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# CFD Study on Hot Water Layer Formation for KIJANG Research Reactor

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## 1. Introduction

KIJANG Research Reactor (KJRR) is an open-pool type multi-purpose research reactor designed by Korea Atomic Energy Research Institute (KAERI). Hot water layer system in this facility is designed to generate a hot water layer at the upper part of the pools in the reactor building. The hot water layer provide a shielding function to reduce the radiation level above the pool as low as achievable.

The hot water layer should be formed prior to the reactor operation considering the time required for hot water layer formation. Therefore information on the initial transitions of the temperature and flow at the upper part of the pools during the hot water layer formation is of importance to evaluate proper reactor operation procedures.

In this study, CFD calculations are conducted to estimate initial transitions during the development of the hot water layer. Distributions of the hot water layer temperature and flow are obtained for initial 48 hours and presented in the results. The required time for sufficiently stabilize the hot water layer is also evaluate from the results.

## 2. Hot Water Layer System

In an open-pool type research reactor, the reactor core is located in the lower part of the pool. The reactor core is cooled by a forced circulation flow from the primary cooling system and the removed core heat is transferred to the secondary cooling system. Then the primary cooling water is dumped into the lower part of the pool and circulates into the reactor core. During this process, a strong forced convection flow dominates in the lower part of the pool. Although the pool water is purified by the pool water management system, the water in the lower part of the pool has significant radioactivity. Therefore the water should be prevented from rising up to the pool surface to protect the workers and researchers in the reactor hall.

The hot water layer system basically consists of a pump, an ion-exchanger, and an electric heater. The pump circulates the process water from the upper part of the pool to the hot water layer system. Then the ion-exchanger removes ionic radioactive impurities dissolved in the water. Finally the electric heater increases the water temperature to the desired temperature and the process water goes back to the upper part of the pool.

The hot water layer generated by the hot water layer system is maintained in a higher temperature than the lower part of the pool. This prevents the forced convection flow in the lower part of the pool from rising up to the pool surface. Consequently a mass transport from the lower part of the pool which transfers the radioactive materials to the pool surface is largely reduced. In addition to this, the water in the hot water layer is simultaneously purified by the ion-exchanger to remove the ionic radioactive materials in the water to decrease the radioactivity level on the pool top to a negligible level.

The pools of KJRR consists of the reactor, service, and spent fuel storage pools. The dimensions of the pools are 16.6 m in total length, 4 m in width, and 12 m in maximum depth. A T-shaped pipe distributor is located in the reactor pool at the 0.6 m depth from the pool surface. The distributor is intended to make uniform and slow distribution of the hot water to guide calm and stable formation of the hot water layer. To confine the water circulation only in the hot water layer, the suction ports of the hot water layer system are also located at the upper part of the pools, in reactor and spent fuel storage pools. The depth of the suction ports are 1.2 m from the pool surface considering sufficient hot water layer thickness.

## 3. CFD Methods

For the CFD, the geometries and meshes for the reactor, service, and spent fuel storage pools are produced by the Geometry and the Mesh in the ANSYS Workbench 13.0. The patch conforming tetrahedrons method and the multi-zone method are used for the mesh generation. The tetrahedrons mesh is adopted for the hot water layer region and the multi-zone method is adopted below the hot water layer where the thermal stratification develops. Mesh sizing functions which consider the proximity and curvature of the geometry is used. The minimum and maximum cell sizes are restricted to 0.003 m and 0.1 m, respectively. Number of generated mesh cells is about 3.1 million. The calculation is done using a transient solver. RNG k-e model is adopted for the viscous model. For the pressure-velocity coupling, SIMPLE scheme is adopted with the spatial discretization of second order upwind for momentum, turbulence, and energy. A user-defined function is used to set the discharge temperature considering the suction temperature and the actual heater capacity. In this function, the information of suction temperature is taken and the discharge temperature is set by adding the temperature difference produced by the heater for each time-step.

## 4. Results and Discussion

Fig. 1 shows the temporal distribution of the pool water temperature. As time goes by, the hot water layer is formed at the upper part of the pools. The thickness is nearly same along the all pools. The temperature at the pool surface is slightly lower than the hot water layer core region due to the evaporation heat loss at the pool surface. As can be seen in the pool surface temperature, the hot water distributed form the T-shaped distributor is approaching to the pool surface with dividing in to left and right direction. Therefore the surface temperature in the reactor pool is slightly higher than those of the other pools.

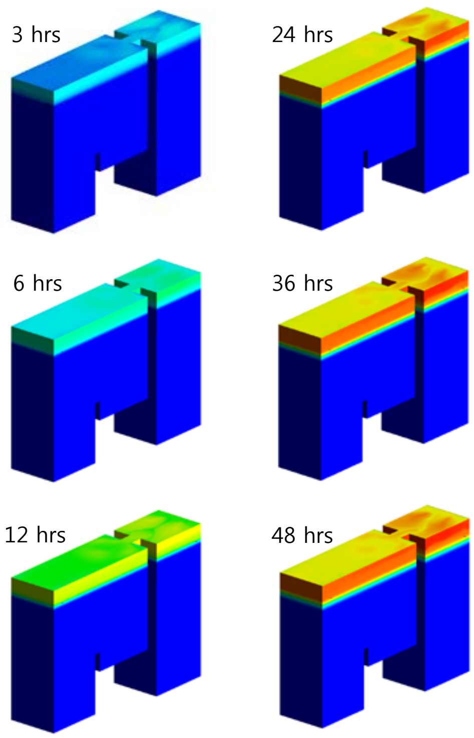


Fig. 1. Distribution of the pool water temperature according to the time of hot water layer system operation.

Depth-wise temperature profiles at the center of reactor pool are presented in Fig 2. As time goes by, a convergence trend can be seen in the temperature distributions. During the first 24 hours from the hot water layer system operation, the temperature profiles show drastic changes into the near-steady state. In this period, the heat is transferred into the hot water layer by vigorous mixing of the flows. However the mixing is well confined in 1~1.5 m thick in the upper part of the pool. After 24 hours, core temperature of the hot water layer is nearly same and the thickness of the hot water layer show slow expansion in the depth-direction. This expansion is very slow and it seems to be induced by conduction heat transfer at the bottom of the hot water layer. From this result, it can be concluded that the required time for the initial hot water layer formation is at least 24 hours.

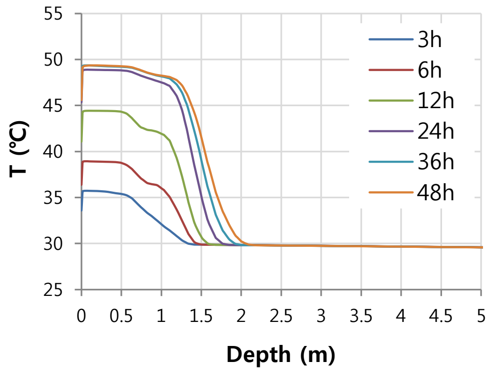


Fig. 2. Depth-wise temperature distribution at the center of reactor pool.

## 5. Conclusion

In this study, the initial transitions during the development of the hot water layer are estimated. Distributions of the hot water layer temperature and flow are obtained for initial 48 hours. From the results, it is shown that the hot water layer is properly formed as intended in its basic design. The required time to produce the hot water layer at near-steady state is evaluate to be at least 24 hours. This result can be used to make efficient reactor operation procedures. In addition, current design of the hot water system is validated from this study by a conventional CFD method and the obtained information will be utilized for fine tune of the detail design.

## Acknowledgement

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