

Estimation of Siphon Breakers for Jordan Research and Training Reactor

Kwon-Yeong Lee^{a*}, Kyoungwoo Seo^a, Dae Young Chi^a

^aResearch Reactor System Design Division, Korea Atomic Energy Research Institute, Daejeon

*Corresponding author: kylee10@kaeri.re.kr

1. Introduction

In the Jordan Research and Training Reactor (JRTR), the reactor core is cooled by natural circulation through the flap valves to the reactor pool after the Primary Cooling Pump (PCP) is turned off. The pool water itself is the ultimate heat sink of the residual heat. Thus, it is very important to guarantee that the pool water level be higher than the minimum level from a safety point of view.

The JRTR is an open pool-type research reactor and has a downward core flow. To meet the required net positive suction head (NPSHr) of the PCPs, some components of the Primary Cooling System (PCS) are installed below the core level. When a postulated pipe break occurs at below the reactor core position, the pool water can be drained below the core by siphon phenomena, and the core cannot be cooled by natural circulation. Therefore, siphon breakers are installed in the PCS to limit the pool water drain during and after all postulated initiating events.

Because the open-type reactor is operating at low pressure and low temperature conditions, guillotine break LOCA (Loss of Coolant Accident) is almost impossible. However, for a design purpose, a pump casing rupture by a failure of moving part has been considered in this study.

2. Simplified prediction model

An analytical prediction model for the siphon breakers of research reactors was developed by Lee et al. [1]. The model predicts well the undershooting heights by considering the air flow rate effect, the water flow effect to the air side, and the effect of a hydrostatic head, except the pipe break size. Kang et al. [2] performed an experimental study using the real-scale siphon breaker test facility for the JRTR. This means that a study of the pipe break size effect and the main pipe size effect is not required for the siphon breaker estimation of the JRTR. Thus, the prediction model is simplified for the JRTR as below:

$$y = f(F(a)) \left(\frac{\Delta h_{23,a}}{\Delta h_{23,ref}} \right)^{3/2} \quad (1)$$

Here, y is the undershooting height, F is the air flow rate factor, Δh_{23} is the hydrostatic head of the elevation difference between the apex and the LOCA position, a

is the case in which we want to know the undershooting height, and ref is the reference case from the experiment.

The air flow rate factor is defined as below

$$F \equiv A \sqrt{\frac{2}{\rho_{air} K}} \quad (2)$$

Here, A is the area of the siphon breaker, ρ is the air density, and K is the resistance coefficient of the siphon breaker.

Figure 1 shows the relationship between the undershooting height and the air flow rate factor for the experimental cases with a 10-inch LOCA size at break position #1 [2]. As shown in Figure 1, $f(F(a))$ is $0.0141 * F^{-1.282}$ in this study.

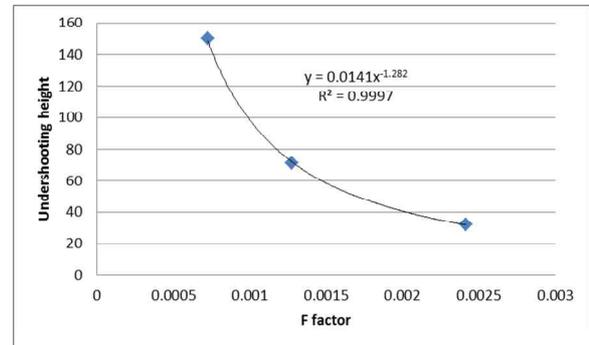


Fig. 1. $f(F(a))$ for JRTR from experimental results [2]

3. Estimation results

Siphon break valves are installed on the siphon break lines of the reactor inlet/outlet PCS pipes outside the pool. When the pool water level drops to a specified level, the siphon break valves are opened, and siphon drainage stops automatically. The pool water level shall be guaranteed well above the top of the reactor structure assembly in any Design Basis Accident (DBA). This guarantees the natural circulation flow for the decay heat cooling of the core.

One 16-inch main pipe and two 10-inch pump suction lines are designed with an 11 m hydrostatic head. 2.5-inch siphon break lines with siphon break valves are considered as siphon breakers. They also have some valves, fittings and pipes, as summarized in Table I. Here, the gate valves are used to isolate the siphon break valves for maintenance. The K values were calculated using a Crain book [3].

Table I: JRTR siphon breakers

Valve and fitting	Reactor inlet PCS pipe	Reactor outlet PCS pipe
	No. or Length	No. or Length
Straight pipe line	12 m	10 m
Entrance	1	1
Exit	1	1
45° elbow	2	2
90° elbow	5	5
Tee (flow through branch)	2	2
Siphon break valve	1	1
Isolation valve	2	2
Air flow rate factor (F)	0.00132	0.00137

Initially, the undershooting height was defined as the elevation difference between the end position of the siphon break line inside the pool and the final pool water level. This definition was used for the analytical model [1] and previous siphon breaker researches [2][4]. However, the heights of the end position of siphon break line were a little different according to the experimental cases. In additional tests, it was found that the final pool water levels are same for the tests with different end positions. Moreover, in some experiments with large siphon breakers, the water continuously drained after siphon breaking at least until the final levels were the same with the height of the apex pipe bottom. So, we defined two types of undershooting height for model and for design, respectively. The ‘undershooting height for model’ is defined as the elevation difference between the center of pipe (COP) for the apex pipe and the final pool water level. The ‘undershooting height for design’ is defined as the elevation difference between the bottom of the apex pipe and the final water level. In design point of view, we can say that there is no undershooting if the final pool water level is same with the bottom of the apex pipe. For the JRTR and its experiment, the undershooting height for design is about 20 cm less than the undershooting height for model because the 16-inch main pipe has about 40 cm diameter.

It was estimated that the siphon breakers have maximum 62 cm undershooting height for model and 42 cm undershooting height for design as shown in Table II. The performance of the siphon breakers is sufficient to guarantee the natural circulation after a large break LOCA because the top of the reactor structure assembly

is about 2 m below from the apex pipe. For design of the siphon breaker we should consider a reasonable safety margin.

Table II: Prediction results

From model	Undershooting height for model (cm)	Undershooting height for design (cm)
Inlet siphon breaker	62	42
Outlet siphon breaker	60	40

3. Conclusions

An estimation of the siphon breakers was performed with the analytical undershooting prediction model. 2.5-inch siphon break lines with siphon break valves were selected as siphon breakers for the JRTR. From this study we could say that the pool water level will be guaranteed well above the top of the reactor structure assembly in a large break LOCA in the JRTR.

REFERENCES

- [1] K.Y. Lee, K.W. Seo, D.Y. Chi, J. Yoon, “Prediction model development for siphon break phenomena in a research reactor”, KNS Spring Meeting, Jeju, Korea, May 17-18, 2012
- [2] S.H. Kang, H.S. Ahn, J.M. Kim, H.M. Joo, K.Y. Lee, K.W. Seo, D.Y. Chi, J. Yoon, G.D. Jeon, M.H. Kim, “Experimental study of siphon breaking phenomenon in real-scale research reactor pool”, Nuclear Engineering Design 255, pp.28-37, 2013
- [3] CRANE Co., “Fluid of fluids through valves, fittings and pipes”, 1988
- [4] K.W. Seo, S.H. Kang, J.M. Kim, K.Y. Lee, N.G. Jeong, D.Y. Chi, J. Yoon, M.H. Kim, “Experimental and numerical study for a siphon breaker design of a research reactor”, Annals of Nuclear Energy 50, pp.94-102, 2012