Conceptual Design for a Core Residual Heat Removal System of a Research Reactor

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1. Introduction

A research reactor is cooled by a primary cooling system during normal power operation. After a normal or abnormal shutdown, the residual core heat is removed by a natural convection through an enormous pool to flap valves. The residual heat is dissipated into the reactor pool and the heat transferred to the pool is cooled by a pool cooling system. If the pool cooling system is unavailable to cool the pool, the pool water inventory shall become an ultimate heat sink. When the flow rate of the primary cooling system is reduced, the flap valves installed on the primary cooling system pipe inside the pool are designed to be passively opened. The openings of these valves provide flow paths for the natural convection from the flap valves through the core and the pool to remove the core residual heat. To guarantee the natural convection, the flap valves are installed in two separated trains and designed and fabricated in safety class.

However, the primary coolant can be designed to flow downward through the core in normal power operation mode. The downward core flow design feature requires an initial forced convection cooling in most accidents because the coolant flows upward for natural convection cooling. This is the most important design feature from the residual heat removal point of view. The purpose of this research is to compare and evaluate the core residual heat removal system type according to the research reactor power.

2. A core residual heat removal system for a low power research reactor

Research reactors can be classified as a low and a high power type. According to the core power, it is necessary to design an additional residual core cooling system after the reactor trip. After the reactor trip due to DBEs including a loss of electric power, the residual heat still occurs. When the primary cooling pumps are turned off, the downward core flow should be maintained appropriately by a inertia force due to the flow inversion from the downward flow of a normal power operation to the natural convection. If the power is low, the residual heat can be removed by the inertia force of a fly wheel attached to each primary pump shaft [2]. This can maintain the downward flow through the core for a demanded period of time after the pumps stop and the flow inversion occurs after the residual heat is removed sufficiently.

3. A core residual heat removal system for a high power research reactor

For a relatively high core power research reactor, the inertia force by flywheel is not sufficient to remove the residual heat. Therefore, an additional core residual removal system is required. For the research reactor, the systems are can be classified as active and passive type.

3.1 Active core residual heat removal system

Figure 1 and Figure 2 show the conceptual flow diagrams for the active core residual heat removal system. If the residual heat removal system is independently installed as shown in figure 1 and is not used during a normal power operation, the system including the residual heat cooling pump can be simply designed. Even though the small pump can be designed to cool the residual heat, the pump shall be classified as a safety-related and active equipment to run when the safety signal is supplied. Therefore, the system shall be composed of two identical circuits, which are physically and electrically separated. In addition, the flywheel is still needed to maintain the downward flow for a waiting period to run the residual heat cooling pump. During the loss of electric power, the pump will be powered by an un-interruptible power source or an emergency diesel generator. However, the cooling line cannot be used to remove the heat generated from silicon doping facilities or a grid plate.

As shown in figure 2, the primary cooling system needs a purification system in order to purify the coolant passing the core. The second concept for an active core residual heat removal system is to utilize the purification system. The system is operated during normal power operation as well as after a reactor trip. Therefore, the residual heat cooling pump has two operation points; a power operation and a residual heat removal operation. However, because the residual heat removal system needs a relatively low flow rate, the system has a low system pressure loss even though the residual heat cooling pump is operated by undergoing an entire primary cooling system loss. Therefore, the pump can be easily designed and operated with high pump efficiencies at two operation points. In addition, the residual heat removal system can be utilized to remove the heat from silicon doping facilities or a grid plate because the system is operated during normal power operation mode and the coolant is relatively clean by the filter and ion exchanger in the system. However, the system also needs an un-interruptible power source or an emergency diesel generator.

