New Research Reactor Project in Korea

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ABSTRACT

New research reactor project in Korea aims to increase self-sufficiency in terms of medical and industrial radioisotope supply, to enlarge the supply of NTD silicon doping and to make up the advanced technology related to research reactor. As a major national project for nuclear science and engineering in Korea, this project has been officially started on Apr. 2012 funded by the Government and Local Governments, Kijang-Gun and Busan City, that accommodate this facility in their land. It has five years project schedule from design to commissioning just before starting the normal operation in 2017. KAERI, who is the owner contracted with the Government, is doing the design by itself based on our own knowledge and experiences from the KRR-1, KRR-2 and HANARO. The reactor is be composed of 8.0 g/cc U-Mo fuel, which is the First-of-a-kind application in world, and will be enable of operating over 300 days per year and 60% high burn-up pertinently to produce the required neutron flux. It is expected that the construction permit application will be submitted to regulatory body by the first half of 2014 and the first criticality by 2017.

1. Introduction

1.1 Background of the project

Korea has imported most of radioactive isotopes (RIs) from other counties. Imports of the open RI and the sealed RI sources were up to about 25,000 Ci and 71,000 Ci, respectively in 2009. The sort of RIs on a commercial scale produced from the HANARO, a 30 MWth research reactor of Korea, is only I-131 and Ir-192. For this reason, the RI market of Korea has easily affected by the international price and the conditions of world's RIs supply. Moreover, a continuous increase in demand for a variety of RIs and neutron transmutation doping (NTD) for silicon is expected though the HANARO shares a little portion of RIs and NTD. To cope with the growing demand of RIs and NTD service, Korea government had considered a new research reactor project since 2009. [1, 4] To self-sufficiently supply RIs, to increase the production capacity of the NTD and to develop the research reactor-related technologies, The Kijang Research Reactor (KJRR) project was officially launched in Korea on the first of April 2012. [4]

The Korea Atomic Energy Institute (KAERI) as a managing department has proceeded with the project in cooperation with the Kijang municipality since the commencement. The KAERI undertakes system design, licensing preparation and commissioning and the Kijang municipality is assigned to serve infra-structure like a water supply. On 10th of April, 2013, the Daewoo engineering & construction company a subcontractor, joined the project to carry out architect engineering (AE) works. The other tasks will be assigned to prospective vendors.

1.3 Chronology of the project

The KJRR is scheduled to be normally operated by Apr. 2017. For the first couple of years, we plan to finish conceptual and basic design and aim to obtain construction permit for the KJRR by March, 2014. For next two years, we will construct buildings for reactor, radioactive wastes and auxiliary facilities. And there will be licensing and commissioning for a last year. Table 1 presents the chronology of the project briefly. We are now working on installation of a meteorological monitoring tower, contracts for components and facilities and etc. Those activities are also shown in the table 1. Among the issues, the agreement with the Idaho National Laboratory (INL) on a cooperative research for the performance test of U-Mo plate type fuel is one of our major achievements. In short, we are mainly preparing the preliminary safety analysis report (PSAR) for the construction permit. [2]

Data	Achievements
Mar. 2010	Pre-evaluation by MOSF
Jul. 2010	Site Selection by a committee of MEST
Jun. 2011	Feasibility Study completed by KDI
Dec. 2011	Budget approval by the National Assembly
Apr. 2012	Official start of the project
Dec. 2012	Conceptual design
Apr. 2013	Conclusion of the contract for architect engineering
Jun. 2013	Completion of preliminary site investigation
Jul. 2013	Conclusion of collaborative research on the U-Mo plate type fuel irradiation test with INL
Sep. 2013	Start of the meteorological monitoring tower installation
Sep. 2013	Basic design in progress

Tab 1: Chronology of the project

2. Design Basis

The design basis of the KJRR is based on its top-tier requirement and the top-tier requirement is oriented for utilization of isotope production, NTD production, and the related research activities. The design basis had been carefully prepared to satisfy its purpose and the conceptual design was conducted to meet the basic design requirements. Table 2 shows the design basis and the concept design results.

