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Optimized design on water cooling system of CHMFL

J.L. Tang *, Z.R. OuYang

High Magnetic Field Laboratory, Chinese Academy of Sciences, Shushanhu Road 350, Hefei, Anhui 230031, China

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ABSTRACT

The effectiveness of the technique of naturally stratified and the dispersible uniformity of the diffuser that is used in the conditions of large flow rate and large temperature difference has been verified. The thermocline in all these experiments is close to or less than 1m, which proves that the design of this octagonal diffuser is feasible. This optimized design of water cooling system is necessary for the long-term stable operation of the resistive magnet, and it will increase the capacity of chilled water storage and prolong the experiment time

1. Introduction

China High Magnetic Field Laboratory (CHMFL) was founded to provide first class steady high magnetic field facilities to researchers and to better develop high magnetic field science. The water cooling system of CHMFL was designed for taking away the heat produced by the high power resistive magnets. The designed heating load of the de-ionized water cooling system is 28 MW [1] and it consists of three parts: de-ionized water circulation system, chilled water system and control system.

The resistivity of the de-ionized water can achieve 18 MΩ cm and remain higher than 15 MΩ cm during the resistive magnet experiment. The de-ionized water needs chilled water for cooling and its maximum flow rate is 860 $m^3\Omega\ h^{-1}$. The temperature of the chilled water must be controlled under 7 °C to assure the temperature of de-ionized water at magnet inlet is not higher than 10 °C by heat exchanger. But now the chilled water storage capacity is nearly 3000 mΩ, and just can maintain 3 h of the experiment when the magnet runs at 20 MW. The maximum flow rate of chilled water is 1000 $m^3\Omega\ h^{-1}$, the temperature difference between the supply and return chilled water is about 20 °C in experiment. Increasing the capacity of chilled water storage is the key point of prolonging experiment time of the resistive magnet, so the water cooling system must be optimized. Especially, it is necessary to optimize the method of chilled water storage.

2. The operation analysis of chilled water system

The total refrigerating capacity of two centrifugal chillers is 8 MW. The chilled water can be cooled from 26 °C to 6 °C by these two chillers which are connected in series. At present, the operation procedure is as follows: the chilled water is stored in the chilled water tank, and the return water after heat exchange will run into the buffer tank. The principle of current

* Corresponding author. Tel.: +86 551 65595668.
E-mail address: tangjl@hmfl.ac.cn (J.L. Tang).

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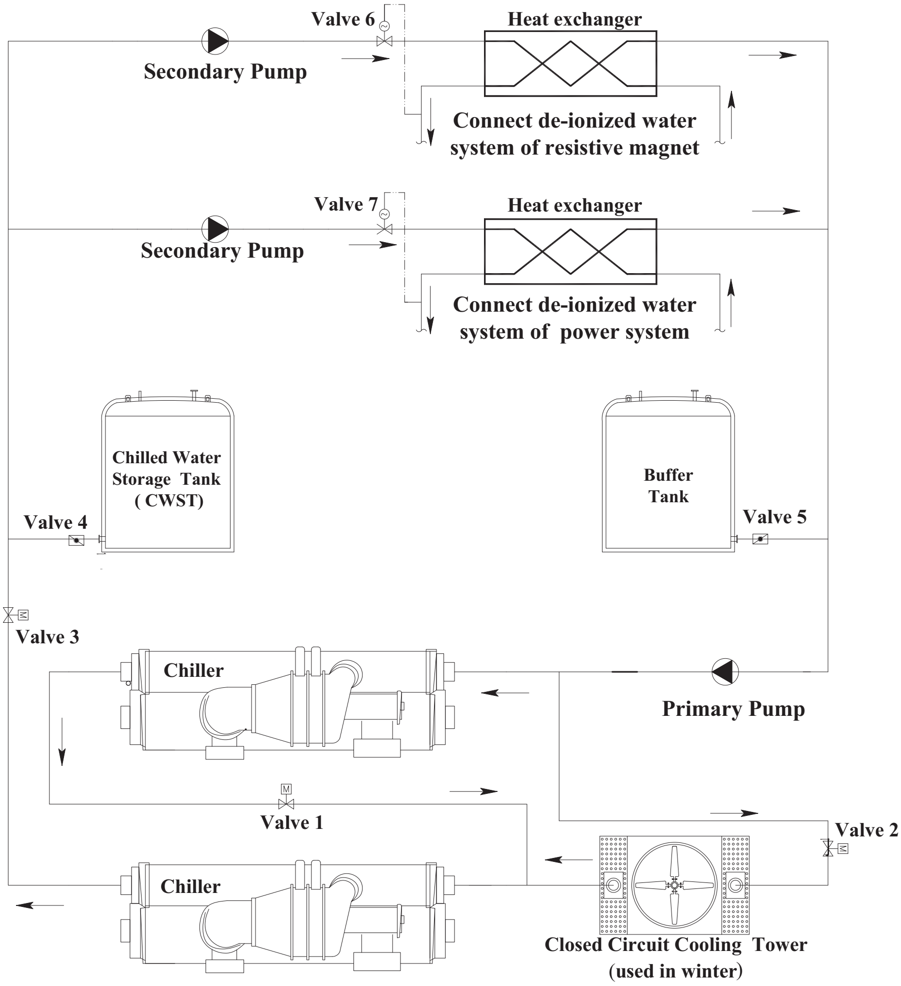

