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Preliminary Analysis on Pool Cooling Performance in a Open-Pool Research Reactor using the MARS-KS 1.5 Code

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1. Introduction

A research reactor of open-pool type is designed to provide various purposes, such as Radioisotope (RI) production, Neutron Transmutation Doping (NTD), nuclear fuel and material test, etc. Since the pool surface is opened to the atmosphere, the top of the pool forms hot water layer using thermal stratification phenomenon to prevent the generated radioactive materials from rising to the pool surface. Therefore, the bulk temperature of the pool water should be kept lower than the hot water layer temperature to maintain stable thermal stratification layer. Also, the pool water and primary coolant need to be purified to minimize the corrosion of the cladding and Primary Coolant System (PCS) [1].

To meet these requirements, Pool Water Management System (PWMS) is designed to control the bulk temperature of pool water below the allowable temperature limit and to purify the pool water. So, the PWMS needs to have adequate cooling and purification capabilities [2]. In this study, pool cooling performance of the PWMS was analyzed using MARS-KS 1.5 code [3]. The analysis was carried out for three operation modes of the PWMS, and this study evaluated whether its cooling performance is sufficient to cool the pool water.

2. PWMS Modeling

2.1 Description of PWMS

Figure 1 shows a schematic diagram of the PWMS. The system flow and heat removal capacity of the PWMS is designed to meet the requirements on purification of pool water quality and cooling capacity as follows:

$$C = C_o e^{-Ft/V}, \qquad (1)$$

$$Q = \dot{m} C_p \Delta T, \qquad (2)$$

where C is concentration, F is purification flow, V is purification capacity. The PWMS consists of pumps, a plate-type heat exchanger for heat removal, filters and ion-exchangers for purification of the pool water, etc.

The PWMS has three operation modes as follows: (1) normal operation, (2) operation after reactor shutdown, and (3) operation during maintenance. During the normal operation, the PCS removes the heat generated from the reactor core. The PWMS is operated to cool the spent fuels in the spent fuel storage pool and irradiated objects in the service pool, and it purifies each pool water. After the reactor is shutdown, the PWMS removes the decay heat after it is sufficiently cooled through the PCS. And the heat of the spent fuel and irradiated objects in the pools is removed by the PWMS. The water quality of all pools is also controlled in this operation. When the reactor pool is under maintenance, the PWMS only cools and purifies the spent fuel storage pool and service pool. In this case, after cooling for 24 hours, the decay heat released from the spent fuel transferred from the reactor core to spent fuel storage pool is additionally removed by this system.

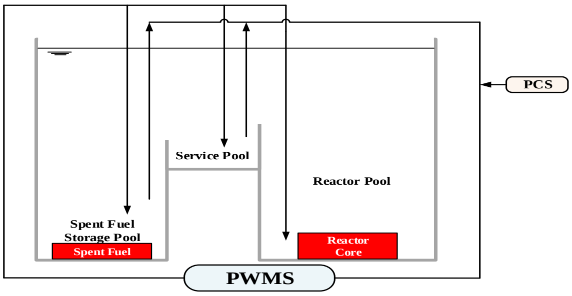

Fig. 1. Schematic diagram of PWMS.

2.2 MARS-KS Modeling

The MARS-KS 1.5 code is used to analyze the cooling performance of the PWMS. The nodalization of the PWMS is shown in Fig. 2. To be conservative, the pool water in each pool is modeled not to mix with other pools and is set to a higher temperature than normal condition. In addition, the volume of the pool water is considered only the lower part of the working platform by conservative assumption.

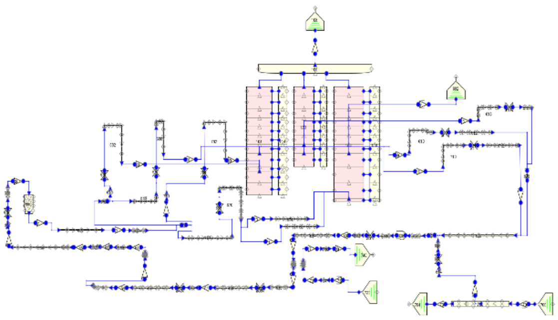
Fig. 2. MARS-KS nodalization of PWMS.

3. Results and Discussion

The analysis results are shown in Figs. 3 to 5. The results are normalized to the allowable temperature limit (1.0) and inlet temperature of the secondary side of the heat exchanger (0.0).

