Geometrical effect of the reactor pool for the performance of siphon breaker in a research reactor using Computational Fluid Dynamics

Hong Beom Park*, Minkyu Jung, Seong Hoon Kim and Kyoungwoo Seo
Korea Atomic Energy Research Institute, Daejeon 34057, Korea
**Corresponding author: hbpark@kaeri.re.kr*

1. Introduction

In an open pool type research reactor, reactor core is cooled by natural circulation after the primary cooling pump is turned off and the pool water is used as the ultimate heat sink. The reactor pool water also behaves as a shielding barrier against many kinds of radio-nuclides from the reactor core. So pool water is essential for nuclear safety in a research reactor. Guaranteeing the pool water inventory to be higher than the required minimum level is one of the most important tasks of a research reactor design. The lowest pool penetration level of Primary Cooling System pipes should be located above the reactor core against a pipe rupture. However, system components of the Primary Cooling System outside the pool can be installed below the core level due to the component requirements such as the acceptance of a net positive suction head of the Primary Cooling System pump for a downward core flow research reactor. In the case the pool water can be drained below the core through siphon effect and the core can't be cooled through natural circulation when a postulated pipe break occurs below the reactor core position. Therefore siphon breaker should be installed to limit the pool water drain.

Siphon break is very complex two phase phenomena because water and air move fast and mix with fast speed. So it is needed to understand the siphon break phenomena for siphon break design in a research reactor. For siphon break design, there are several parameters to consider. In this study, three dimensional numerical simulations are performed for siphon breaker of a research reactor. ANSYS CFD is used to solve the Navier-Stokes equation with k-epsilon turbulent model and VOF two phase model. The geometrical effect of the reactor pool for the performance of siphon breaker is analyzed.

2. Method and Results

For siphon breaker in a research reactor, performance of the siphon breaker is difference between Primary Cooling System highest pipe level and final pool level after siphon break. This is called to undershooting height. The performance of the siphon breaker is analyzed with undershooting height.

2.1. Initial pool level effect

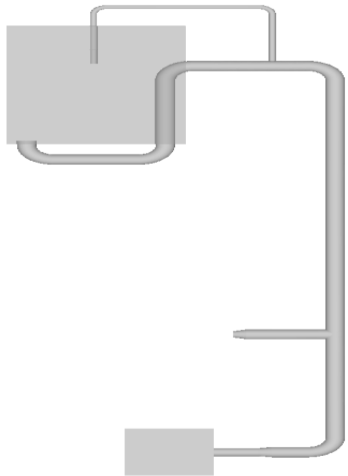

Fig. 1. Geometry of siphon break analysis

Initial pool level effect is analyzed by three cases of different initial reactor pool level. The geometry of domain is Fig. 1. Cases of initial pool level are 5m, 8m and 11m. Fig. 2 is the pressure when air flows into the siphon break pipe. In three cases, pressure is similar when air flows into the siphon break line.

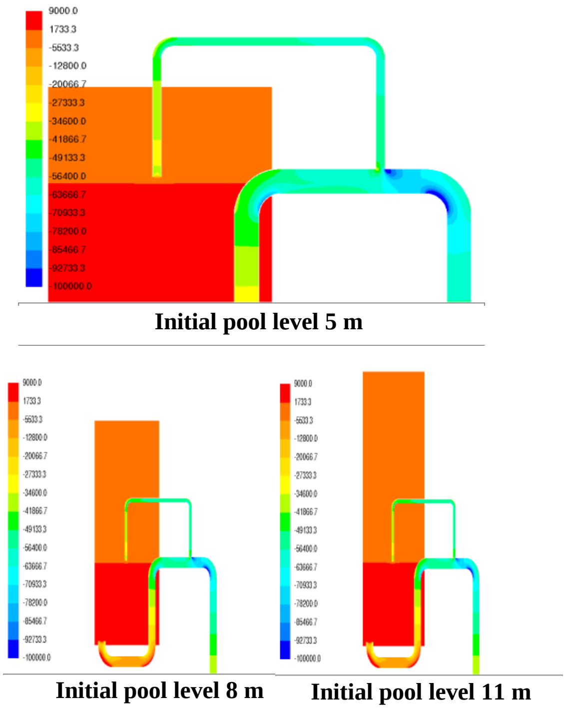

Fig. 2. Pressure contour with initial pool level

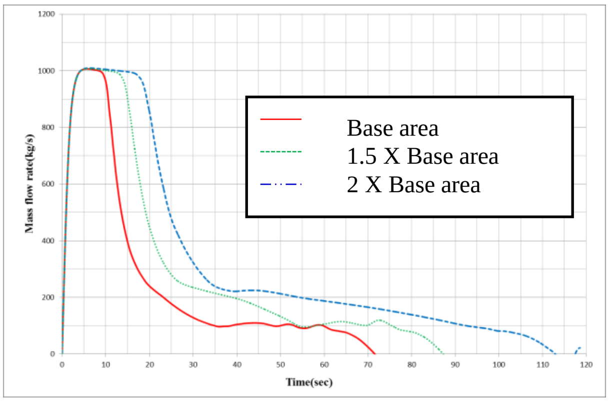

Fig. 3. Flow rate of main pipe with different pool area

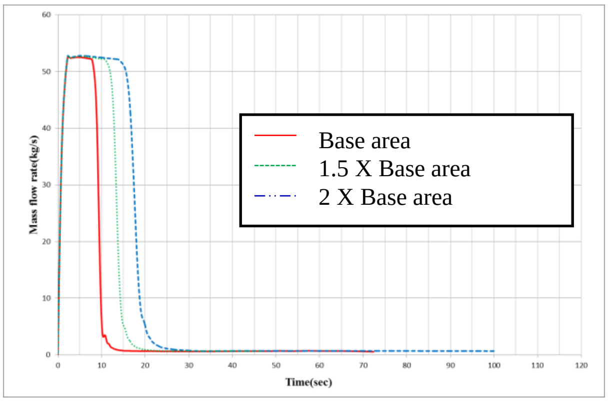

Fig.4. Flow rate of siphon break pipe with different pool area

2.2. Pool area effect

Pool area effect is analyzed by three cases of different reactor pool area. The cases of pool area is base area, 1.5 times base area and 2 times base area. Fig. 3 is flow rate of main pipe with three cases. Maximum flow rate is same with three cases. Time for decreasing flow rate is shortest in base area case and longer in larger area cases. Fig. 4 is flow rate of siphon break pipe with three cases. Water flows through siphon break pipe in early phenomenon. When end pipe of siphon break pipe meets air, air flows through siphon break pipe. Maximum flow rate is same with three cases. Time for decreasing flow rate is shortest in base area case and longer in larger area cases. This means that different pool area has same effect with maximum flow rate of main pipe and siphon break pipe. Pool area has different effect with siphon breaking time because of much water should be drained for large pool area. Performance of siphon breaker is almost same.

3. Conclusion

Geometrical effect of the reactor pool for the performance of siphon breaker in a research reactor is analyzed using Computational Fluid Dynamics. When air flows into siphon break pipe, pressure distribution and water velocity in main pipe is similar with different initial reactor pool level. So undershooting height of different initial reactor pool level is almost same. The initial pool level has effect to time of siphon break phenomenon and does not have much effect for performance of siphon breaker. Reactor pool area also has effect to time of siphon break phenomenon and does not have much effect for performance of siphon breaker.

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