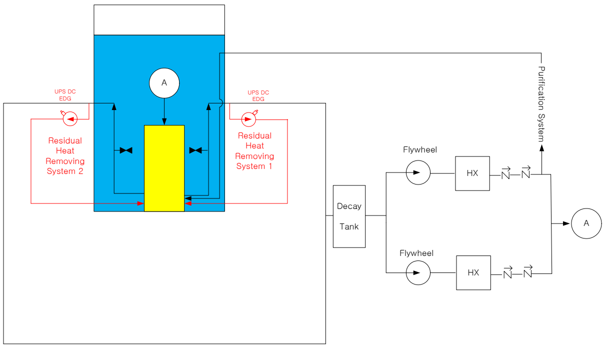

Figure 1. Active core residual heat removal system 1

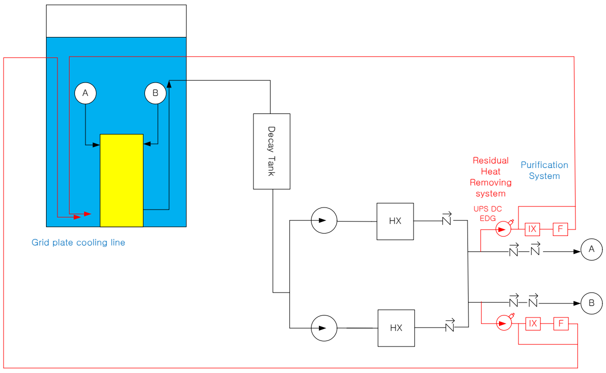

Figure 2. Active core residual heat removal system 2

3.2 Passive core residual heat removal system

Figure 3 shows the conceptual flow diagram for a passive core residual heat removal system. The passive type utilizes directly the pool water as a core residual heat removal system with an additional pool. The reactor pool is connected to the residual heat removal pool by a pipe. Before running the primary cooling pump, each pool level is maintained at A. As soon as the pump is operated, the level of the reactor pool rises to level C and that of the residual heat removal pool decreases to level B for compensating the reactor pressure loss as shown Figure 4.

$$P_1 = P_4 \quad (1)$$

$$\Delta P_2 = \Delta P_3 \quad (2)$$

After reactor trip, the level of the residual heat removal pool rises back to level A. Then, the reactor pool level decreases and the downward flow can be maintained through the core while balancing the pool levels. This system can be used as the residual heat removal system without a pump or a valve. However, the passive system concept should consider operations of the pool level change and the connection pipe break between the pools because the pipe is located near the bottom of the pool.

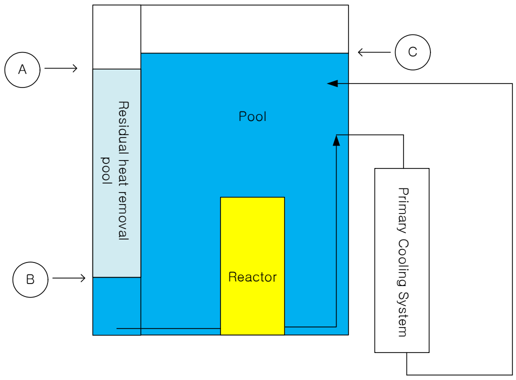

Figure 3. Passive core residual heat removal system

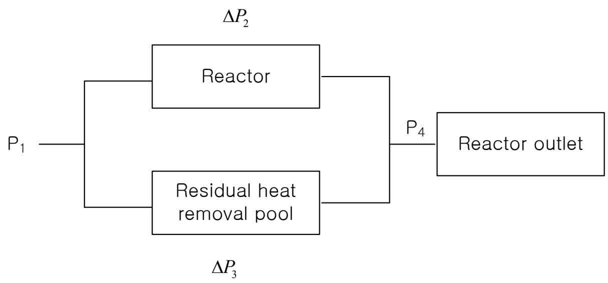

Figure 4. Conceptual diagram for calculating pressure loss

4. Conclusion

This research work sought to design and evaluate the core residual heat removal system type according to the power of a research reactor.

For the low power, the inertia force of a fly wheel attached to a primary pump shaft can maintain the downward flow through the core during the required time and can sufficiently remove the residual heat. For a relatively high power, an additional system should be used to remove the core residual heat because the inertia force by the flywheel is not sufficient to remove the heat. The active core residual heat removal system removes the residual heat by residual heat cooling pumps. The passive system employs the level difference of the pools without an additional pump or valve.

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