Overall Design Features and Key Technology Development for KJRR

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Abstract: The KJRR project is being conducted in order to secure the supply of key medical and industrial radioisotopes and to develop the core technologies of research reactors (RRs) This project aims to establish a RR with 15 MW and related utilization facilities for RI production and neutron transmutation doping (NTD) services at Kijang-Gun, Busan City in Korea. The KJRR is under detail design and is planned to put into operation in 2019.

1. Introduction

The KJRR (Ki-Jang Research Reactor) project was launched on Apr., 2012; 1) to make up the advanced technology related to RRs, 2) to provide the self-sufficiency in terms of medical and industrial radioisotope (RI) supply, and 3) to enlarge the NTD silicon doping services for growing the power device industry [1].

The major facilities to be built through the KJRR project are,

- 15 MW Research Reactor and Reactor building
- Radioisotopes Production Facility (RIPF) and related R&D Facility
- Fission Mo Production Facility (FMPF) with LEU Target
- Radio-waste Treatment Facility (RTF)
- Neutron Irradiation Facility such as PTS and HTS.

This paper describes the overall design features of the KJRR and the key technology development for RRs during the project.

2. Overal Design Features

The KJRR is an open-tank-in-pool type research reactor with 15 MWth, which will be dedicated to produce radioisotopes such as Mo-99, I-131 and Ir-192 and to provide the Si NTD service [2]. Detail design is being conducted to meet the established design and performance requirements. The major design requirements are given in Table 1.

Table 1. Design specipications of the KJRR

Parameter	Value
Power	15 MW
Reactor Type	Open-tank-in-pool type
Max. thermal neutron flux	> 3.0×10^{14} (n/cm^{2}s)
Annual operation	~300 days
Fuel	Plate type, U-7Mo (19.75% enriched)
F-Mo Target	UAlx plate type (LEU, 2.6 g/cc)
Reflector	Be and Al
Coolant and Cooling method	H_2O, downward forced convection flow
Decay heat cooling	SRHRS and Natural circulation by flap valves
Reactor building	Confinement

1) Fuel

The fuel assembly is a typical MTR type fuel with a total of 21 flat fuel plates, which is widely used for many RRs worldwide. Two types of fuel assembly, a standard fuel assembly (SFA) and the follower fuel assembly (FFA), are used for the KJRR, as shown in Fig. 1.

The fuel meat is made of a homogeneous dispersion of uranium-molybdenum (U-7Mo/Al-5Si) particles in an aluminum matrix. The U-235 enrichment is 19.75 weight %. But, two different uranium densities fuel meats will be used for the initial core to obtain a flat power distribution. (19 inner plates of 8.0 gU/cm^3, 2 outer plates of 6.5 gU/cm^3) [3].

2) Reactor core

The reactor core consists of a total of 22 fuel assemblies, 16 SFAs and 6 FFAs, as shown in Fig. 2. Fuels are positioned in a 7 x 9 rectangular array with an active height of 60 cm [3]. A maximum of six fission moly targets can be loaded during the normal operation. Three flux traps and nine irradiation holes, where on-power loading is possible, ar*e* employed to produce Mo-99 and other radioisotopes. The irradiation holes for NTD are large enough to house a Silicon ingot with a diameter from of 6 inch up to 12 inches. One HTS and two PTS are also located inside and outside of the core box.