Fig. 1. The current operation scheme of the water cooling system.

operation procedure is shown in Fig. 1. This method cannot upgrade the effective storage capacity of chilled water if resistive magnet needs to prolong the experiment time in future. An optimized method should be carried out.

If the technique of naturally stratified can be used in chilled water storage system, two tanks both can be used for chilled water storing and supplying, which will double the experiment time of resistive magnet. The schematic diagram can be seen in Fig. 2. The difficulties of this optimized method in practice are listed in the following aspects:

(1) the maximum flow rate of chilled water is 1000 $m^3\Omega\,h^{-1}$, the larger the flow rate is, the thicker the thermocline becomes [2];
(2) the temperature difference between supply and return chilled water is about 20 °C in experiment. However, the larger the temperature difference is, the thicker the thermocline becomes [2]; and
(3) the volume of the two tanks is huge, and the dispersible uniformity of the diffuser is important for the stability of supply chilled water temperature.

The chilled water system has a strict requirement for the temperature. The supply chilled water temperature must be controlled under 7 °C, otherwise the steady operation of resistive magnet cannot be guaranteed. The water in thermocline is unusable and the thickness of thermocline decides the effective capacity of chilled water. The design target of the diffuser is to assure the thermocline will be controlled less than 1 m. An octagonal diffuser [3–5] has been designed and installed in the chilled water storage tank. Table1 is the design parameters of the diffuser and Fig. 3 shows the schematic of the diffuser.

3. Thermocline testing experiments in different conditions

At present, the resistive magnet which runs at 20 MW has not been completed, and the testing cannot be carried out under the conditions of maximum flow rate and temperature difference. WM4 is the only resistive magnet that has been

