# The Function and Formation of Hot Water Layer in Research Reactors

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## 1. Introduction

Research reactors are designed to enable operators to perform tasks in reactor hall while operating reactor, unlike commercial nuclear power reactors. The pool top radiation level of the open-tank-in-pool type research reactors should be managed. According to the radioactivity analysis of the reactor primary coolant, various kinds of radioactive nuclides are generated in the reactor when the reactor is in power operation. These are dissolved in the reactor pool. It is analyzed that this is one of the main causes increasing the radiation level in the pool top. According to the radiation source evaluation report of the research reactor, the nuclide that has the greatest effect on the pool top radiation level was found to be Na-24, one of the radioactive products of aluminum which is material of the fuel clad. This is because the half-life time of Na-24 is longer than that of other major radioactive products, so that it remains in the pool water for a long time relatively and some amount reaches the upper part of the pool water.

In research reactors, hot water layer (HWL) is designed to be formed on the top of the pool water to minimize the amount of the nuclides reaching the upper part of the pool water. The hot water layer serves to form a thermal stratification in which the water temperature decreases along the water depth in the reactor pool by keeping the pool top water temperature higher than the pool bottom. The hot water layer is in a vertically stable state, so that high radiation level coolant can be prevented from rising to the upper part of the pool. The purpose of this paper is to present the generation of radionuclides in the pool water in research reactors and the effect of the hot water layer formation to inhibit the nuclides rising to the pool top surface.

## 2. Radionuclides and HWL in the Reactor Pool

### *2.1 Radionuclides*

The main nuclides released in a research reactor pool are activated products of aluminum and argon. The radionuclides of aluminum are Al-28, Na-24, and Mg-27, and Ar-41 is a radioactive nuclide of argon. The prediction of the generation rate, the relation between the half-life of the radionuclides and the solubility of the coolant have been studied in the research reactor. In the commissioning stage of the research reactor, pool top radiation level was high without hot water layer system. Many efforts were made to lower the radiation level of the reactor pool in the process of installing hot water layer but not to satisfy, and various methods were suggested to maintain the radiation level to a minimum, with installing hot water layer system. The effect of the hot water layer in the pool water was reduced to less than about 1/30 of the initial radiation level.

### *2.2 Design Considerations on Hot Water Layer System*

In order to establish the hot water layer in the pool water, the hot water layer system (HWLS) is designed and the basic equation for heat transfer in the hot water layer is as follows.

$$M_{hwl} c_p \frac{dT_h}{dt} = \dot{Q}$$

Where,

$M_{hwl}$ = Mass of hot water layer
$c_p$ = Specific heat of pool water
$T_h$ = Temperature of hot water layer
$\dot{Q}$ = Net transferred heat rate

The heat balance at the hot water layer should consider pool surface evaporation rate, convection in the pool water, conduction to the bottom of the pool water and conduction to the pool wall. In addition, hot water layer heater capacity (pool surface area and hot water layer thickness), inlet and outlet temperatures for hot water layer formation, hot water layer flow rate should be considered.

On the other hand, demineralized water passing through an ion exchanger is operated while restricting the conductivity and purifying the HWL water.

In order to maintain the hot water layer, it should be designed and operated so that there is no influence by cooling water in the primary cooling system inside the pool.

The schematic diagram of the hot water layer system is as Fig. 1.

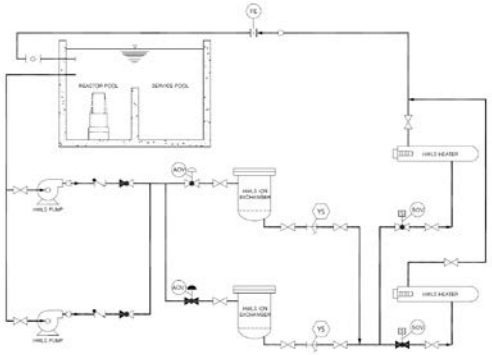

Fig. 1. Schematic diagram of the hot water layer system

## 3. Effect of HWL and Results

In the research reactor, comparing with before and after the installation of the hot water layer, the radiation level was decreased to 1/2 time after installation but it did not decrease to the target level. The reasons are the method of pool water make-up to the reactor pool, flow in primary purification system, influence of pool door, influence of peripheral devices (shutdown rod pump, hydraulic transfer device) and rotational flow in the pool. By optimizing these parameters, the radiation level was reduced to 1/30 time. Therefore, it was confirmed that the installation of the hot water layer has the effect to reduce the pool top radiation level.

The temperature distribution was measured in the depth direction from the pool surface during the system performance test in order to confirm whether the hot water layer was formed as designed. The following is the temperature distribution obtained during the system performance test of the hot water layer system. It was confirmed that the hot water layer was formed to a reasonable thickness.

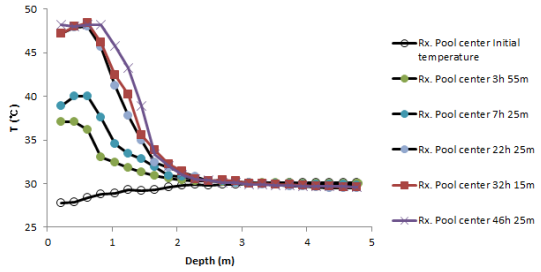


Fig. 2. Variation of temperature distribution according to depth in the reactor pool water

## 4. Conclusions

### *4.1 Need for Hot Water Layer*

The pool top radiation level of the open-tank-in-pool type research reactors should be managed to be sufficiently low in order to make comfortable environment for workers in a reactor hall. It is effective to install hot water layer system to suppress the rising of higher radioactive water in lower part of reactor pool during reactor operation. Most of recently designed in pool-type research reactors install and operate the hot water layer system in the pools.

### *4.2 Design and Installation Considerations*

The system design should take into account heat balance so that stable formation of the hot water layer temperature remains. The hot water layer must be verified to ensure stable operation of the reactor. In order to do this, it should be designed considering the effect of flow inside the pools. Generally, the hot water layer system is firstly operated to maintain the hot water layer temperature in the pool before reactor operation, and until the end of the reactor shutdown. The hot water layer system should be operated to restrict the conductivity and purify the HWL water. Although a hot water layer system is designed as a non-safety class system, it should be designed in consideration of the position of the pipe penetration and the equipment so that the pool water does not leak, since the necessary piping penetrates the reactor pool.

## ACKNOWLEDGEMENT

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## REFERENCES

[1] B. J. Jun, B. C. Lee, and M. S. Kim, “Analysis on the Coolant Radioactivity of HANARO”, KAERI/TR-4053/2010.
[2] Y. G. Cho, Y. C. Park, J. S. Ryu, C. Park, and H. T. Chae, “Experiences on Design/Operation of HANARO (1): Mechanical Design and System Design”, KAERI/TR-2311/2002.
[3] G. H. Ahn, C. Park, B. C. Lee, S. J. Park, and H. Y. Choi, “Analysis of the Radiation Level Variation at the HANARO Pool Top”, KAERI/TR-1432/1999.
[4] Y. S. Choi, “Stable Thermal Stratification by Hot Water layer in Large-scale Pool”, Trans. of the Korean Society of Mechanical Engineers, Autumn Meeting, Korea, 2017.
[5] Y. S. Choi, H. G. Yoon, D. Y. Chi, S. H. Kim, and C. Park, “Initial Formation of Hot Water layer in Open-pool Type Research Reactor”, Trans. of the Korean Nuclear Society, Spring Meeting, Jeju, Korea, 2016.