# Design Guideline for Cooling Tower as Heat Sink in a Research Reactor

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## 1. Introduction

Research reactors should incorporate the cooling system for the cooling of the reactor core power. The Research Reactor modeled in this paper is also equipped with the Primary Cooling System (PCS), Secondary Cooling System (SCS), the primary heat exchanger (Plate-type Heat Exchanger, PHE) between two systems, and the cooling towers as a heat sink of SCS as shown in Fig. 1. The PCS circulates demineralized water to remove the heat generated in reactor core. The heat is transferred to the cold water of the SCS through the primary heat exchanger. The SCS removes the heat being transferred from the PCS in order to maintain the temperatures of the reactor coolant at specified normal operating conditions. The heat is discharged to the atmospheric air by a module of the closed circuit cooling tower. The cooling tower automatically sets the SCS inlet temperature constant by fan speed control. The flow rate of SCS is adjusted to be identical with the PCS flow rate.

To design the PHE and closed circuit cooling tower, the inlet and outlet temperatures and the flow rates for both sides should be determined. But the problem is that he flow rate has the allowable band for the safe operation from the lower limit to upper limit due to the measurement uncertainty, the margin for flow decrease, and system design margin. This allowable range of the mass flow rates results in different temperature distribution in the PHE and closed circuit cooling tower. Specially, the PCS heat exchanger outlet temperature which is the core inlet temperature is used for a safety parameter to trip the reactor against abnormal condition. Lee et al. (2016) analyzed the variation of the PCS temperatures in conditions of the constant core power and constant SCS inlet temperature [1]. The result shows the low limit of the allowable flow band should be used for the conservative design of primary heat exchanger.

In this paper, to study the effect of the allowable band for the mass flow rate in the design of the cooling tower, the variation of the SCS temperatures in conditions of the constant core power and constant air inlet temperature in the closed circuit cooling tower was analyzed.

## 2. Modeling and Results

### *2.1 System Modeling*

The system shown in Fig. 1 is one-dimensionally modeled with the commercial one-dimensional system code, FLOWMASTER 7. Fig. 2 shows the diagram of the modeled system which is composed of a PCS pump, a SCS pump, a plate heat exchanger, the reactor pool, core, closed circuit cooling tower, and piping.

In this paper, all the components are not specified in detail for the confidential reason. However, the main components such as the closed circuit cooling tower and PCS pump and SCS pump are briefly described in 2.2 and 2.3.

During the simulation, the air inlet wet-bulb temperature in the closed circuit cooling tower and the core power were constant at 27 ℃ and 6.1 MW respectively. The flow rates of PCS and SCS (200 kg/s, 230 kg/s) were controlled by adjusting the loss coefficients of PCS piping and SCS piping.

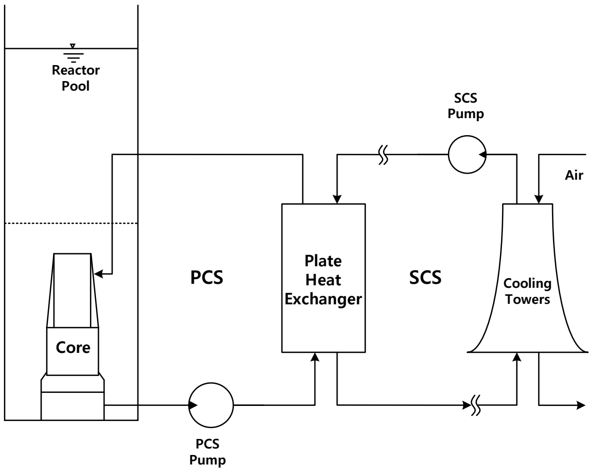


Fig. 1. Schematic diagram of system.

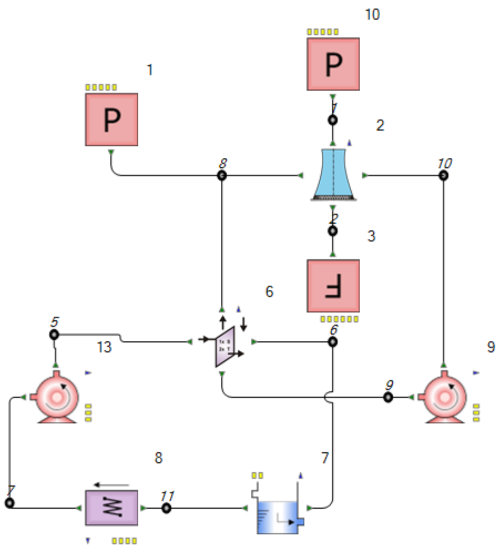


Fig. 2. System modeling.