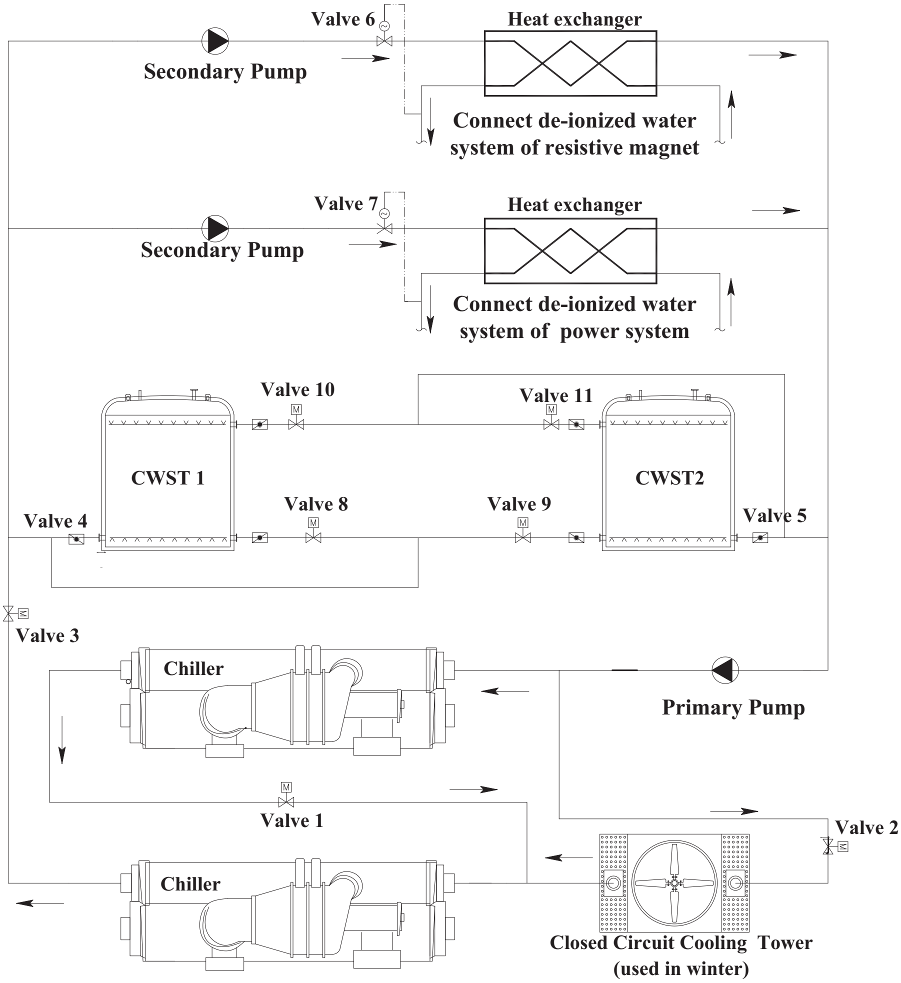

Fig. 2. The schematic diagram of the optimized water cooling system.

Table 1
The design parameters of the diffuser.

Design parameters	Parameter values
Tank height, m	10
Tank diameter, m	21
Supply water temperature, °C	≤7
Return water temperature, °C	26
Maximum flow rate, $m^3\ h^{-1}$	1000

completed now, and it runs at 10 MW. The testing experiments just can be done in the flow rate of 1000 $m^3\Omega\ h^{-1}$ and the temperature difference of 20 °C separately. Some important conclusions will be obtained by these experiments.

3.1. Chilled water storage in large temperature difference

The temperature of the chilled water in the tank was increased by supplying to the high stability power debugging. It provides the setting for the thermocline testing experiment in large temperature difference. In this experiment, the temperature difference is about 20 °C and the flow rate is 370 $m^3\Omega\ h^{-1}$. The temperature measurement cable which is included in the control system contains 37 temperature measuring probes, and two probes are 0.25 m apart. The temperature data at different times can be gathered by control system.

Fig. 4 shows the result of the data analysis. Time1 is the start time of the chilled water storage. Time5 is near the end time, and the temperature of the chilled water in the tank is close to the target temperature. Five curves have the same trend

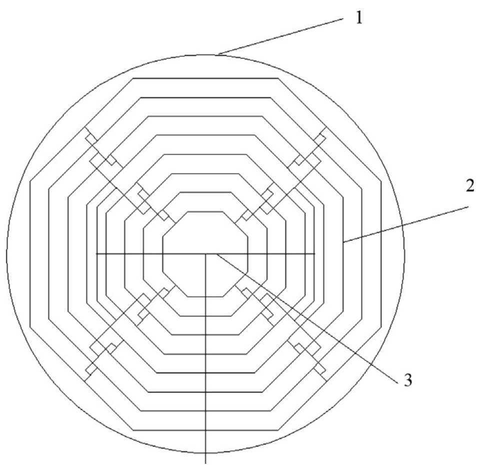

Fig. 3. The schematic of the diffuser. 1 – Tank wall, 2 – the diffuser, and 3 – the distribution pipe.

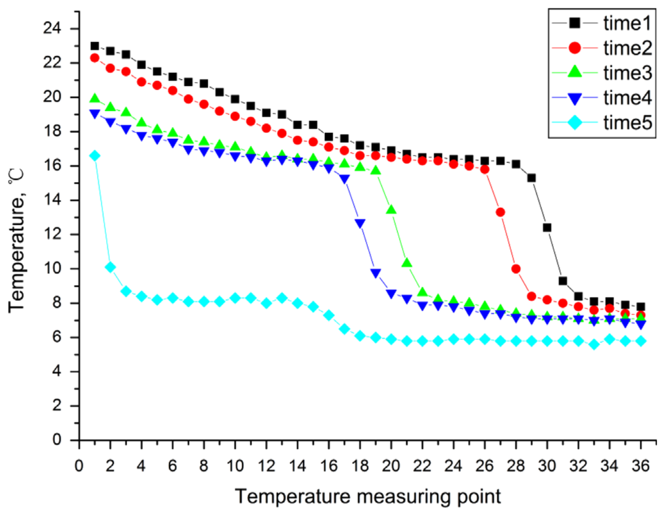

Fig. 4. The temperature distribution at different times of chilled water storage in large temperature difference.