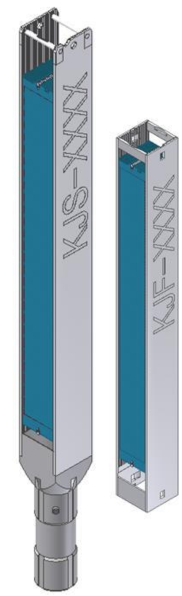

Fig. 1 SFA and FFA

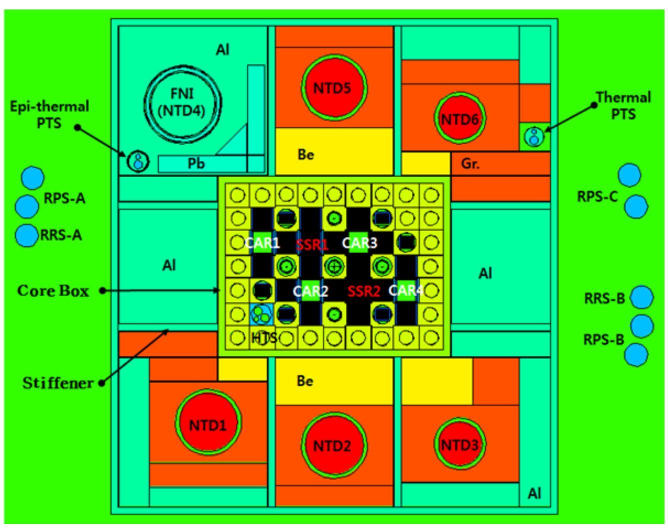

Fig. 2 Reactor core configuration

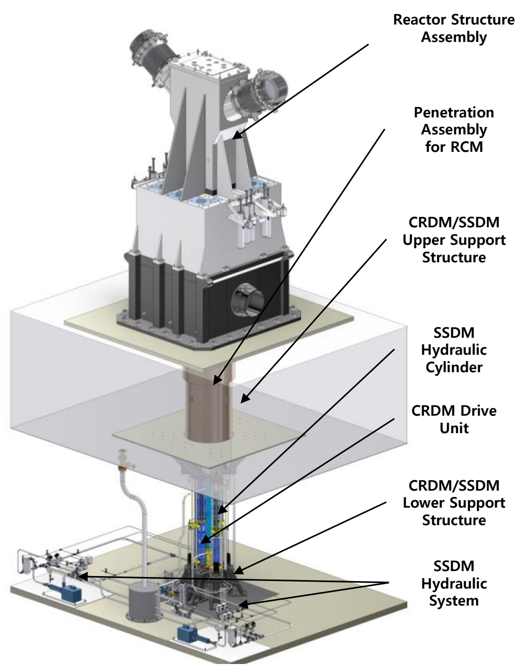

Fig. 3 Reactor assembly and CDRM/SSDM

3) Reactor Assembly and CRDM

The reactor assembly (RA) is composed of a reactor structure assembly (RSA), fuel assemblies, reflectors, and reactivity control units, as shown in Fig. 3. The RSA comprises the outlet plenum, grid plate, upper guide structure, and detector housings. It supports the guide structures of two kinds of Control Absorber Rod (CARs) and Second Shutdown Rods (SSRs).

Four (4) CRDMs, with command from the Reactor Regulating System (RRS), control the core reactivity during the normal operation. A CRDM inserts or withdraws a CAR or maintains it at the required position using a stepping motor. All CARs are dropped by gravity when a reactor trip is required by the Reactor Protection System (RPS) or by the Alternate Protection System (APS). Two SSDMs, as an independent shutdown system, provide a diverse means of reactor shutdown by the gravity drop of SSRs (Second Shutdown Rods) if a reactor trip is required by the RPS or APS. The neutron absorber material of CARs and SSRs is hafnium [4].

4) Reactor Cooling System

The cooing and connected systems of the KJRR, as shown in Fig. 4, are composed of the Primary Cooling System (PCS), Safety Residual Heat Removal System (SRHRS), Pool Water Management System (PWMS), Hot water Layer System (HWLS) and Secondary Cooling System (SCS).

The PCS circulates demineralized light water to the reactor assembly to remove the heat generated in the fuel and other reactor components. Two flap valves are installed to provide the natural circulation flow paths for core decay heat removal when the PCS pumps are off. The SRHRS is installed to secure the core decay heat removal in case that all PCS pumps are not available. The PWMS is designed to remove decay heat from the spent fuels, to cool the reactor pool water during the normal operation and reactor shutdown. It controls and maintains the quality of the primary coolant and the reactor pool water such as the visual clarity, purity, and radioactive content. The HWLS is installed to establish a hot water layer at the top of the reactor and service pools in order to reduce the radiation level near pool top during the normal operation.