*2.2 Closed circuit cooling tower Modeling*

The cooling tower modeled in this paper is a closed wet cooling tower as shown in Fig. 3 which is most commonly used type of cooling tower. The detailed mathematical formulation is not described in this paper but referred in [2].

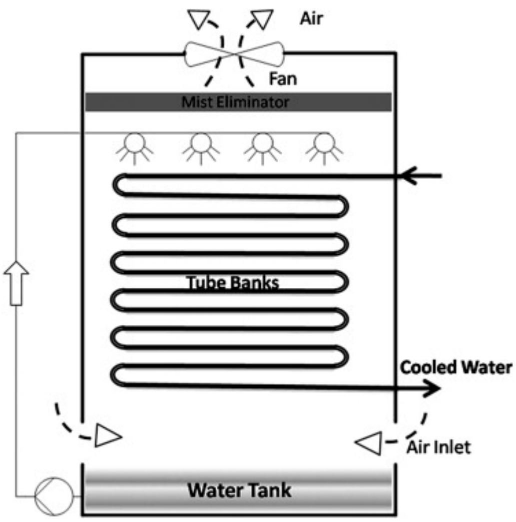


Fig. 3. Geometry of closed circuit cooling tower.

*2.3 Pump Modeling*

Fig. 4 shows the pump performance curve which is used for both PCS and SCS pump, and the rated flow rate and head of the two pumps are 200 kg/s and 20 m, respectively.

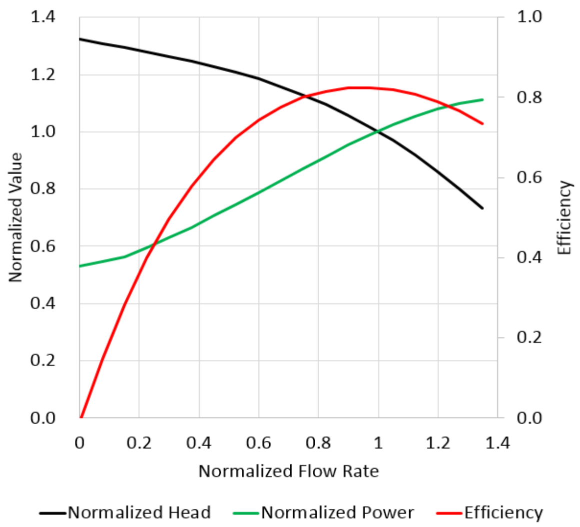


Fig. 4. Pump performance curve

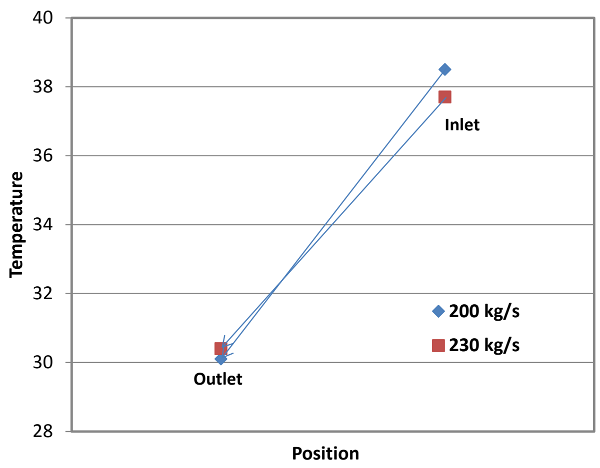


Fig. 5. Results

## 3. Conclusions

Fig. 5 shows the inlet and outlet temperatures of SCS and air in the closed circuit cooling tower at two flow rates (lower limit of flow band; 200 kg/s, upper limit of flow band; 230 kg/s). At 200 kg/s of SCS flow rate, the inlet and outlet temperatures are 38.5℃and 30.1℃, respectively. With increase of the flow rate, the inlet SCS temperature decreases to 37.7℃ and the outlet SCS temperature increases to 39.9℃.

This result means that the high limit of the allowable flow band should be used for the conservative design of the cooling tower. If the lower limit of the allowable flow band is used for the SCS flow rate in design of the cooling tower, the increase of the SCS outlet temperature leads to an increase of the PCS outlet temperature which is the safety parameter used for the reactor shutdown. The increase of PCS outlet temperature can cause a high possibility of the reactor shutdown.

## REFERENCES

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[2] V.D. Papaefthimiou, E.D. Rogdakis, Thermodynamic study of the effects of ambient air conditions on the thermal performance characteristics of a closed wet cooling tower, Applied Thermal Engineering, 33-34, p199-207, 2012.