Parameters	Requirements	Conceptual Design
Reactor power	~ 20 MWth	15 MWth
Max. thermal neutron flux	> 3.0×10^{14} n/cm2s	3.2×10^{14} n/cm^2s
Operation day per year	~ 300 days	> 300 days
Excess reactivity at EOC	> 25 mk	27.6 mk
Reactor life	50 years	50 years
Fuel	LEU U-Mo plate type fuel	LEU U-Mo plate type fuel (U density: ~8.0gU/cc)
Reflector	Beryllium	Beryllium
Coolant and core cooling	H_2O, downward flow	H_2O, downward flow
Average discharge burn-up	60~70 %U-235	64.6 %U-235
Cycle length	> 37.5 days	> 50 days
Shutdown margin	> 10 mk	1^{st} : 22 mk, 2^{nd} : 25 mk
Power defect	negative	-0.99 mk
Fission Mo production	2,000 Ci/week	2,300 Ci/week (6 targets)
NTD	150 ton/year	200 ton/year
Flux at HTS, PTS	HTS >1.0×10^{14} n/cm^2s PTS >1.0×10^{12} n/cm^2s	HTS >1.4×10^{13} n/cm^2s PTS >1.2×10^{12} n/cm^2s
Fuel consumption per year	-	12 EA

Tab 2: The design basis and conceptual design results

The design of KJRR ought to comply with the Korean Nuclear Law, regulatory requirements and guidelines. In addition, the regulatory submittals will adhere to internationally applicable standards and guidelines such as the IAEA safety standards. In parallel with the IAEA guidelines, the technical requirements and criteria for such kind of industrial codes and standards are applied as detailed technical requirements. The requirements for safety must be established and applied coherently with other requirements for human performance, quality, and security. An information service system for the management of facility must be provided together with the facilities for the integrated management and experience feedback for operation and utilization. The information service system shall provide the operator with an advanced notice of the activities that could result in the increase of area radiation level or release to the environment. The information service system periodically providing data of radiation dose, radio-waste generation and radioactive effluents shall be easily accessible by the operators and users. The design shall minimize the possibility of risk occurrence by the mistakes of users. All practical efforts shall be made to prevent and mitigate nuclear or radiation accidents. [3] A target holder with LEU to produce Mo-99 will be loaded and unloaded while the reactor is on operation, more than 2,000 Ci/w as calibrated at 8 days after removal from the core. Other radio-isotope requirements for Ir-192 (300,000 Ci/w), P-33, Lu-177 (50 Ci/w), I-131 (4,000 Ci/w), and Co-60 (medical purpose) are considered on the design bases. The irradiation holes for Si ingot will be located and designed to meet the doping capacity specified in the top-tier requirement and to cope with the need from irradiation service market. The irradiation holes and related facilities shall be designed to accommodate 6, 8, and 12" (OD) ingot. The selection of ingot size will depend on the market need.

3. Basic Design

Innovative technologies and facilities will be applied to the KJRR for safety, reliability and economy. First of all, U-Mo plate type fuels based on U-7Mo dispersed in Al-5Si will be applied to the KJRR. U-Mo fuels produce a rather larger amount of neutrons with a small amount of uranium, compared to the other types of fuels. The KAERI is unique manufacturer to make U-Mo fuels. Nowadays, under the Nuclear Non-Proliferation Treaty (NPT), every country is encouraged to use low-enriched uranium fuels: enriched below 20 %. However, unfortunately, the other types of fuels generate relatively very low amount of neutrons with the same enrichment of uranium fuels. To date, it is a fact that without the U-Mo fuel, there are no ways to generate neutrons economically and to meet the policy at the same time. For this reason, the Nuclear Security Summit highlighted the importance of the U-Mo fuels on 27th of March, 2013. In addition, many countries are considering converting the high-enriched uranium fuels of their reactors such as BR-2, ILL and FRM-II, to the U-Mo fuels and they have a plan to apply the U-Mo fuels to new research reactor projects.