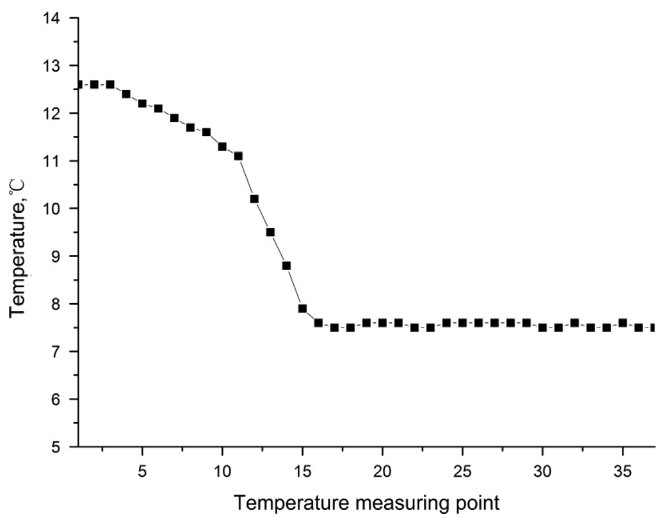

Fig. 5. The temperature distribution at one point of chilled water supply in large flow rate.

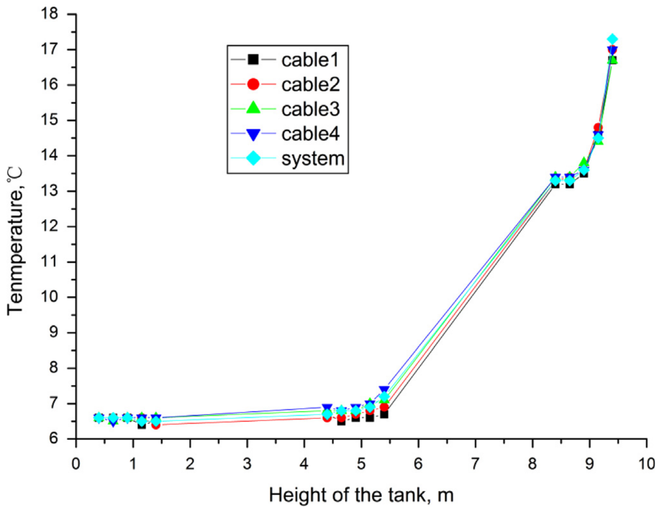

Fig. 6. The data analysis of four temperature measurement cables and control system.

and the thermocline is stable. Two probes of the temperature measuring cable are 0.25 m apart, so the thickness of the thermocline is about 0.75 m as shown in Fig. 4.

3.2. Chilled water supply in large flow rate

In this experiment, the flow rate is about 1000 $m^3\Omega h^{-1}$ and temperature difference is about 5.5 °C. The experiment lasted about 1 h, and the result of the analysis is shown in Fig. 5. The transitional region from low temperature to high temperature concentrated at four temperature measuring probes, so the thickness of the thermocline is about 1 m. Therefore, the large flow rate can be considered as the more important factor of the thermocline than the large temperature difference.

4. Uniformity testing experiments of the diffuser

To verify the dispersible uniformity of the diffuser, four temperature measurement cables have been placed vertically at different radii in the chilled water storage tank. Each cable contains three temperature measurement sections, and each section contains five temperature probes. Two probes in the same section are 0.25 m apart. Three temperature measurement sections are near the bottom, middle and top of the tank and they correspond to the formation, stabilization and end stage of the thermocline, respectively.

With this design, the temperature uniformity of thermocline can be monitored in the experiment. Fig. 6 shows the analysis result of an experiment with a large chilled water flow and temperature difference. As can be seen in Fig. 6, there are a few differences among different cables. Accordingly, the thermocline has good temperature homogeneity, so the dispersible uniformity of the diffuser can be confirmed.

5. Conclusion

An optimized design on chilled water storage system has been successfully tested. Experimental results have demonstrated the effectiveness of the technique of naturally stratified that is used under the conditions of large flow rate and large temperature difference. The dispersible uniformity of the diffuser has also been verified. In the future, the diffuser can be installed in two tanks, and the capacity of chilled water storage will be doubled. This optimized design is the key factor to upgrade the water cooling system of CHMFL, which will prolong the experiment time.

Acknowledgments

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