NEUTRONIC ANALYSIS FOR THE FISSION MO PRODUCTION USING LEU TARGET AT HANARO

Byung Chul Lee and Heonil Kim
HANARO Center
Korea Atomic Energy Research Institute
P.O. Box 105, Yuseong, Daejeon, Korea
Email: bclee2@kaeri.re.kr; hkim@kaeri.re.kr

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ABSTRACT

Study on the use of low-enriched uranium for the fission Mo production at HANARO has been performed. Using U metal foil and UO_2 as a target material, the target geometry of low-enriched uranium is specified in consideration of the irradiation hole size and the producible amount of Mo-99 activity. The thickness and length of target are decided to be in the range of 80~100μm and 10~20cm, respectively. The target reactivity is calculated for various conditions of the control absorber rods, the target and the irradiation hole. As a result, it is estimated to be negligible compared with the reactivity limit of 12.5mk. The fission power generated at the target is calculated to 26~37kW at the reactor power of 30MW. With the target power, Mo-99 activity that can be produced from the target, is calculated using the ORIGEN2 code. Assuming 5 days irradiation, 1 day cooling and 1 day processing, the Mo-99 activity in a 6-day reference is estimated at 100~141Ci/week.

INTRODUCTION

Tc-99m, a daughter isotope of Mo-99, is the most widely used radioisotope in diagnostic medical imaging procedures not only at home but also in the world. It is totally imported and its steady supply is very important to the patients considering the relatively short half-life, 66hours, of Mo-99.

The operation of HANARO, a multipurpose research reactor, made it possible to enlarge the research and utilization in the areas of neutron beam research, radioisotope production, etc. From this point of view, the technology development for the fission Mo production using high-enriched uranium (HEU) had been studied with the HANARO[1-3]. Many parametric studies for the target such as geometry, shape, material, etc., were performed to examine the nuclear characteristics of reactivity worth, surface heat flux and Mo-99 activity. Because of a change in circumstances, however, it is studied on the use of low-enriched uranium (LEU) as a target based on the results of HEU target.

This paper describes the reactivity effects and the expected Mo-99 activity for irradiating LEU target to produce fission Mo.

OVERVIEW OF HANARO

HANARO is a 30MW open pool type reactor, cooled and moderated by light water. Its core consists of 23 hexagonal and 16 circular sites shown in Fig. 1. Of these, 8 circular sites called OR are located just outside the inner core. For the irradiation experiment inside the core, 3 hexagonal sites in the inner core and 4 circular sites in the outer core are reserved. One of OR holes, OR3, is selected for irradiation of fission Mo target. There are two kinds of fuel assembly types, 36-element hexagonal fuel assembly and 18-element circular fuel assembly. At HANARO, radioisotopes such as Ho-166, Ir-192, etc. for the medical and industrial uses, are currently being produced.

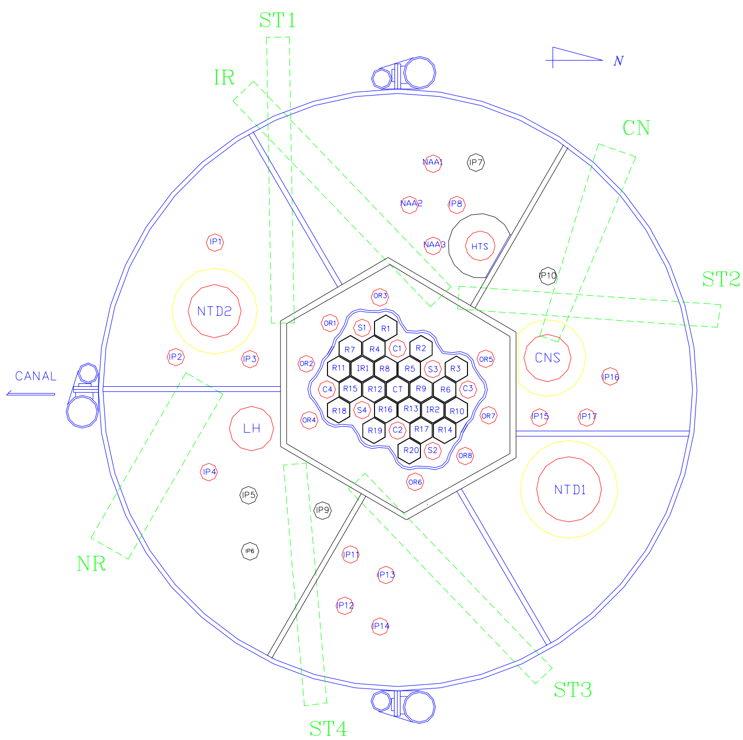

Fig. 1. Plan View of the HANARO Core

LEU TARGET DESIGN

Design Goal

The goal in the LEU target design is to produce the Mo-99 activity corresponding to the domestic demand. The current domestic demand of Mo-99 activity is less than 100Ci per one week in a 6-day reference. Considering the anticipation of the continuous increase in domestic demand, a loss during processing and calculational uncertainty, the Mo-99 activity to be produced from the target is set to over 100Ci assuming an irradiation of one LEU target in a week.