As the first application, the performance and the integrity of the U-Mo plate type fuel is needed to be verified. To this end, we made a plan for the irradiation test of the U-Mo plate type fuel. The plates and the fuel assemblies will be irradiated in two research reactors, the HANARO in Korea and the ATR in the USA respectively. We agreed on that the KAERI is going to share the irradiation test result with the INL, and the INL will offer the budget, 280 million $, for the irradiation test in the ATR.

General arrangement (GA) of the reactor building was conducted for several months and Fig 1 represents the latest results of GA. In the figure, the left side is the Rx. area and the other is FM and RI area. Lots of elements regarding accessibility, mobility, usability, safety, economy, etc. of material, components and human were took into consideration. The Rx. pool has the same level with the ground. The spent fuel storage is between the Rx. pool and the Fission Molybdenum (FM) area, of course, the Rx. the FM area separated by the wall. The inclined tunnels in the middle connect the spent fuel storage pool and the FM area. Heavy components such as the heat decay tanks, the primary cooling pumps and so on are mainly placed on the first and second floor under the ground.

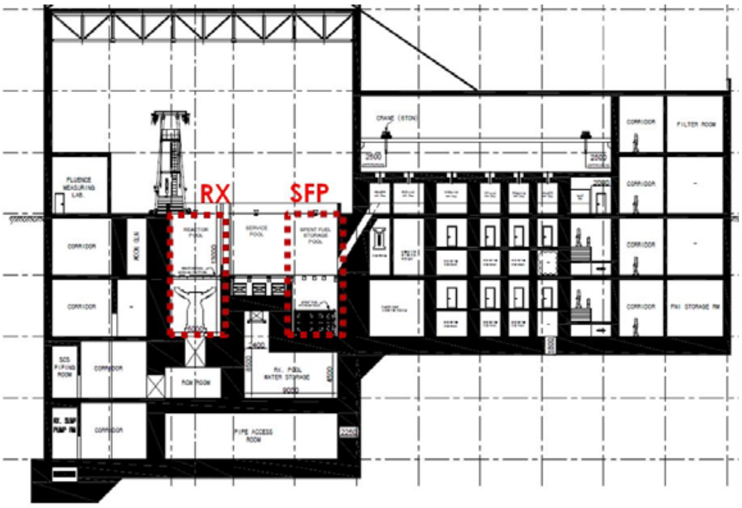

Fig 1. The general arrangement of the reactor building

In figure 2, the fluid system of the KJRR has several sub-systems, the Primary Cooling System (PCS), the Safety Residual Heat Removal System (SRHRS), the Primary Purification System (PPS), the Pool Water Management System (PWMS) and the Hot water Layer System (HWLS). In the early stage of the basic design, a big decay tank was considered but the big decay tank was split into two rather small tanks because of disadvantage in general arrangement. To secure residual heat removal against the case that the all PCS pumps are not available, the SRHRS was introduced. After shutdown with PCS pumps' failure, residual heat of the core is initially cooled by the inertia wheels of the PCS pumps for a while. And then the SRHRS will be activated. For the long term cooling, residual heat will be removed by natural circulation though the flab valves.

