Estimation on a Siphon Breaker Type of a Research Reactor

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1. Introduction

A research reactor has been developed for various neutron applications. Most research reactors are required to be contained in the enormous pool for a safety aspect. Because it is necessary to keep the reactor pool water level during normal operation, a pool water service system is designed to supply demineralized water. The water supply is automatically controlled by opening or closing a valve installed on the system with a signal. If the pool water loss is greater than the pool water make-up capacity and the pool level continues to drop, other system pumps or heaters should be stopped. For preventing to drop the pool water level above the reactor core, all system should be located above the core. However, a component of a system can be installed below the core level due to the component purpose. Then, the system should install a siphon breaker to cover the reactor core with pool water and to protect from a siphon leak of the reactor pool water during and after all postulated initiating events.

The purpose of this research is to determine the siphon break type according to the research reactor types for designing the siphon breaker.

2. A siphon breaker for upward core flow type

Research reactors can be classified as an upward flow type and a downward flow type for the core flow. Even though the purpose of the research reactor is to use neutrons, the heat generated by the core should be removed and the core flow should be guaranteed by a cooling system. Figure 1 shows an upward core flow type of a core cooling system.

For an upward flow type, a siphon break hole in the reactor outlet line can be used for the siphon breaker because the siphon break hole for the outlet line does not affect the core flow. For the inlet line, because the siphon break hole has an effect on the core flow rate, a system flow should be increased to satisfy the requirement of the core flow and a hole size should be optimized by considering a pump capacity and the under-shooting of the siphon break.

The bypass flow rate ratio was calculated to design the siphon break hole size for the inlet line of the system as follows;

$$Q_{total} = Q_{core} + Q_{bypass} \qquad (1)$$

$$\Delta P_{core} = k_{core} Q_{core} \qquad (2)$$

$$\Delta P_{bypass} = k_{bypass} Q_{bypass} \qquad (3)$$

$$\Delta P_{core} = \Delta P_{bypass} \qquad (4)$$

Bypass flow rate ratio = Q_{bypass}/Q_{total} (5)

When the required core flow rate was 400kg/s, the ΔP_{core} was calculated by the core pressure loss, the pipe friction pressure loss, and the pipe elbow pressure loss [1, 2, 3]. Table 1 shows the bypass flow rate ratio for the 1inch, 2inch, and 3inch hole size. As shown in Table 1, the bypass flow rate ratio and the total flow rate for the 1 inch case of siphon break hole size was calculated as 4.9% and 420.7kg/s. As the hole size increases, the bypass flow rate sharply increases to 14.4% and 26.8% for the 2 inch and 3inch hole. However, the hole size will increase to reduce the under-shooting of the siphon break. In future, the research for the under-shooting will be performed by analyzing the siphon breaking phenomena with a CFD model.

Table 1. Bypass flow rate ratio

Siphon break hole size	1inch	2inch	3inch
Total flow rate	420.7kg/s	467.3kg/s	546.3kg/s
Core flow rate	400kg/s	400kg/s	400kg/s
Bypass flow rate	20.7kg/s	67.3kg/s	146.3kg/s
Bypass flow rate ratio	4.9%	14.4%	26.8%

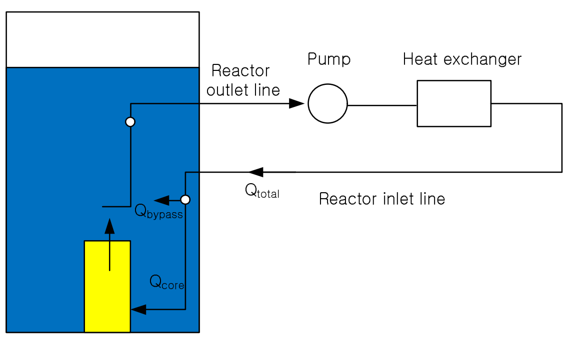

Figure 1. Upward core flow type

3. A siphon breaker for downward core flow type

Figure 2 shows a downward core flow type of a cooling system. For a downward flow type, a siphon break hole can be manufactured in the reactor inlet line without considering the requirement of the core flow. However, the siphon breaker for the reactor outlet line maynot be designed as a siphon break hole due to the effect on the core flow rate. For applying a siphon break hole for the outlet line of the downward flow type, the system flow rate should increase for compensating the bypass flow through the hole as described in the previous chapter. If the system flow rate increases, the pressure loss of the pump suction line of the system also increases and the available Net Positive Suction Head (NPSH) can be smaller than the required NPSH [4,5].

$$NPSH_A = \frac{P_{atm}}{\rho g} - Z_1 - \sum h_L - \frac{P_v}{\rho g} \quad (5)$$

Because proper pump operation, it is necessary that the available NPSH is higher than the required NPSH.

$$NPSH_A \geq NPSH_R \quad (6)$$

To satisfy the requirement for the NPSH, the siphon breaker of the reactor outlet line may be a valve type, which is opened or closed by an external signal or is passively operated.

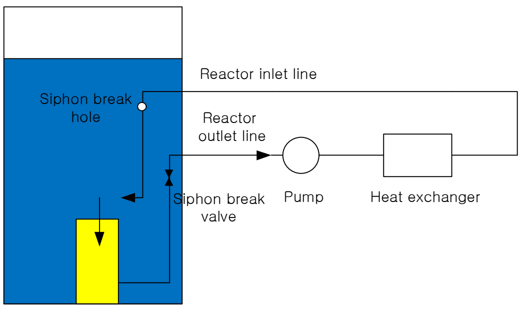

Figure 2. Downward core flow type

4. Conclusion

Our research work sought to determine the siphon breaker type according to the core flow direction of a research reactor.

For the upward core flow type, the siphon break hole, which is easily manufactured and passively operated, can be installed on the reactor inlet and outlet line. However, the siphon break hole for the reactor inlet line should be optimized by considering the bypass flow rate ratio and the under-shooting of the siphon break.

For the downward core flow type, the hole for the siphon break can be installed on the reactor inlet line because the line doesn't need to consider the core bypass flow. However, for the reactor outlet line, NPSH should be considered for determine the siphon breaker type since the line is the suction line of the system pump. For satisfying the requirement of the NPSH, the siphon breaker may be designed as a valve type.

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