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Experimental Analysis on Temperature Stratification Characteristics of Storage Tanks for Geothermal Heating

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ABSTRACT

In a geothermal heating system coupled with storage tanks, temperature stratification effect of the storage tank is greatly influenced by different internal structures. A horizontal multi-sink storage tank with flow equalizing plate was designed and a test rig of storage tank was established in order to study the stratification characteristics. Experiments of three storage tanks with different flow sharing plate structures (full opening, middle opening and near water side opening) were carried out. The initial water temperature in the tank is 30℃ and under the same inlet water temperature, the temperature distribution cloud map of each heat storage tank under different flow rates is drawn according to the experimental data. Results showed that:(1) The temperature stratification characteristics of the storage tank can be optimized by selecting the near water side opening at low flow rate and the full opening at high flow rate;(2) The thickness of the thermocline can be significantly reduced and the temperature stratification characteristics can be improved by adding the flow equalizing plate.

Keywords: Geothermal heating, Storage tanks, Temperature stratification, Experimental analysis

1. INTRODUCTION

China is rich in geothermal resources, and the use of geothermal resources for heating is widely used in China [1-3]. The combination of ground source heat pump system and water energy storage technology is the main way to use geothermal energy for heating [4]. Water storage tank is the key equipment of water energy storage heating system, and its structure has a significant impact on the performance of the system [5].

To improve the temperature stratification characteristics of storage tank, scholars have deeply studied the internal structure of storage tank. Famahini [6] found through simulation research that increasing the height diameter ratio of storage tank can make the stratification effect better. Huang et al. [7] built a test rig of storage tank and carried out experiments of three different structure tanks (direct import, three layers and stratifier). Li [8] designed and built a heat storage condition test-bed, and carried out the heat preservation experiment of storage tank and layered heat storage experiment.

Based on the abovementioned scholars' research on the storage tank, this paper proposes a horizontal multi tank heat storage tank with flow equalizing plate and establishes a test rig of storage tank. Experiments of three storage tanks with different flow sharing plate structures (full opening, middle opening and near water side opening) are carried out.

2. SYSTEM DESCRIPTION

2.1 Structural design of storage tank

The storage tank designed in this paper is divided into four small tanks, and the flow equalizing plate is installed in the middle two tanks, as shown in Figure 1. The size of the storage tank used in the experiment is 1500mm × 600mm × 800mm and the volume is 0.72m^3.

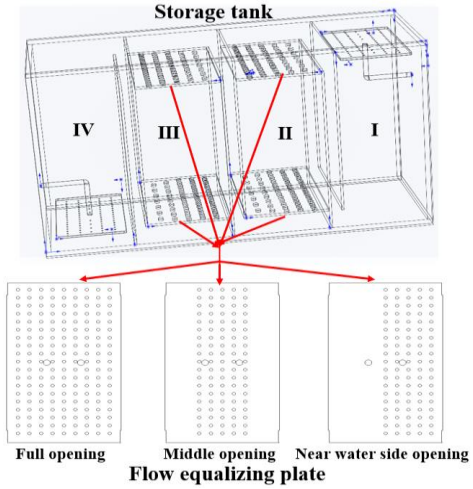

Fig.1 Structural diagram of the storage tank

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To study the temperature stratification of each water tank in the process of heat storage, a row of thermocouple temperature measuring points are arranged in the middle of each water tank along the vertical direction. There are 15 temperature measuring points in each column with an interval of 50mm. In addition, a thermocouple temperature measuring point is arranged at the inlet and outlet of the water tank to measure the temperatures. Therefore, there are 90 temperature measuring points in the whole experimental system. The flow direction of water and the layout of temperature measuring points are shown in Figure 2.

