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Innovative Design Concepts for the KIJANG Research Reactor

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been successfully operating the HANARO research reactor of 30 MW power. Based on the HANARO experiences, we started to design a new research reactor, which is named the KIJANG Research Reactor (KJRR), which has finished the conceptual design stage. The KJRR is a medium flux reactor of 15 MW power and loaded with MTR (Materials Testing Reactor) type fuel assemblies. The HANARO uses U_3Si fuel of 3.15 gU/cm^3, but the KJRR adopts U-7Mo fuel of 8.0 gU/cm^3 as a reference fuel. The KJRR has many different design characteristics from those of the HANARO. This paper presents the unique nuclear design concepts for the KJRR.

2. Design Requirements

The core design is dependent on the user's requirements. The KJRR will be mainly utilized for isotope production, NTD (Neutron Transmutation Doping) production, and the related research activities.

2.1 Basic Design Requirements

The basic design requirements should be carefully prepared to fulfill its purpose. The requirements are as follows:

- Reactor power: ~20 MW
- Reactor type: pool type
- Max. thermal neutron flux: > 3.0×10^{14} n/cm^2s
- Operation day per year: ~ 300 days
- Reactor life: 50 years
- Fuel: LEU (Low Enriched Uranium) plate type fuel
- Reflector: Beryllium
- Coolant and flow direction in operation: H_2O, downward forced convection
- Reactor building: confinement

2.2 Performance Requirements

Basically, the nuclear design should satisfy the basic design requirements of the project. The reasonable performance requirements should be prepared for the reactor to be competitive. In the KJRR, safety and economics were preferentially considered. Based on the experiences, operation and maintenance were considered important also. The performance requirements are summarized as follows:

- Fuel assembly
  - MTR type fuel
  - Enrichment: 19.75 w/o
  - U-7Mo: > 6.0 gU/cm^3
- Shutdown system
  - 1st shutdown system
  - 2nd shutdown system with diversity
- Shutdown margin: > 20 mk
- Excess reactivity at EOC (End Of Cycle)
  - Xe override: > 10 mk
  - Irradiation targets: > 15 mk
- Total power coefficient
  - Negative, < -0.5 mk
- Temperature and void coefficient
  - Negative
- Max. thermal neutron flux
  - Core center: > 3.0×10^{14} n/cm^2s
  - Reflector: > 1.5×10^{14} n/cm^2s
- Thermal neutron flux at HTS
  - > 1.0×10^{14} n/cm^2s
- Discharge burn-up
  - Assembly average: 60~70%U-235
  - Local peak: < 90%U-235
- Cycle length: > 37.5 days
- Max. power peaking factor: < 3.0
- Neutron flux interference by other irrad. hole
  - < 5%
  - Minimized at the NTD holes
- Reflector
  - Beryllium, but minimized.
- Fission Mo production
  - 100,000 Ci/year
- Ir production
  - 200,000 Ci/year
- NTD production
  - several holes for 6″ or 8″ Si ingots
  - 300 mm ingot could be accommodating
- FNI (Fast Neutron Irradiation) hole
  - 8 inch wafer
- On power loading
  - Fission Mo production
  - Other RI (Radio Isotope) production
- Coolant and flow direction
  - Core: downward forced convection
  - Reflector: upward forced convection

3. Design Concepts

The nuclear design of the KJRR should satisfy all design requirements prepared. The KJRR core adopts U-7Mo fuel of 8.0 gU/cm^3 density for higher fuel economy. A high uranium loading gives us a longer cycle length, but following disadvantages are given at the same time.

- Smaller control rod worth
- Lower thermal neutron flux
- Higher power peaking

In the design of the KJRR, several important concepts are employed to overcome the disadvantages as follows.

1) Core with edge trimmed irradiation hole: Usually a research reactor core has a core configuration with a constant fuel assembly pitch. Sizes of in-core irradiation holes are limited to multiple sizes of the fuel assembly. We developed a new design concept to overcome this constraint [1]. It was found that this concept is very useful, and the KJRR core uses the new concept. The new concept is used to construct a core using edge trimmed irradiation holes. Edges of the irradiation hole are trimmed, unlike conventional irradiation holes which are rectangular boxes with one more holes. As the frame of the conventional irradiation hole is rectangular in shape, the space is not fully used for experimental facilities, which are of cylindrical shapes. The frame of the new irradiation hole becomes more compact by trimming the superfluous parts. This core concept provides a large irradiation volume and large space for the Control Absorber Rods (CARs). An effective irradiation volume increases about 39%.
2) Detachable CARs: The KJRR core uses detachable CARs to control and shut down the reactor. Thus, the core is constructed using two types of fuel assemblies, a standard type and a follower type. The standard fuel and follower fuel have the same box size by virtue of the new irradiation hole. When a follower fuel is loaded into the core, a Hf absorber is attached to the end of the fuel. As the fuel assembly and Hf absorber are moving together, a larger control rod worth is available to control the KJRR core with large uranium loading, in which the total uranium loading of the nominal core is 70.1 kgU.
3) Unique core configuration: The core configuration should be optimized according to its purpose. The core design is strongly dependent on the number of in-core irradiation holes and CARs. A core model with 3 in-core irradiation sites fully surrounded with fuel assemblies is selected as shown in Fig. 1. This core is composed of 7x9 lattices with its active length of 60 cm. The nominal core consists of 22 fuel assemblies, in which 16 standard and 6 follower fuel assemblies are loaded. The core has 6 CARs to control and shutdown the reactor. The reactor regulating system shares 4 CARs with the reactor protection system, which are driven by stepping motors. The independent secondary shutdown system uses 2 CARs, which are fully withdrawn at a normal operation state by hydraulic force. The arrangement of the CARs is carefully studied to minimize the flux perturbation and maximize the reactivity worth. Figure 1 shows that 4 fission moly targets are loaded at the lateral positions, but more targets can be loaded.

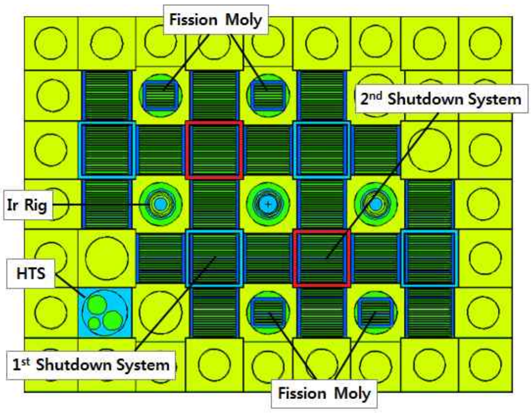

Fig. 1: A core configuration of the KJRR

The core is located within a core box, which will prevent core uncovered at any emergency state. A HTS (Hydraulic Transfer System) is located within the core box to get a thermal flux above 1.0x10^{14} n/cm^2/sec. Two PTS (Pheumatic Transfer System) and 5 NTD holes are located outside the core box. One hole is prepared for the FNI facility, which can be easily used for NTD. The outside of the core box is surrounded with Be, Graphite and Al, in which its materials are chosen depending on its accessibility and the fast flux level.

4. Conclusions

We succeeded in obtaining a new conceptual core for the KJRR. The conceptual core provides proper thermal fluxes at 15 MW power. The cycle length of 50 days is very long when compared with 28 days of the HANARO. The high discharge burn-up will provide us with a highly economic benefit.

REFERENCES

[1] Chul Gyo Seo and Nam Zin Cho, "A Core Design Concept for Multi-purpose Research Reactors," Nuclear Engineering and Design **252** (2012) 34-41, 2012.