Study on the recharge ability of sandstone geothermal reservoir in Dongying formation of Liaocheng City

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Study on the recharge ability of sandstone geothermal reservoir in Dongying formation of Liaocheng City

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Abstract. In order to find out the recharge ability of the sandstone reservoir in the Dongying formation of Liaocheng City, the recharge test of geothermal tail water was carried out. The results showed that under the natural conditions, when the recharge of geothermal tail water was 27 m³/h, the recharge ability was lost. Under the pressure of 0.2 MPa, the recharge capacity tended to decay with the recharge time increasing. The maximum recharge volume is 20 m³/h. From the analysis of the geological condition of the thermal reservoir, the pressure condition of the water head and the recharge ability, we find that the reirrigation capacity of the sandstone reservoir in Dongying formation of Liaocheng is weaker.

1. Introduction
Geothermal resources are valuable comprehensive mineral resources, which have broad prospect of development and utilization. Over-exploitation of geothermal resources will make the thermal reservoir water level continuing decline and the geothermal wells’ water production being weakened. Long-term emission of geothermal resources is a huge waste, and it will cause land subsidence and environment pollution caused by waste heat and the harmful substances of abandoned water[1].

In 1969, the Geysers geothermal field recharge project in California opened a prelude to geothermal recharge. In 1982, China conducted the first geothermal recharge experiment in Beijing. Subsequently, Tianjin and Xi’an also conducted geothermal recharge attempts and achieved fruitful results. At present, geothermal recharge reservoirs are mostly selected as karst fissure type thermal reservoirs and pore-fissure type thermal reservoirs. Due to the development of fractured karst in karst fractured thermal reservoirs, the recharge effect is better. However, the pore-fissured sandstone thermal reservoirs have small particle size, low porosity and low permeability, which lead to the recharge amount too small to achieve continuous and stable recharging. This make it a difficult problem for recharging at home and abroad[2-4].

In order to find out the recharge capability of porous thermal reservoirs in Dongying Formation in Liaocheng City, natural recharge and pressurized recharge experiments of the same layer wells were carried out. We carried out the test of natural recovery and pressurized recharge of the same layer, and analyzed the feasibility of implementing geothermal recharge under the current technical conditions, so as to provide basis for geothermal recharge of Dongying formation.

2. Geothermal recharge test

2.1. Strata
The outcropping strata in this area are all Quaternary. According to the borehole data, the hidden from old to new: Paleogene, Neogene and Quaternary strata.
2.1.1. **Paleogene Jiyang group.** The Paleogene Jiyang group in the area from the old to the new, Kongdian, Shahe street and Dongying formation. The lower part of the Kongdian formation is sandstone or conglomerate sandstone, and the upper part is mudstone sandwiched sandstone and gypsum. The Shahe Street formation is mainly mudstone and marl, with sandstone and conglomerate at the bottom. Dongying Formation is mainly inter-bedded mudstone and sandstone with a thickness of about 800m.

2.1.2. **Neogene Huanghua Group.** The lower part of Neogene Huang Hua Group is Guantao Formation, and the upper part is Minghua Town Formation. Guantao Formation consists mainly of sandstone, sandy mudstone and mudstone, about 200m thick. Minghuazhen Formation consists mainly of clay rock, siltstone and glutenite interbedded layers, about 600m thick.

2.1.3. **Quaternary.** The upper part is a thick layer of fine - coarse sand folder clay, which is dark yellow, and the lower part consists of dark yellow clay, brown yellow clay, gray-yellow clay, fine sand, sand, coarse sand and silt interbed, about 300m thick.

2.2. **Structure**
A large fracture, which is closely related to the geothermal power of the city, is a Liao-Kao fault. The Liao-Kao fault is a normal fault with a NNE strike extending from the eastern part of the urban area, with a tendency of NWW of about 260km. The fracture communicated the relationship between the thermal reservoir and the heat source, and became a better heat transfer channel\(^{[5-6]}\).

2.3. **Test conditions**
The recharge site is located at the Guangyue Hotel in Liaocheng City. The production well is 1654m deep and the water temperature is 53°C. The recharge well depth is 1670m and the water temperature is 58°C. The reclaimed water is the geothermal water in Dongying group, and the way of recharge is the same layer recharge.

2.3.1. **Completion technology of recharge well.** 0 ~ 200.00m, hole diameter 420mm, 273.1 * 8.89mm oil casing. 200 ~ 1670.60m, hole diameter 216mm, 139.7 * 6.98mm oil casing and filter pipe. Filter pipe diameter is 18mm. Xinzong hole distance is 50mm. Horizontal distance is 50.80mm, and the porosity is 25%. The depth of the water intake section of the Dongying formation is 1258.9-1622.4m, and the accumulative thickness of the water extraction layer is 184.6m.

