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Evaluation of Annual Radioisotope Production in H-LPRR

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1. Introduction

On the basis of the IAEA Research Reactor Database (RRDB) [1], the operational and temporary shutdown reactors of about 44% have relatively low power less than 100 kW_{th}. The low power research reactors are widely used for education & training, reactor physics analysis, Neutron Activation Analysis (NAA), and Radioisotopes (RIs) production. Also, as a fundamental infrastructure for nuclear energy program, many countries around the world are planning to build new research reactors before the introduction of nuclear power plants.

The Korea Atomic Energy Research Institute (KAERI) has been developing the new model called as Hybrid-Low Power Research Reactor (H-LPRR) [2]. The new reactor model can be applied as a general research reactor and a critical assembly, and an inherent safety function is increased to prevent reactivity insertion accident. In addition, the H-LPRR has several irradiation holes on the edge of the reactor core for use in NAA and RI production.

The annual RIs production in the H-LPRR is evaluated to confirm the applicability as a RI production facility. Since the ^{99}Mo and ^{131}I isotopes among various RIs are mainly used for the diagnosis and treatment in many hospitals, this study considered with these isotopes only, and a series of calculations are performed using MCNP6.1 code with ENDF/B-VII.0 library [3].

2. Methods and Results

2.1 Core Characteristic and Configuration of H-LPRR

The H-LPRR is designed to be capable of operating for at least 20 years without replacing the nuclear fuels and to be used as a critical assembly. In order to easily access the reactor core, the reactivity compensator of the H-LPRR is located in the center of the core, unlike other reactors. If it is needed to require additional excess reactivity, the water region at the center of the core is partially filled by the reactivity compensator made with beryllium. The H-LPRR is an open tank-in-pool type of 50 kW thermal power (see **Figure 1**), which is designed for education and training, NAA, and medical RIs production (e.g., ^{32}P, ^{99}Mo, and ^{131}I). The reactor core consists of 20 fuel assemblies, reflector blocks, and irradiation holes. The nuclear fuel is 4.65 wt% enriched UO_2 and is the same as the fuel specifications used in the OPR-1000 reactor, except for the axial length. The fuel assembly has a square structure consisting of 3×3 arrangement of UO_2 fuel rods and is designed to enable replacement with surrounding reflectors. The H-LPRR uses two types of reflectors made of beryllium and graphite. The beryllium is used as an inner reflector, which is surrounded by an outer reflector of the graphite canned with aluminum. The fuel assemblies and reflectors are placed on the grid plate and are designed to stand by themselves without any support equipment. The reactivity control is performed by four Control Absorber Rods (CARs) filled with natural B_4C, and the reactor core is cooled by natural convection. There are eight irradiation holes on the edge of the core which is classified into two types: IR (RI production) and NA (NAA) holes.

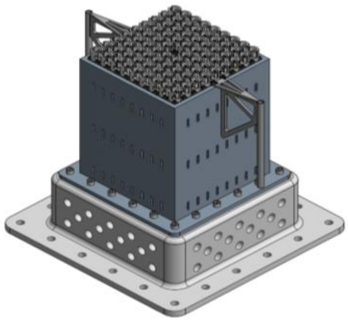
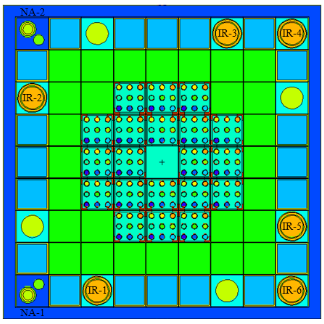


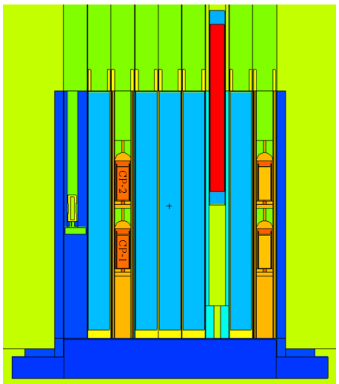
Figure 1. Conceptual Design of the H-LPRR

2.2 Neutron Irradiation Equipment for RI Production

The neutron irradiation holes (IR and NA) are symmetrically arranged on the outermost surface of the core, and unlike IR, the NA irradiation holes (NA-1 and NA-2) are located only on the left side of the core. The IR-1, 2, 3, and 5 among IR irradiation holes have relatively higher neutron flux than IR-4 and 6, and two irradiation capsules (Bottom: CP-1 and Top: CP-2) are loaded in each irradiation hole in the axial direction. It is assumed that the capsules in IR-1 and 5 are filled with MoO_3 powder for producing ^{99}Mo isotope and the capsules in IR-2 and 3 are filled with TeO_2 powder for producing ^{131}I isotope. **Figure 2** shows the X-Y and X-Z cross-sectional views of the H-LPRR MCNP model, respectively.



(a) X-Y Sectional View



(b) X-Z Sectional View

Figure 2. MCNP Model for the H-LPRR

3. Results and Discussions

In order to evaluate annual ^{99}Mo and ^{131}I production in the H-LPRR, some details are considered, as follows;

1) ^{131}I Production
   - TeO_2 Density: 5.67 g/cm^3
   - Irradiation Period: 14 days
   - Cooling Time: 2 day

2) ^{99}Mo Production
   - MoO_3 Density: 1.25 g/cm^3
   - Irradiation Period: 7 days
   - Cooling Time: N/A

Table 1 shows the amount of annual RIs produced in the H-LPRR. As shown in the table, the produced activity in each capsule is almost same each other, regardless of their position in axial direction. It can be estimated that one irradiation hole makes the ^{99}Mo isotope of about 14 Ci and the ^{131}I isotope of about 10 Ci. That is, the H-LPRR can simultaneously provide the ^{99}Mo isotope of about 28 Ci and the ^{131}I isotope of about 20 Ci in every year. Since the radiation therapies using $^{99}Mo/^{99m}Tc$ and ^{131}I use an average of 15 mCi [4] and 30 mCi per treatment [5], respectively, in case of using RIs produced by the H-LPRR, the $^{99}Mo/^{99m}Tc$ and ^{131}I treatments are expected to be possible 1860 times and 666 times, respectively.

Table 1. Annual RIs Production [Unit: Ci]

Irradiation Position		^{99}Mo Activity	^{131}I Activity
IR-1	CP-1	7.06	
	CP-2	7.24	
IR-2	CP-1		4.96
	CP-2		5.02
IR-3	CP-1		4.99
	CP-2		5.07
IR-5	CP-1	7.13	
	CP-2	7.37	

4. Conclusions

In this study, the amount of annual RIs produced from the H-LPRR is evaluated by using the MCNP6.1 code with ENDF/B-VII.0 library. Since the ^{99}Mo and ^{131}I isotopes are widely used in the many hospitals, it is assumed that the H-LPRR produces only two isotopes. As a result, the ^{99}Mo and ^{131}I isotopes can be simultaneously produced at least 28 Ci and 20 Ci per year, and it is expected to be used for 1860 times and 666 times, respectively, when they are used for patient treatment. Therefore, when the H-LPRR is installed in developing countries, it is expected to be sufficiently used for the purpose of RIs production, in addition to education and training purposes.

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