Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Overview of Fluid System Design for the KJRR

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1. Introduction

The KIJANG Research Reactor (KJRR) is an open-pool type research reactor that KAERI has been designing since 2012. The KJRR site is in Jwadong-ri, Jangan-eup, Kijang-gun, Busan.

The main purpose of the KJRR is to produce medical and industrial radioisotopes, such as Mo-99, Ir-192, I-131 etc., and to irradiate silicon ingots for Neutron Transmutation Doping. The thermal power of the KJRR is 15 MW_t and the maximum thermal neutron flux is 3.0×10^{14} n/cm^{2}s. The fuel type is LEU U-Mo plate type and the reflector is Beryllium and Graphite. The Reactor Structure Assembly is submerged in the reactor pool [1].

The reactor core is cooled by a downward forced flow that is maintained by pumps. Due to the downward flow the fuel assembly can be fixed on the grid plate without using the special device.

This paper introduces the fluid system design to fulfill the above mentioned requirements. The considerations and design change experiences are also presented.

2. Consideration for Fluid System Design

The main purpose of the fluid system for a RR is to remove the heat generated in the core and to transfer it to the secondary cooling system in which the heat is dissipated in the atmosphere. In the open-pool type research reactor, it needs to cool, purify, and make up the pool water. These requirements give the idea for the basic configuration of the Reactor Cooling and Connected System.

The downward core flow adds another constraint for the fluid system design. The core inlet pressure is set by the pool water depth. The pressure at the core outlet is lower than that at the core inlet by the pressure decrease at the core. This core outlet pressure, which is around the atmospheric pressure, restricts the location of the Primary Cooling System pump. The pump NPSH (Net Pumping Suction Head) decides the minimum depth required for the pump location. The higher core differential pressure becomes, the deeper is the pump location in the reactor building. It causes the increase of the construction costs [2].

Another design aspect induced by the high differential pressure is the pool water inventory remained after the primary piping is broken and coolant is discharged. The siphon phenomenon causes the entire pool water to be lost if there is no design implementation against it. To prevent this, the pool penetration of the Primary Cooling System pipe is located as high as possible. And siphon valves which can induce air into the pipes to break water stream are generally installed on that pipe. However, the pipe penetration height is restricted by the cavitation. If the differential pressure across the core is too high, it is difficult to design the reactor with the downward core flow as an open-pool type. In this case, reactor type shall be an open-pool type with the upward core flow or a tank type reactor with closed loop.

3. Configuration of KJRR Fluid System

The KJRR fluid system consists of four systems: Primary Cooling System (PCS), Safety Residual Heat Removal System (SRHRS), Pool Water management System (PWMS), and Hot Water Layer System (HWLS). Fig. 1 shows the schematic diagram of the KJRR Reactor Cooling and Connected System.

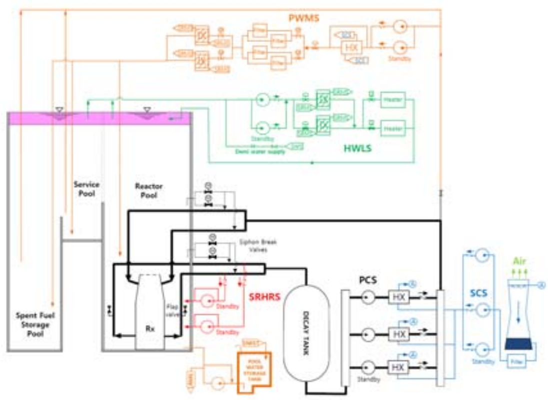

Fig. 1. Schematic Diagram for Reactor Coolant System and Connected System

3.1 Primary Cooling System

The PCS removes the heat generated in the core by transferring it to the Secondary Cooling System. The coolant heated at the core flows to the decay tank, PCS pump, PCS Heat Exchanger and returns to the core. In order to reduce the N-16 activity by using its short half-life, the coolant flows at a very low velocity in the decay tank due to its volume. A flywheel is attached to the pump shaft to increase the coastdown time.

After the forced convection flow in the core is diminished, the decay heat is removed by the natural convection. To form the natural circulation flow path, the flap valves are installed on the core outlet PCS pipe in the reactor pool and are open passively as the core flow is decreased to a certain limit.

3.2 Safety Residual Heat Removal System

The core flow in the KJRR is maintained downward during the normal operation. When the PCS pump is stopped, the flow direction changes to the upward. If the flow inversion occurs when the decay heat is high, the fuel integrity can be deteriorated. To delay the flow inversion, it needs to maintain the downward flow at the core after PCS pump is stopped.

The SRHRS is introduced to meet this requirement. The pump draws the water from the PCS pipe at downstream of the core and discharges it into the pool. By doing that, the decay heat is dumped to the reactor pool.

The SRHRS consists of a check valve, a pump, and isolation valves. In the normal operation, the check valve prevents the pump from sucking up the PCS flow. The SRHRS is a safety system. The 1E class electricity is provided by the safety class battery bank and the inverter.

3.3 Pool Water Management System

There are three pools in the KJRR: reactor pool, service pool, and spent fuel storage pool. These pools are connected in the normal operation. The pool door is installed between the reactor pool and the service pool when the maintenance in the reactor structure assembly is required. Because of the connected operation among the pools, it is possible to purify and cool the pool water with a single PWMS. The PWMS takes water from the pools and the Primary Coolant System and purifies it with the ion exchanger and the filter. The PWMS can store the pool water during the maintenance.

3.4 Hot Water Layer System

There can be many experimenters and operating personnel on the pool top during the normal operation. To reduce the pool top radiation, the hot water layer is formed on the top of the pools. The hot water layer that is warmer than the lower part of the reactor pool stabilizes the upper part of the pool. This stabilized water prevents the relatively more radioactive water in the lower part of the reactor pool from rising up to the pool surface. The HWLS consists of ion exchangers to purify the coolant and heaters to compensate the heat loss.

Evaporation from the pool requires the make-up of pool water. In KJRR, the demineralized water from the Service Water System is supplied to the pool through the HWLS Heater.

4. Design Experiences

At the early stage of the KJRR project, the residual heat removal system for a loss of the off-site electric power was a passively working system [3]. That system is a single tank connected to the core outlet part of the reactor structure assembly. The water level in the tank is lowered to level corresponding to the pressure decrease at the core in the normal operation. When the forced flow is diminished and the pressure difference at the core is reduced, the water level begins to recover to the reactor pool level. It keeps the core flow direction be downward for the required time.

However, the power level of the KJRR was judge to be quite high to implement this concept. It was found that a large volume is required to remove the decay heat until the flow inversion is allowed. This large volume also induces an operational difficulty due to the reactor pool level variation by the PCS pump operation status.

After analysis and discussions, it was decided that an active residual heat removal system shall be required against a loss of the off-site electric power event. The introduction of the safety system leads to 1E class electricity.

5. Concluding remarks

The fluid system of the KJRR is introduced and the objective of each system is explained briefly. The fluid system in research reactors is designed to meet the requirements from the upstream design areas, especially the core design and required experiments.

KAERI have been successfully operating HANARO and constructing the Jordan Research and Training Reactor (JRTR). Along with the KJRR project, the fluid system design for a medium power research reactor has been developed and matured from the economic and the safety point of view.

ACKNOWLEDMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. NRF-2012M2C1A1026909)

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