Target Material and Size

Uranium metal foil and UO_2 are taken as the LEU target materials. Foil is currently regarded as the most competitive LEU target compared with the HEU target for fission Mo production. ANL is developing the technology for fission Mo production using foil[4]. KAERI is also developing the foil as the fission Mo target.

Based on prior feasibility studies[1,2], the geometry of the foil target is decided that the length is 10cm and the thickness is 80μm~100μm. The foil is coated with Ni of 10μm thickness to prevent the interaction between uranium and Al cladding. The Ni-coated foil is then clad with 1.5mm thick aluminum to make the LEU target assembly. It is an annulus type. The target will be loaded into the irradiation hole during the reactor operation because the HANARO is a multipurpose reactor and its operation should not be interrupted by the fission Mo target irradiation. The OR hole size of the inner diameter of 6cm and the thickness of irradiation guide tube confine the available size of the target. With a 2mm coolant gap, the maximum available outer diameter for the target is about 4.4cm. The cross section of the foil target is given in Fig. 2.

UO_2 target is a Cintichem type target. UO_2 is electro-deposited on the inner surface of stainless steel tube of 800μm thickness. The thickness of UO_2 is selected as 80μm or 100μm and its length as 20cm and/or 15cm. The geometry is also drawn in Fig. 2.

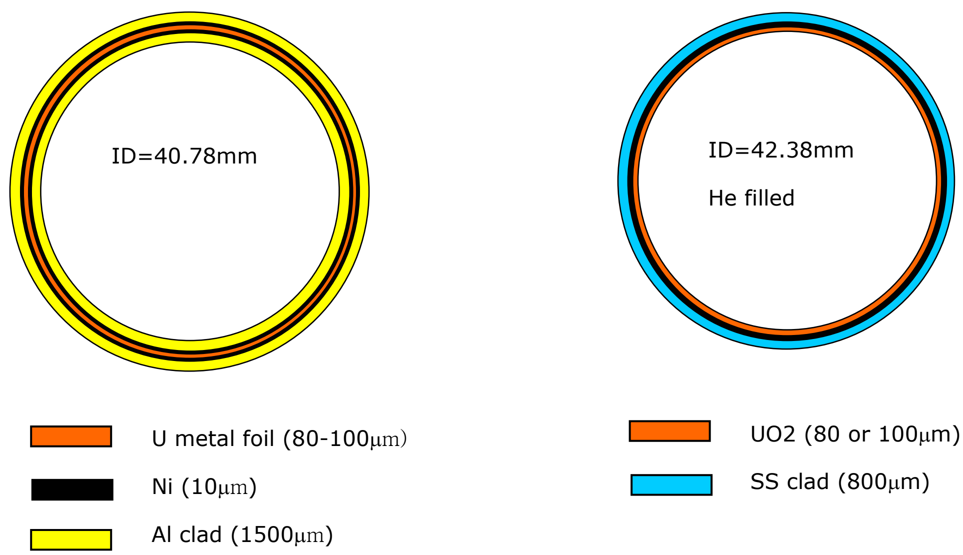

Fig. 2. LEU Target of U Metal Foil and UO_2

CALCULATIONS

Target Reactivity

HANARO has many utilization areas such as neutron beam experiment, material irradiation test, NTD-Si production, etc. The reactor should not be interrupted due to the loading and unloading of the fission Mo target. Thus, the on-power loading equipment is necessary for the target irradiation.

The reactivity inserted into the core due to the target loading is estimated for various cases using MCNP. It is assumed in the calculation that the target is irradiated while clinging to the on-power loading equipment. The core is assumed to consist of fresh fuels and the CARs (Control Absorber Rods) are inserted by half. When the target is irradiated at the position of peak neutron flux in OR3 hole, the target reactivities are summarized in Table 1. The total reactivities of the target are calculated to 0.25~0.66mk. Even though the statistical uncertainty is taken into account, the induced target reactivity is revealed to be very small compared with the reactivity limit of 12.5mk in HANARO. In addition, the reactivities are calculated for different irradiation positions of foil target. They are also calculated to be small of -0.09~0.89mk. Fig. 3 shows the reactivity for different target irradiation position.

