Basic Design Status of Hot Water Layer System for Open Pool Research Reactor

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1. Introduction

For the design and construction of the open pool research reactor, the basic design of reactor itself and the main systems relevant to the reactor have been proceeding in Korea Atomic Energy Research Institute. The main systems are composed of the primary cooling system, the pool water management system, the emergency water supply system, the hot water layer system and the heavy water system. Unlike the nuclear power plant, the research reactor is the open pool type for the multi-purposes utilization: radio-isotope production, irradiation facility operation, and so on. Therefore, the hot water layer system to reduce the radiation level on the surface of the reactor pool is one of the main systems for the research reactor.

In this paper, the basic design status of the hot water layer system is presented at the aspect of design bases, system description including constitution, and system operation.

2. Basic Design of the HWLS

The Hot Water Layer System (hereafter HWLS) is aimed that the personnel can work under the allowable low radiation level at the top of the reactor pool and service pool. For this purpose, the HWLS has a heat source available for hot water layer forming at the top of reactor and service pool during the normal operation of the reactor. In addition to, the system has a purification component to remove traces of corrosion, fission or radioactive impurities so as to reduce the radiation emitted from the impurities in the pool water. The HWLS will decrease the pool top radiation by preventing the radioactive primary coolant from rising up to the surface of the pool and by improving the water quality of the hot water layer.

2.1 Design bases

The HWLS should be designed under the following design bases:

First, the stable hot water layer should be formed at the top of the reactor pool and service pool in order to maintain the low level of radioactivity allowable for daily work without any physical hazards of personnel in the reactor hall when the reactor is on normal operation.

Secondly, the water quality of the hot water layer is less than 1.0 μS/cm in terms of its conductivity.

2.2 System Description

The HWLS establishes the hot water layer of 45℃ on the surface of the reactor pool and service pool so as to prevent the radioactive primary coolant from reaching at the pool surface by natural convection.

Due to the temperature difference between the hot water layer and the ambient environment, the water evaporates on the surface of the hot water layer, and the temperature decrease of hot water layer results from a heat transfer by conduction with the reactor concrete island and the fluid medium beneath the hot water layer. Based on all heat loss from the hot water layer, the thermal capacity of the heater is determined under the design margin.

For the satisfaction of the design bases, pumps, ion exchangers, heaters and fresh resin supply tank are equipped in the HWLS as main components and located in the HWLS equipment room. The schematic diagram of the HWLS is shown in Fig. 1.

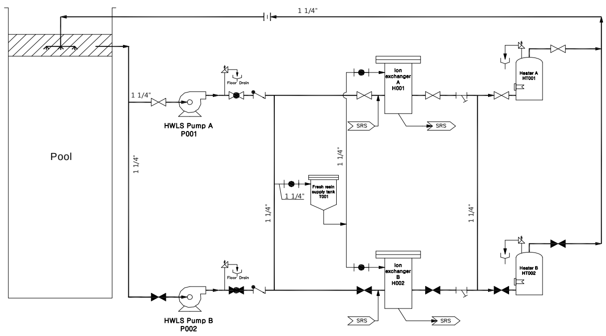

Fig. 1. Schematic diagram of the hot water layer system

The suction line from the pool is divaricated into two parallel arranged lines with the separate train including pump, ion exchanger, and heater (100% capacity each, one on standby). Two divided lines are combined into the discharge line after passing through the heater. Between two trains, two bypass lines connected are to ensure that operation failure of one component does not result in the functional failure of whole system.

In order to establish the stable hot water layer, ends of the suction and discharge line are submerged below the pool surface and located at the same level in the reactor pool. The discharge line end is shaped as a diffuser to distribute the discharge flow uniformly at the top of the pool water.

Through the pump, the water in the reactor pool flows into the ion exchanger, surrounded by the lead shielding blocks to remove the corrosion, fission and radioactive impurities. The purified water flows into the heater with a 50kW thermal capacity to heat up to the desired temperature. The heated water flows back to the hot water layer through the diffuser in the reactor pool.

For the resin replacement, each ion exchanger has an outlet nozzle for the resin evacuation with circulated water and inlet nozzle for the circulated water which are connected to the dewatering hopper and buffer tank. This is a part of the solid radwaste system to transport the spent resin out of the ion exchanger. The empty ion exchanger is filled with the transported fresh resin through the HWLS pump from the fresh resin supply tank.

2.3 System Operation

The HWLS operation modes are determined along reactor operation modes. When the reactor is on operation in the power mode, the HWLS is operated to establish the hot water layer over the reactor and service pool. A day before the reactor operation, the HWLS is required to be in operation so as to stabilize the temperature of the hot water layer at the desired value. One day after the reactor shutdown, the HWLS shall be in operation to decrease the pool top radiation by removing the residual radioactive impurities from the pool.

During the start-up of the HWLS, either pump is operated to take the water at the upper section of the reactor pool and leads the water into the ion exchanger (on the same train with the pump) under open status of all necessary isolation valves. After the purified water gets through the strainer to prevent the resin scrap from entering the pool, the heater comes into operation to warm it up to the desired temperature. The outlet flow of the heater empties into the reactor pool through the diffuser. In the initial operation of the heater, the outlet temperature is much lower than the designated temperature. As the heater gets to its steady state, the temperature at the upper section of the pool gradually reaches its design value. Redundancy and the appropriate safety margin of the thermal capacity in the HWLS ensures its continuous performance during any malfunctioning of the system. For the duration of HWLS steady state, the HWLS satisfies its design bases by establishing the stable hot water layer over the reactor and service pool.

The conductivity is measured after the ion exchanger outlet to check the purity of the hot water layer. Water purity is guaranteed that the mixed anionic and cationic resins are polished by capturing the radio-activated impurities. When the mixed ion exchange resins are deteriorated during the reactor normal operation, the ion exchanger is switched on so that on the other train is operated to maintain a low top radiation level. After the reactor is shutdown, the resins are replaced with the fresh resins in the fresh resin supply tank through the HWLS pump. The spent resins from the previously operated ion exchanger are evacuated through the SRS through the connection on the ion exchanger. Temperature sensors, located in the suction line, discharge line, and also inside the service pool, not only monitor the HWLS water temperature but also verify the thermal performance of the heater. Thus, two sets of differential pressure indicator and switch are measuring the differential pressure across the ion exchanger and strainer.

3. Conclusions

The basic design of the HWLS has been performed from the aspect of the establishment of the hot water layer on the top of the service and reactor pool. To satisfy the design bases, system components such as the pump, ion exchanger, fresh resin supply tank, and heater are equipped in the HWLS equipment room. Thus, the thermal capacity of the heater is determined by the heat loss source from the hot water layer in the pool to maintain the stable hot temperature water layer. The detailed design for the hot water layer system of the open pool research reactor will be continued in terms of the design parameter adjustment reflecting the equipment manufacturer's information.

REFERENCES

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