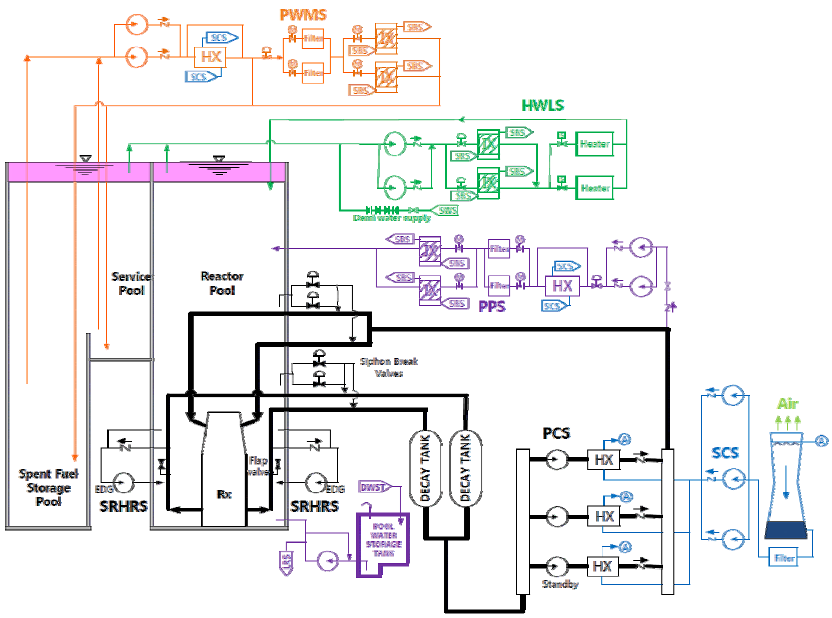

Fig 2. The fluid system of the KJRR

4. Project Progress

In the stage of conceptual design, we considered the gravity core cooling tank (GCCT) as a passive heat removal system. However, it was turned out from the detailed safety analysis that the GCCT is not available in case of a high power research reactor like the KJRR. Of course, the KJRR equips not only an active system that is the safe emergency diesel generator (EDG) but also we introduced the safe residual heat removal system to make sure that residual heat of the core is being cooled in any situations. And we made the safe classes of some systems higher than legal requirement. Through conceptual and basic design, we have completed some designs illustrated in table 3.

Core	- Established the concept of the core - Decided the configuration of the core - Developed a reflector model - Optimized the arrangement of fuel plates, irradiation holes and CARs
Systems and reactor building	- Established the concept of primary cooling system (PCS), hot water layer system (HWLS), secondary cooling system (SCS), reactor regulation system (RRS), reactor protection system (RPS) and etc. - Produced the initial version of general arrangements
Components & facilities	- Developed the process of Mo-99 production - Devised the irradiation holes for RI production and scientific researches - Designed reactor assembly, NTD, CRDM/SSDM, CAR and etc. - CFH tests of fuels & fuel irradiation tests
Site	- Determined the final location of the reactor - Initiated specific site investigation (Next step)
Project engineering	- Set up management system - Quality assurance program - Published level 3 schedule

Tab 3: Progress of conceptual and basic design

5. Concluding Remarks

The conceptual design of KJRR has completed in the end of 2012; reactor characteristics, a primary cooling system concept, a general arrangement of the facilities and a site plan of the buildings were proposed. Based on the experiences of research reactor projects, it is showed that a conceptual core design provides required thermal flux at 15 MWth with a satisfaction of safety in view of the thermal-hydraulics, fuel performance, and inherent safety. The high discharge burn-up will provide very much economic benefit and even in 300 days of operation per year with 8.0 gU/cm3 U7Mo fuel. The connection of a fission moly building to a reactor building through a compact canal allows a safe and efficient transfer of irradiated targets between buildings. Based on these conceptual design results, the basic design activities are being conducted with the preparatory activities for a construction permit application. After basic design and construction permit, we will move on the next stage that includes detail design, manufacturing major components and construction of reactor building and auxiliary buildings. In the last couple of years, we will obtain operating license and then will conduct fuel loading, commissioning and pre-service inspection. And finally, we will start the commercial operation of the KJRR by Apr. 2017.

6. References

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[4] I.C. LIM, S.I. WU, Y.S. KWON, J.J. HA, 'PROGRESS OF KI-JANG RESEARCH REACTOR PROJECT,' RRFM2013, 2013.