3.1 Temperature Change in Normal Operation

The calculation results on pool water temperature during normal operation is shown in Fig. 3. In the normal operation mode, the PCS removes the heat generated in core, so the reactor pool temperature continuously decreases according to the PWMS operation. In case of the spent fuel pool, the temperature slightly increases due to the decay heat of spent fuel. However, it can be seen that the temperature maintains at certain temperature that is sufficiently lower than the allowable temperature limit. The heat of irradiated objects in the service pool is appropriately cooled by the PWMS.

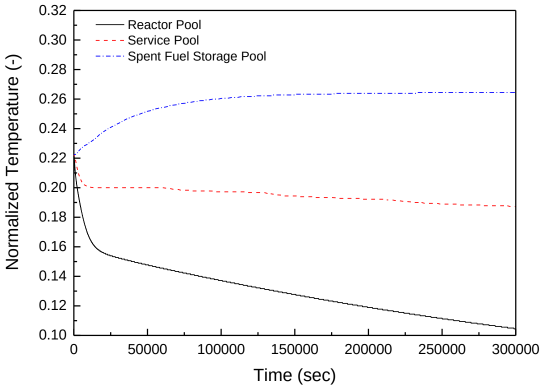

Fig. 3. Temperature change in normal operation.

3.2 Temperature Change in Operation after Reactor Shutdown

As shown in Fig. 4, the temperature of the reactor pool rises due to the decay heat in the initial phase. However, the PWMS has sufficient cooling flow and capacity, the pool water temperature is cooled again and does not exceed the allowable limit with enough margin. The spent fuel storage pool and service pool show that pool water temperature is properly cooled.

3.3 Temperature Change in Operation during Maintenance

During maintenance, the reactor pool is isolated from other pools. The flow to the PCS is switched to flow to the spent fuel storage pool. Therefore, the PWMS only cools the spent fuel storage pool and service pool. In the spent fuel storage pool, additional spent fuel transferred from reactor core after 24 hours of cooling is stored. The heat source in the spent fuel storage pool is increased, but it maintains a lower temperature than other operation modes due to the increased flow into this pool as shown in Fig. 5. Also, it can be seen that service pool cools down to sufficiently low temperature.

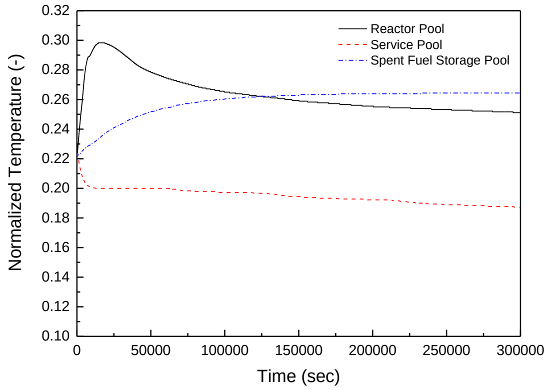

Fig. 4. Temperature change in operation after reactor shutdown.

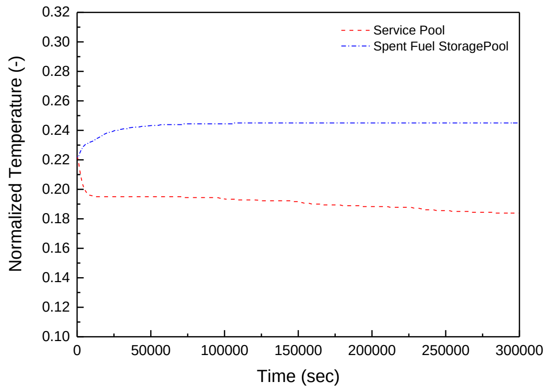

Fig. 5. Temperature change in operation during maintenance.

4. Conclusion

In this study, the pool cooling performance of the PWMS was analyzed using the MARS-KS code. It can be seen that the cooling performance of the PWMS is enough and the temperature of the pool water is kept well below the allowable temperature limit. In this analysis, conservative assumptions were used in the modeling, so the actual pool water temperature is expected to be lower.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Park, K.J., et al., Commissioning Test and Experience for Pool Water Management System in an Open-pool Type Research Reactor, Transaction of the Korean Society Spring Meeting, May 17-18, 2018.

[2] Choi, J.W., et al., Pool Cooling Evaluation in the Open-Pool Research Reactor, Transaction of the Korean Society Spring Meeting, May 18-19, 2017.
[3] KINS, MARS-KS CODE MANUAL VOLUME II: Input Requirements, KINS/RR-1282 Rev.1, 2016.