxi Formation was 101.5m, and the bottom was the Ordovician Central Majiagou Formation, which was not drilled to 4000m. The ground outcropping is all of the fourth series, mainly lacustrine, lacustrine and fluvial sedimentation. The lithology is mainly clay, silty clay and fine sand, medium fine sand, silty sand, and local coarse sand or gravel-bearing sand. The thickness is generally 210~350m, and the southwest, east and northwest are thicker. The fourth series aquifer has a small burial depth, low temperature, generally does not have heat storage conditions, and the cohesive soil has good thermal insulation performance, which is a good cover layer for the newly related thermal reservoir.

The Huaiyang Formation developed from bottom to top Cambrian-Ordovician, Carboniferous-Permian, Middle and Lower Triassic, Paleogene, Neogene and Fourth Series, missing the Upper Triassic and Jurassic-Cretaceous, of which the Carboniferous-Permian and Middle and Lower Triassic were 1000~1800m thicker than the new Near and Fourth Series, the thickest Paleogene in the eastern region, up to 6000~7000m, and the thin in the western region, generally about 1000m. Among them, the new world, from the old to the new, is the Liaozhuang Formation, Guantao Formation, Minghua Town Formation, and Fourth Plain Formation. Among them, the Liaozhuang Formation is composed of brown mudstone and variegated conglomerate, mixed with light gray fine sandstone and conglomerate-bearing sandstone. The upper part of the Guantao Formation and the Minghua Town Formation are light brown-yellow, brown-red clay and variegated gravel with unequal thickness and interlayered; The central part is light brownish-red, light gray-yellow mudstone and medium sandstone interbedded; The lower part is a brownish-red mudstone and variegated conglomerate interbedded; The plain group is composed of light brown, light gray-yellow clay, medium sandstone, and variegated gravel interbedded (Yuhezhong, 2005). The main thermal storage in Huaiyang County is the thermal reservoir of the Neogene Minghua Town Formation and the Guantao Formation, which is mainly composed of Cenozoic sediment, and the lithology is mainly sandstone, of which the roof of the Neogene Minghua Town is buried 220~240m deep, and the floor is buried at a depth of 920~1030m, which accumulates sandstone and silty clay layers with huge thickness to form a stable water-bearing space. The fourth series has a dense structure and large thickness, which plays a good role in thermal insulation and provides good geothermal storage conditions.

2 THE CURRENT SITUATION OF DOMESTIC GEOTHERMAL WATER RECHARGE

At the beginning of 1982, China carried out reinjection experiments in the southeast of geothermal fields in Beijing urban area, and the thermal reservoirs were mainly carbonate rocks of Tieling Formation and Wumishan Formation in Jixian County. In 1996, the research on thermal storage geothermal recharge in Jixian County, Tianjin achieved obvious results. From 2001 to 2002, Beijing carried out a heating period recharge test in Xiaotangshan, the southeast of Beijing urban geothermal field, Xiaotangshan geothermal field from 2003 to increase the amount of recharge year by year, the current Beijing geothermal recharge capacity reached about 80% of the heating production volume, marking that the recharge exploitation of geothermal heat in carbonate karst fracture thermal storage has entered the production practice stage. From 1987 to 1989, Dagang Oilfield Hydropower Plant carried out four reinjection tests with a cumulative time of 197d and a cumulative recharge capacity of 77943m³. During the winter heating period in 1995, the heat storage recharge test of the Neojiguan pottery group was carried out in Xinkaili, Tanggu District, which lasted for 79 days and the cumulative recharge was 21190m³. In 2004, one group of recharge experiments were carried out in Huatai Agricultural Science and Technology Park and Wuqing Guohuan in Dongli District, and a two-stage filtration treatment system was installed in the reinjection process, the former had a cumulative reinjection time of 138d and a cumulative recharge volume of 22077m³; The cumulative recharge time of the latter is 70d, and the cumulative recharge amount is 48665m³. During the above recharge, the amount of recharge decays rapidly with time, and the recharge effect is not satisfactory. In 2010, in the neogene pore type thermal storage geothermal recharge test in Binhai New Area, perforated blasting technology was used for the first time, and breakthroughs were made in recharge amount and recharge continuity, with a recharge capacity of 103-120m³/h.

3 REPERFUSION TEST IN HUAIYANG DISTRICT, ZHOUKOU

(1) Basic information of the test

From October 17 to October 28, 2022, geothermal reinjection tests were carried out on hot 1 well and hot 2 wells using the natural reinjection mode of the same layer, and the two wells were separated by 488m. The depth of the mining well is 1312m, the water intake section is 968-1312 m, and the mining heat storage is mixed with Guantao Formation and Minghua Town Formation, with a water inflow of 90m³/h. The recharge well adopts large-diameter gravel filling process (Figure 2), the depth of the well is 1306m, the water intake section is 953-1306m, and the mining heat storage is mixed with Guantao Formation and Minghua Town Formation, and the water inflow is 90m³/h.