2.3.2. **Recharge test process.** Desander activated carbon filters remove sand, iron and manganese ion from geothermal water. After heat exchange, the tail water enters the recharge system. The geothermal tail water first enters the frequency conversion resonance activated water device. After the descaling, sterilization, antitrust and anticorrosion, it enters the coarse filter and the precision filter. It can filter up to 5μm. After exhaust treatment, the geothermal tail water is poured into the recharge well.

3. **Test results**

3.1. **Recharge amount and depth of liquid level**
The results show that the water level is increased with the increase of the recharge amount, and the increase amplitude is greater than the increase of the amount of recharge. Under the natural recharge condition, when the recharge amount is 10m\(^3\)/h, the accumulative recharge time is 206h, the accumulative recharge amount is 1809.42m\(^3\), and the water level rising is small.
Fig 1. Dynamic curve of 10m$^3$/h recharge amount and water depth.

When the recharge amount is 20m$^3$/h, the accumulative recharge time is 72.33h, the accumulative recharge amount is 1253.72m$^3$, the water level continues to rise, and the sustainability of the recharge is reduced.

Fig 2. Dynamic curve of 20m$^3$/h recharge amount and water depth.

When the recharge amount is 27m$^3$/h, the accumulative recharge amount is 2190.58m$^3$, and the recharge time is 88.67h, and the recharge is lost continuously.
3. Under pressure Dynamic curve of recharge amount and water depth.

3.2. groundwater chemical field and temperature field changes
This test is the same layer recharge test for pair well. The recharge water is the hot water of the Dongying Formation thermal reservoir. The effect of recharge on water quality is small, and the change of the chemical water field is small.

The effect of recharge on water temperature mainly depends on the temperature difference between the recharged water and the original thermal reservoir water, as well as the amount of recharge and recharge time. The greater the amount of recharge and the greater the temperature difference, the greater the effect of reusing water on the water temperature of the thermal reservoir.

4. Analysis of recharge ability

4.1. Conditions of the Dongying formation
The buried depth of the roof of the Dongying formation thermal reservoir is about 1100m. The layer thickness of the aquifer is 5.2-57.5m, and the cumulative thickness is about 180m. Stratum lithology is mainly fine sand, water temperature is 55-60 degrees centigrade, water yield of single well is 1500-
2000m³/d, porosity is 20.62%-27.88%, permeability is (138.91-526.50) *10⁻³μm², and permeability coefficient is 0.46-0.53m/d. Permeability of thermal reservoir is poor.

4.2. Water head
The confined water head and the depth of the water level are the important factors to determine the recharge amount of the pore type thermal reservoir[7]. The higher the confined head, the more shallow the depth of the water level is, and the smaller the natural recharge water is. On the other hand, the amount of recharge water is greater. The confined water head of the reservoir of Dongying formation in Liaocheng city is 1593m, and the depth of the water level is only about 52-77m. Under the present condition, the recharge space provided by the thermal reservoir is limited.

4.3. Recharge ability

4.3.1. Natural recharge. The analysis of the test data shows that when the recharge amount of the Dongying formation is 10m³/h, the recharge head is low and the recharge continuous ability is good. When the recharge amount is more than 20m³/h, the permeability of the reservoir gradually decreases with the time of recharge, and the recharge head continues to rise as well as the recharge ability is reduced. The Dongying formation heat reservoir recharge volume should not be larger than 20m³/h.

4.3.2. Pressurized recharge. Under current geological conditions, when the pressure is 0.2Mp and the recharge volume is 20m³/h, with the extension of recharge time, the recharge capacity of the Dongying Formation thermal reservoir gradually decreases from 20m³/h to 17.5m³/h. It can be seen that, under the current conditions, natural recharge and pressurized recharging capacity are limited.

5. Conclusion
Based on the analysis of the geologic conditions, head pressure conditions, and recharge test results of pore sandstones in Dongying Formation of Liaocheng City, the conclusions are drawn:

- The lithology of Dongying formation thermal reservoir is mainly siltstone, with poor permeability, high pressure head and limited recharge space.
- Under the condition of natural recharge, the amount of recharge should not be greater than 20m³/h while ensuring the sustainability of recharge. Under the condition of pressurized recharge, when the pressure is 0.2Mp and the refilling volume is 20m³/h, the recharge volume tends to decrease with the extension of recharge time.
- Under current conditions, natural recharge and pressurized recharge capacity are limited.

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