A New Idea for Long-Term Cooling Safety Facility of Research Reactors

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1. Introduction

In research reactors, the core of the reactor shall always be submerged inside water, and the pool water has a role as an ultimate heat sink. During an accident, the reactor shall be immediately shut-down, and the residual heat of the core is then removed through natural circulation. The heat is transferred to the pool water and the water is evaporated continuously. From a nuclear safety standpoint, it is therefore very important to secure a sufficient amount of water considering the evaporation rate.

In open-pool type research reactors with a down-ward flow in the core, some equipment or pipes of the Primary Cooling System(PCS) can be installed below the core owing to the Net Positive Suction Head required(NPSHr) of the PCS pumps. If there are pipe breaks below the core, the whole pool water will be drained through a siphoning and the core will be exposed to air. To limit draining of the pool water, a siphon breaker is installed at the highest point of the PCS pipe. After a siphon break, the water level will be higher than the core, and natural circulation is guaranteed. However, as mentioned above, the water level becomes lower by evaporation owing to the residual heat of the core. If it is impossible to access and resolve this problem for several days, the pool will be empty and the reactor will undergo a severe accident.

In addition, there are two limitations to determine the highest point of the PCS pipe. If the point is too low, the siphon breaker will start to operate late, and the final pool water level will be too low. If it is too high, on the other hand, the pressure at the highest PCS pipe will be too low and some vapors will be generated. This is severe for research reactors that have high thermal powers of more than about 10MWt because a large pressure drop is introduced in the core. In summary, the highest PCS pipe should be located between the lowest height limitation by siphon breaking phenomena, and the highest height limitation by vaporization pressure. Unfortunately, when the thermal capacity of the research reactor increases, it is impossible to select the highest PCS pipe point and design the open-pool type research reactor with the down-ward flow in the core because the PCS pipe size and core pressure drop increase. In this situation, an additional cooling water supply for the long-term cooling of the reactor can release the lowest height limitation, and the possibility for the PCS design can be increased.

2. New Idea

A safety facility for the long-term cooling of research reactors by adding supplementary water into the reactor pool passively was developed. A schematic diagram of the open-pool type research reactor with a down-ward flow in the core is shown in Figure 1. The PCS pumps can be located below the core to satisfy their NPSHr. A flap valve around the core is installed in the PCS pipe inside the reactor pool to remove residual heat from the core by natural circulation. A siphon breaker is installed in the highest PCS pipe to cope with a pipe rupture of the PCS pipe. The pool consists of a reactor pool and service pool, and a pool gate between two pools can separate them if required.

Here, the long-term cooling safety facility of the research reactor is shown in Figures 1 and 2. A guide wall of the pool gate between two pools has an opening at the center, and thus some irradiated targets can move through it. A long-term cooling dam is installed at the bottom of the opening near the reactor pool side and two long-term cooling pipes are inserted through the dam at the lowest position.

The flow rate through the long-term cooling pipe should be larger than the evaporation rate of the reactor pool from the residual heat of the core, and is small owing to the high latent heat capacity of water. Therefore, two long-term cooling pipes have a small inner-diameter, but each pipe has a sufficient flow capacity larger than the evaporation rate. Two pipes are to consider a situation that one of them is blocked by some foreign materials.