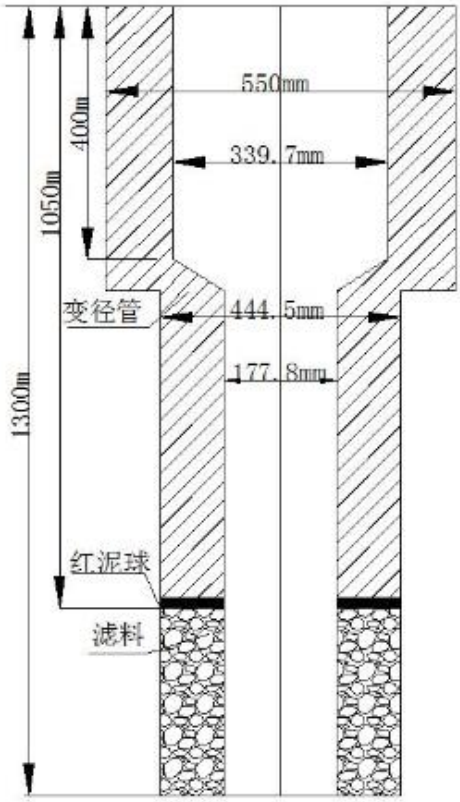

Fig. 2 Structural diagram of large-diameter wellbore

(2) Basic test process

Before this reinjection test, the water level of the recharge well was measured to be 45 m, the pressure of the thermal reservoir was low, and there was a good water storage space, so the natural pressureless reinjection mode was adopted this time. This reinjection adopts the same layer of thermal storage recharge, so directly using heating tailwater as the recharge water source will not have an essential impact on the water quality of the recharge well hot reservoir, so the heating tailwater is suitable as the recharge water source. In order to prevent the blockage of the thermal reservoir by solid particles during the recharge test and ensure the smooth progress of the test, the water supply source was sanded, coarsely filtered and fine-filtered before entering the recharge well. The specific process flow is: geothermal water → cyclone desanding → heat exchanger→ precision filter → recharge well (Figure 3).

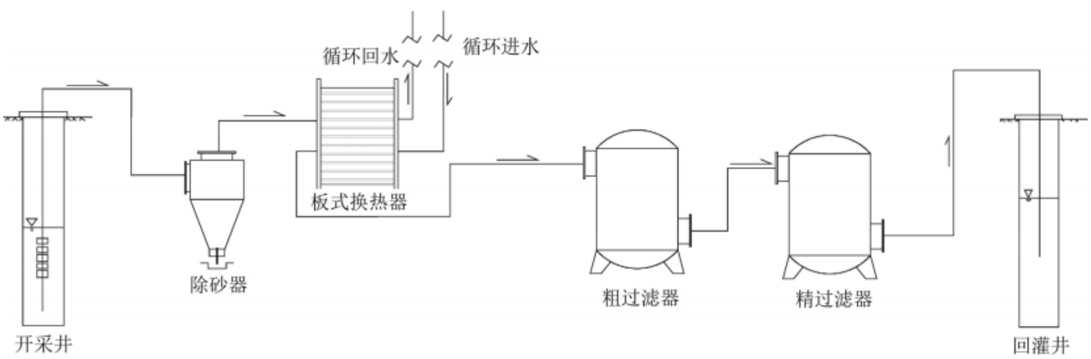

Figure 3 Process chart of recharge test

4 INTERPRETATION OF RESULT

According to the relevant technical requirements in the Technical Regulations for Geothermal Tailwater Reinjection of Sandstone Thermal Storage: "When the water level is less than 10 m from the wellhead, the reinjection should be stopped. "According to the recharge amount obtained by the recharge test and the corresponding water level rise data of the recharge well, a curve of the relationship between the recharge amount and the water level rise can be fitted, and the fitting function relationship is positively correlated. It can be seen that the recharge amount increases with the increase of recharge pressure (head equivalent pressure), and the unit recharge amount decreases with the increase of recharge pressure.

In order to study the effect of reinjection on the water quality of thermal reservoirs, water samples from mining wells and recharge wells were collected and analyzed before, during and after recharge. The salinity of mining wells is greater than that of recharge wells, but because mining and irrigation wells belong to the same layer of heat storage, the salinity of water quality is not much different. Because the recharge well is filled with water sources with higher salinity than its own geothermal water mineralization, the salinity of geothermal water collected after reinjection is higher than before the recharge test, but because the thermal reservoir extracted by the irrigation well belongs to the same layer of thermal storage, the impact of reinjection on the water quality of the thermal reservoir is small.

During this recharge test, the temperature of the recharge tailwater was 34°C, and the water temperature of the mining well was maintained at about 57°C. From the monitoring data of the water temperature of the mining well during the recharge test, it can be seen that the geothermal fluid temperature in the thermal reservoir is not affected by the temperature of the recharge tailwater. The distance of the recharge test well group is 488m, and it can be inferred that the influence range of the recharge tailwater temperature is less than this distance (Wu Lili et al., 2017).

5 CONCLUSION

(1)The recharge well of the test well group adopts large-diameter gravel filling process. The geothermal fluid heat exchange of the mining well is naturally recharged into the same layer heat reservoir of the recharge well after sandremoval and two-stage filtration.

(2) The recharge increases with pressure, while the unit recharge decreases with pressure.

(3) The water quality of recharge well is obviously affected by the water quality of recharge source well, but the water quality of mining and irrigation well itself is not much different, so the recharge has little impact on the water quality of heat reservoir.

(4) The recharge has less influence on the water temperature of the heat reservoir, and the influence range of the temperature field is less than 488m.

(5) The recharge test mode and the well forming process of recharge well have reference significance for the mixed mining heat storage of Minghua Town group and Guantao group, and have guiding value for laminar pore-fissure type heat storage and recharge.

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