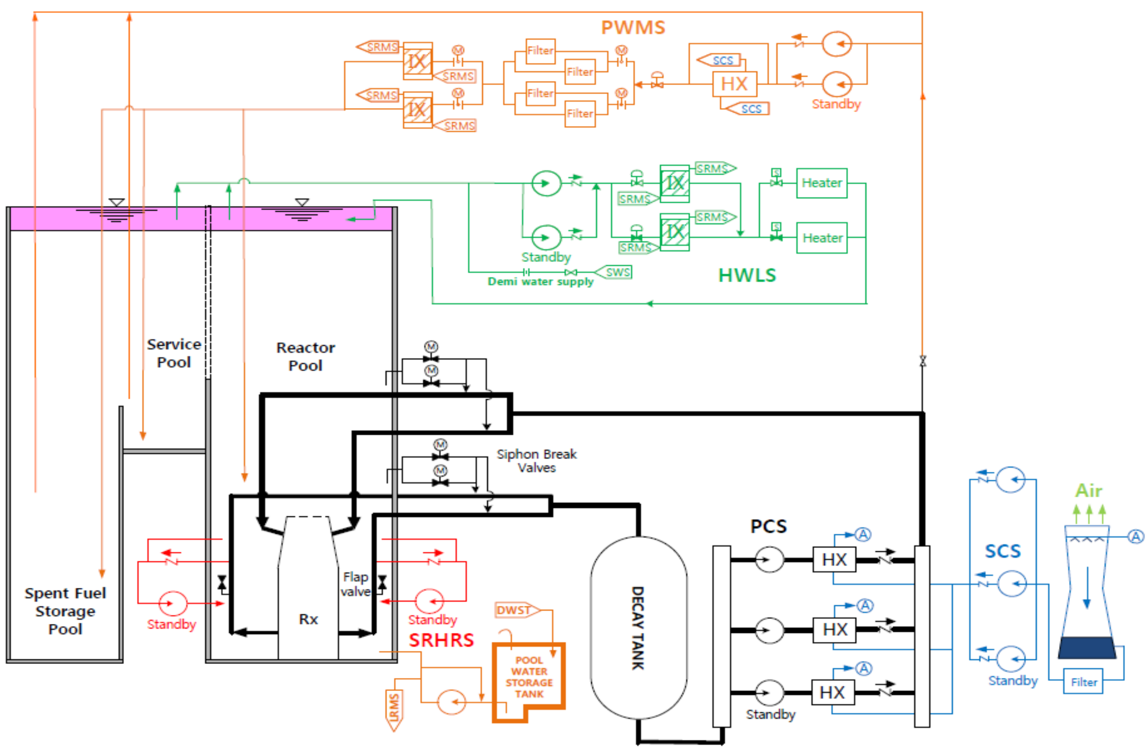

Fig. 4 Schematics of the KJRR cooling systems

5) Istrimentation and Control

The instrumentation and control (I&C) systems are used to control, protect and monitor the reactor facility, which is composed of a Reactor Protection System (RPS), Reactor Regulating System (RRS), Alternate Protection System (APS), Post-Accident Monitoring System (PAMS), Radiation Monitoring System (RMS), Information Processing System (IPS), Process I&C System (PICS), Automatic Seismic Trip System (ASTS), Main Control Room (MCR), and Supplementary Control Room (SCR). Most I&C systems of the KJRR are implemented by using digital computer technology. All I&C systems and equipment are designed, constructed, and maintained in such a way that their specifications, verification, and validation, quality and reliability are commensurate with their classification.

3. Development of key technology

One of this project objectives is to develop and qualify the RR technologies which are not secured in Korea, such as a plate type fuel using U-Mo materials and a bottom mounted CRDM.

1) U-Mo Fuel Qualification

U-Mo fuel has a strong point to achieve more efficiency and higher performance fuel meat for RRs. This is the first try to apply the U-Mo fuel to the RR in practice, which could drive an RR fuel change from high-enriched fuel to low-enriched fuel in compliance with the RERTR program.

The performance and integrity of U-Mo fuel will be qualified by irradiation tests in two RRs, the HANARO in Korea and the ATR in the USA [4]. At HANARO, irradiation tests of mini-plates due to limitations of the test rig size are supposed to be performed three times for the burn-up targets of 45%, 60%, and 90%, respectively (which are called HAMP 1, 2, and 3 tests). The dimensions of the mini-plates for HAMP-1 and 2 is are 35 mm in width and 130 mm in length, while that for HAMP-3 is 35 mm in width and 640 mm in length. The first irradiation test (HAMP-1) was finished in June 2014 and the PIE (Post-Irradiation Examination) will be counducted in the fourth quater of 2015. The second and third tests (HAMP-2, 3) are waiting for irradiation at the first-half of 2016. All tests including PIE (Post Irradiation Examination) will be finished by 2017.

Regarding the full scale test, the irradiation test of a prototype fuel assembly which was manufactured by the KAERI will start at ATR in December 2015 and be finished in Oct. 2016. The completion of PIE is expected to be finished by Dec.., 2017.

2) Development of bottom mounted CRDM

It is usually known that a reactor bottom mounted CDRM is advantageous for the utilization while the CRDM mounted above the reactor has a strong point from the safety and maintenance point of view. The choice is dependent on the design to harmonize with other systems and equipment.

For the KJRR, a bottom mounted CDRM/SSDM has been chosen for the reactivity control of the core. Due to the expensive import cost, KAERI decided to develop it by itself, and a bottom mounted CRDM is being developed in accordance with the KJRR project schedule. All key components such as an electromagnet, extension shaft adapter, guide tubes, a seal valve, and connectors were developed, and their performance tests were also finished in Oct. 2014. Test facility for performance and endurance tests will be set up by March, 2016. Q Class prototype CRDM/SSDM will be also manufactured by March, 2016. With this test facility, performance and endurance tests of CRDM/SSDM will be done by June, 2016. Other test facility for a seismic test will be established by June,2016 and seismic tests of CRDM/SSDM will be performed in this facility until Dec., 2016.

4. Concluding Remarks

The overall design features of the KJRR and RR technology under development have been overviewd. The design of the KJRR will comply with the Korean Nuclear Law, regulatory requirements and guidelines as wll as international standards and guidelines. The KJRR is expected to be put into operation in the middle of 2019.

References

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