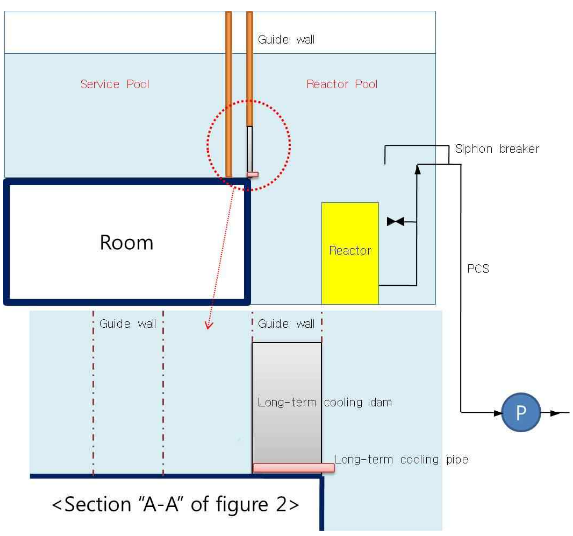

Fig 1. Pool water level under normal operation

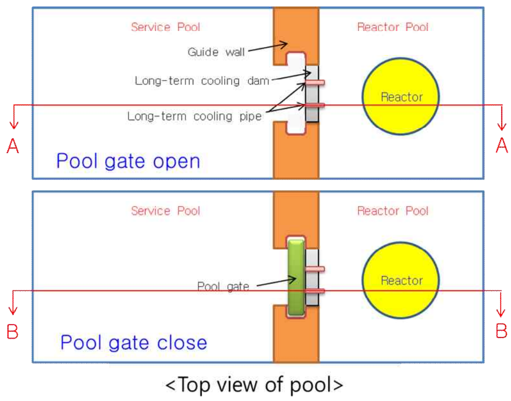

Fig 2. Long-term cooling safety facility

The lowest height limitation of the Long-term cooling dam is determined considering a long-term cooling period, the residual heat of the core, and the area of the service pool. In addition, the highest height limitation is determined considering the shielding thickness of water for irradiated targets when they are moved from the reactor pool to the service pool.

2.1 Normal operation condition

Under normal operation of a research reactor, the reactor pool and service pool are fully opened without a pool gate, and have the same pool water levels, as shown in Figure 1. The water can move freely through the opening between two pools.

2.2 PCS pipe rupture accident

If the PCS pipe is ruptured by an accident, the pool water will be drained and the siphon breaker will act to break the siphoning. At the final point of time of the siphon breaking, the pool water in the reactor pool has a little reduced level from the siphon breaker and the water level in the service pool has the same level with the top of the long-term cooling dam, as shown in Figure 3. An important point is that several days are considered for the long-term cooling even though the siphon breaking phenomena is finished after several minutes. In other words, the water in the service pool is transferred into the reactor pool through the long-term cooling pipe owing to a level difference between two pools during several days.

2.3 Maintenance of research reactor

Figure 4 shows the pool water level for maintenance works in the reactor pool. The pool gate is closed, and some water in the reactor pool is moved into a pool water storage tank. Two pools are perfectly separated without any leakages because the long-term cooling pipes are installed in the long-term cooling dam without any interference with the pool gate. In addition, a worker who works inside the reactor pool for maintenance can easily check the conditions of the long-term cooling pipes.

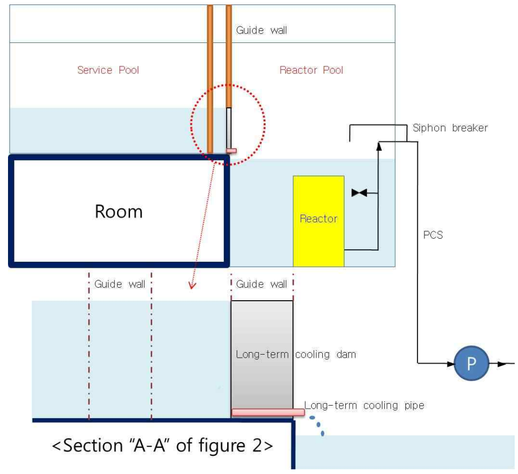

Fig 3. Pool water level in PCS pipe rupture accident

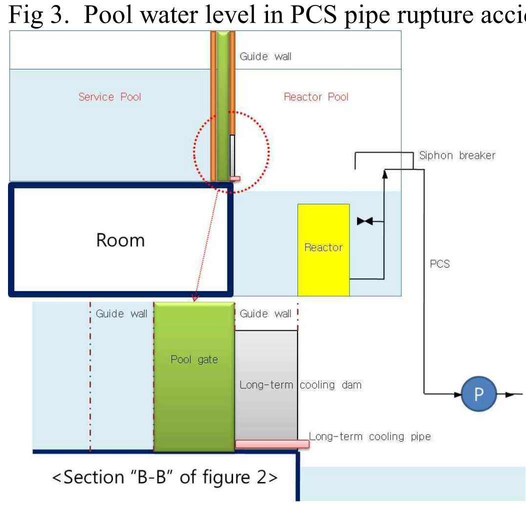

Fig 4. Pool water level in maintenance

3. Conclusions

A simple idea is intoduced to consider the long-term cooling of research reactors. It consists of a long-term cooling dam and long-term cooling pipes in a guide wall between reactor pool and service pool. During the siphon breaking situation, the water drain from the service pool is stopped at a top of the long-term cooling dam even though the water in reactor pool is still drained. After breaking siphon phenomena the water level of reactor pool is lower than the top of the dam and higher than the top of the core. The remained water in the service pool is passively moved into the reactor pool through the long-term cooling pipes. Therefore, this extra water supply is very helpful to remove the residual heat of the core during long time without any follow-up actions by operators.

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