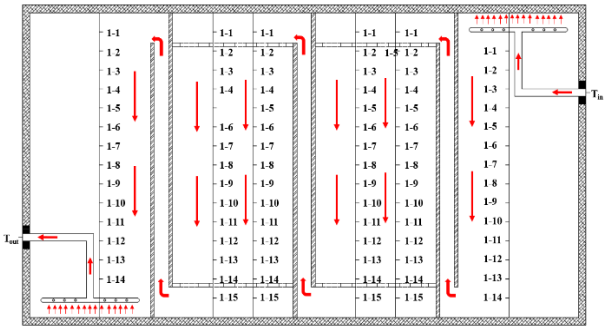


Fig.2 The flow direction of water and the temperature measuring points

2.2 Composition of experimental system

Combined with geothermal energy heating system and referring to some structural parameters of existing energy storage devices, a horizontal multi-sink water heat storage experimental system is designed, as shown in Figure 3.

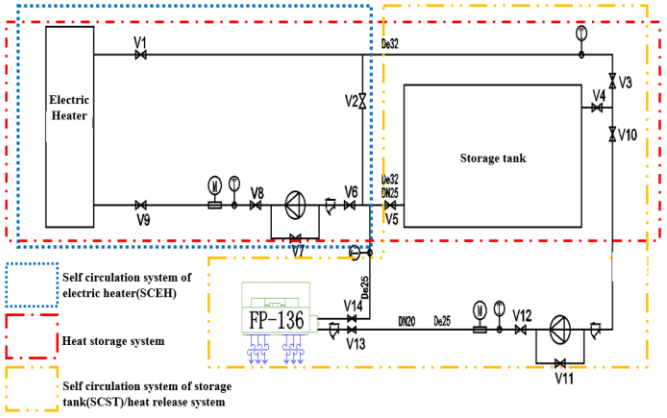


Fig.3 The diagram of experimental system

The system consists of four parts - self circulation system of electric heater (SCEH), self circulation system of storage tank (SCST), heat storage system and heat release system. It is mainly composed of electric heater, fan coil, storage tank, water pump and turbine flowmeter. The test rig is shown in Figure 4

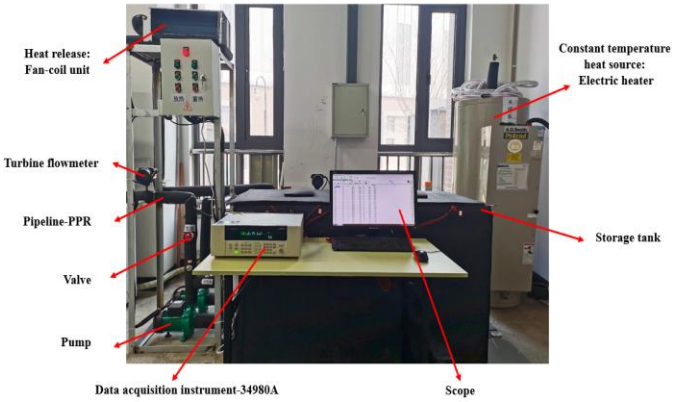


Fig.4 The test rig of storage tank

During the experiments, the status of each valve is shown in Table 1.

Tab.1 The status of valve

Item	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14
SCEH	on	on	off	off	off	on	off	on	on	off	off	off	off	off
Heat storage	on	off	on	on	on	on	on	on	on	off	off	off	off	off
Heat release	off	off	off	on	on	off	off	off	off	on	on	on	on	on
SCST	off	off	off	on	on	off	off	off	off	on	on	on	on	on

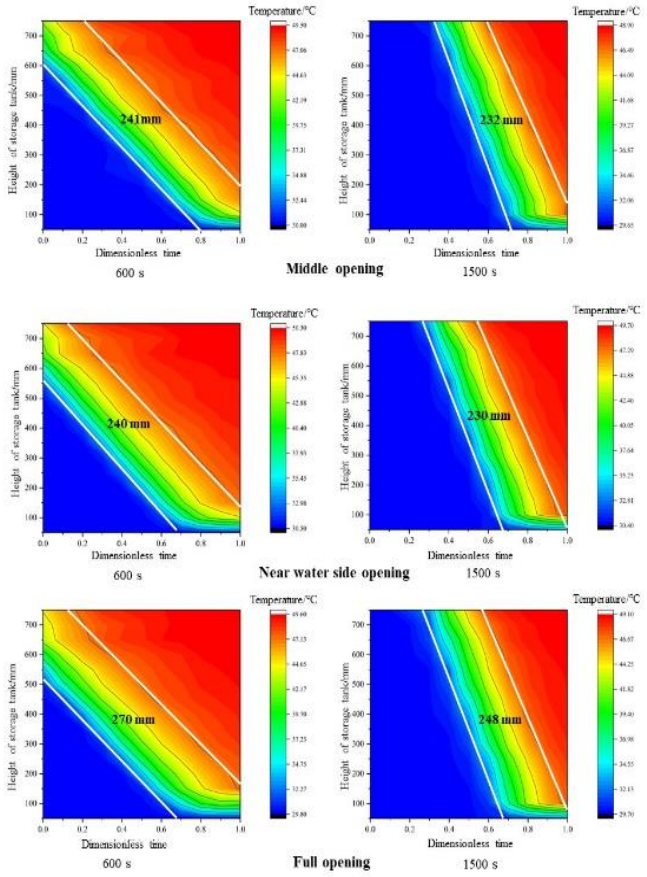
3. RESULT ANALYSIS

In this paper, the thickness of thermocline is selected as the index to evaluate the temperature stratification characteristics, which is used to judge the best temperature stratification performance under different flow rates. The thicker the thermocline, the worse the temperature stratification characteristics, and the thinner the thermocline, the better the temperature stratification characteristics. Under the initial temperature of 30℃ and 0.8 m^3/h, 1.0 m^3/h and 1.2 m^3/h flow rates, the

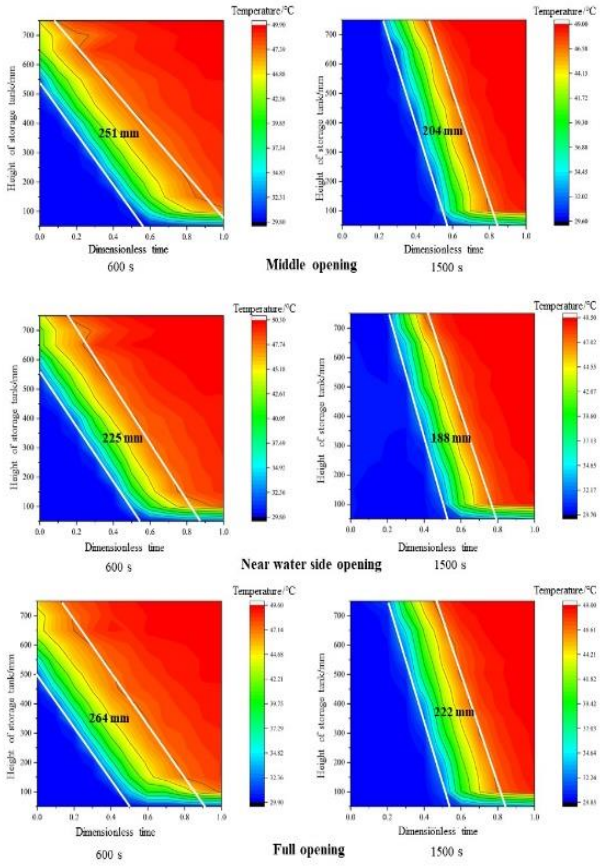
thermocline thickness cloud diagrams of different flow equalizing plate structures at 600 s and 1500 s are drawn.

3.1 Analysis of the thickness of the thermocline at 0.8 m³/h and 1.0m³/h

Figure 5 shows the temperature distribution cloud map of different flow equalizing plate structures when the heat storage time is 600 s and 1500 s, and the flow rate is 0.8 m³/h and 1.0 m³/h. It can be seen that no matter what kind of structure of the flow equalizing plate, the storage tank can achieve temperature stratification during the heat storage process. At the same time, we can get that the flow equalizing plate with near water side opening has the smallest thickness of the thermocline and the best temperature stratification characteristics. This is because the flow rate of water is low, and the flow equalizing plate with near water side opening can reduce the instability of hot water and play a buffering role, thereby reducing the mixing of hot and cold water.



(a) 0.8 m³/h



(b) 1.0 m³/h

Fig.5 Thickness of the thermocline

In addition, we have observed that when the height is about 50-70 mm, the temperature line will have a tortuous phenomenon. That is because there is a dead-water area at the bottom of the water tank. The hot water cannot reach here and enters the next tank from the partition, so the temperature is always very low. However, as the flow rate increases, the height of the dead-water zone becomes lower and lower, and the area becomes smaller and smaller.

3.2 Analysis of the thickness of the thermocline at 1.2 m³/h

Figure 6 shows the temperature distribution cloud map of different flow equalizing plate structures when the heat storage time is 600 s and 1500 s, and the flow rate is 1.2 m³/h. It can be obtained from Figure 6 that when the flow rate is 1.2 m³/h, the thermocline of the full opening flow equalizing plate is the smallest, which is only 162 mm at 1500 s. This is due to the increase in the flow of water during the heat storage process, resulting in a faster flow rate of water, and the full opening flow equalizing plate allows hot water to enter the storage tank more uniformly. The flow rate of hot water passing through the holes of the flow equalizing plate decreases, which reduces the mixing

degree of cold and hot water, and the thickness of the thermocline decreases.

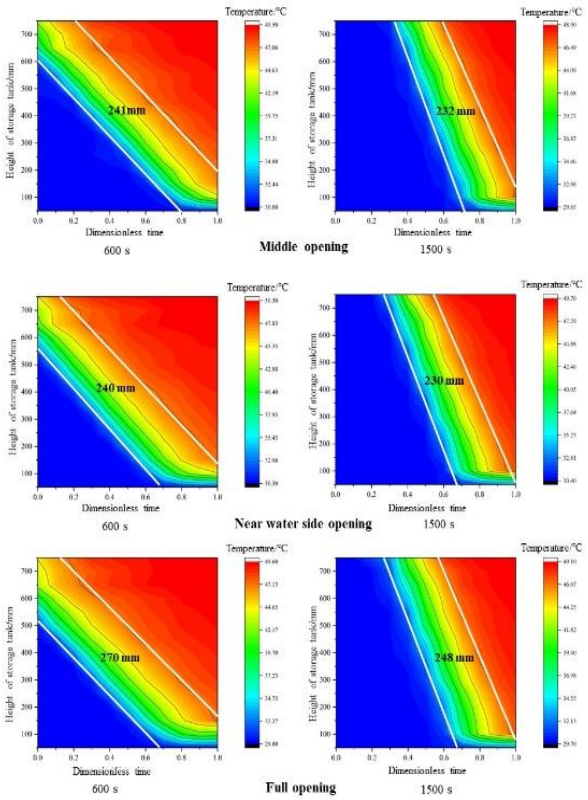


Fig.6 Thickness of the thermocline at 1.2 m³/h

At the same time, it can be seen that under each flow, the thickness of the thermocline at 1500 s is always less than that in the sink at 600 s. This is because the temperature cloud at 600 s represents the temperature stratification in the first water tank, and 1500 s represents the temperature stratification in the second water tank. This shows that after adding the flow equalizing plate, the temperature stratification characteristics of the storage tank can be improved, so as to improve the heat storage efficiency of the energy storage heating system and reduce the heating cost.

4. CONCLUSION

To improve the heat storage efficiency of geothermal heating system coupled with storage tanks, this paper proposes a horizontal multi-sink storage tank with flow equalizing plate. At the same time, experiments of three storage tanks with different flow sharing plate structures (full opening, middle opening and near water side opening) are carried out. Through experimental research, the temperature distribution cloud map in the storage tank with three equalizing plate structures under different flow rates is obtained, and the relationship between the opening mode of the equalizing plate and the flow rate is generalized and summarized, as shown in Table 2.

Tab.2 The relationship between the opening mode of the flow equalizing plate and the flow rate

Fow rate (m³/h)	opening mode of the flow equalizing plate
⩽1.2 m³/h	near water side opening
⩾1.2 m³/h	full opening

At the same time, it can be seen from the temperature distribution cloud map that the thickness of thermocline can be significantly reduced after adding the flow equalizing plate, so as to reduce the mixing degree of cold and hot water in the heat storage process and improve the temperature stratification characteristics.

ACKNOWLEDGEMENT

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