Table 1. Reactivity for Fission Mo Target at OR3 in HANARO

Target	Thickness (μm)	Length (cm)	k-effective (±1σ)	Reactivity (mk)	Target Power (kW)
Reference			1.17299	-	-
U metal foil	80	10	1.17371±0.00033	0.523	30.8
	90	10	1.17334±0.00033	0.254	33.6
	100	10	1.17371±0.00034	0.523	36.9
UO_2	80	20	1.17390±0.00037	0.661	29.5
	100	15	1.17340±0.00033	0.298	26.4
	100	20	1.17359±0.00036	0.436	35.5

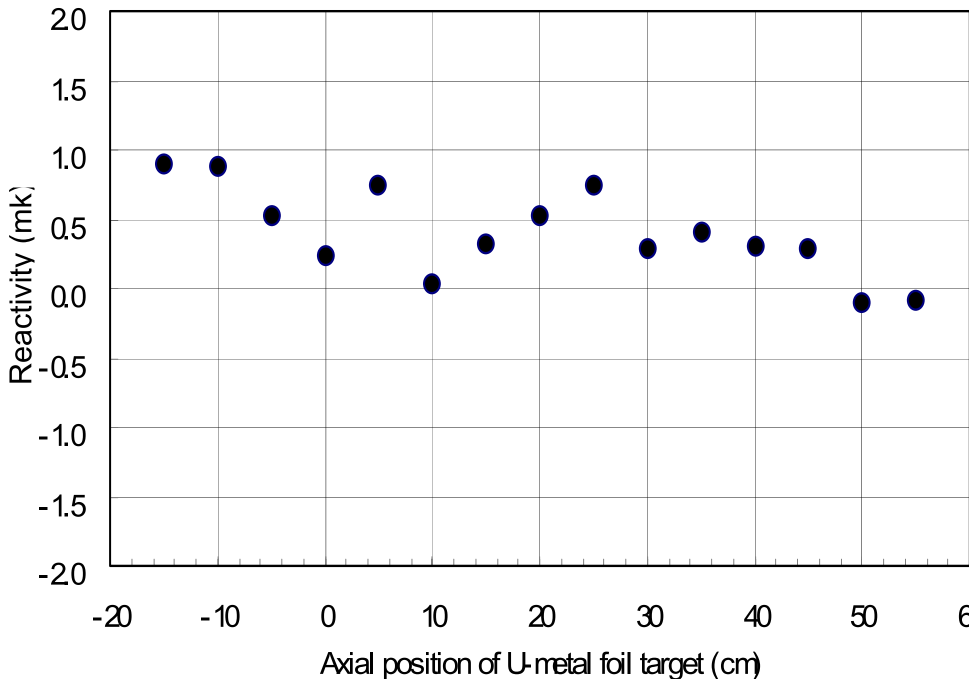

Fig. 3. Reactivity of 10cm Long U Metal Foil Target at Different Irradiation Position.

The target will be loaded and unloaded while the reactor is operating. Thus, the reactivity insertion rate due to the target loading becomes very important from the viewpoint of reactor safety. Considering the small reactivity of the target, it is believed that the target loading equipment to satisfy the limit of the reactivity insertion rate can be designed. Detail analysis to decide the target loading speed will be performed.

Mo-99 Activity

The Mo-99 activity is calculated from the ORIGEN2 using the target power by MCNP. Since the core is assumed to be fresh in the MCNP calculation, 20% of the calculated power is added as the effect of core burnup, which is obtained from the comparisons of the MCNP and depletion calculations. The calculated target power is also given in Table 1.

From the Mo-99 yield ratio and Mo-99 specific activity according to the irradiation time[1], the target irradiation time was decided to 5 days. In the calculation of Mo-99 activity after the irradiation, cooling and processing time are assumed to 1 day each. The calculated Mo-99 activities at the end of irradiation and in a 6-day reference are listed in Table 2. From the foil target of 100μm in thickness and 10cm in length and the UO_2 target of 100μm in thickness and 20cm in length, 141 Ci and 136 Ci Mo-99 in a 6-day reference can be produced, respectively. The design target for the Mo-99 activity can be satisfied for all LEU targets considered here.

Table 2. Mo-99 Activity for Fission Mo Target at OR3 in HANARO

Target	Thickness (μm)	Length (cm)	Mo-99 activity (Ci)	
			End of irradiation	6-day reference[a]
U metal foil	80	10	1106	118
	90	10	1207	129
	100	10	1325	141
UO2	80	20	1059	113
	100	15	948	101
	100	20	1275	136

[a] With an assumption of recovery fraction of 80% in processing.

CONCLUSION

The LEU target to produce fission Mo at HANARO is designed with U metal foil and UO_2 considering the irradiation hole size and the targeted Mo-99 activity. The reactivities of targets with various thickness and length are calculated to be very small compared with the limit at HANARO. Since the target will be loaded and unloaded during the reactor operation, the reactivity insertion rate due to the target loading should be as low as possible within the limit in order to operate the reactor safely. It is believed from the total target reactivity that the on-power loading equipment satisfying the limit of reactivity insertion rate during the target loading can be designed.

The Mo-99 activity that can be extracted from the target, is revealed to be enough for the current and future domestic demands. The actual amount of Mo-99 activity should be determined from an experiment of chemical processing.

Thermal analysis for the proposed LEU target using the calculated target power is in progress. Detail analysis including accident analysis will continue.

ACKNOWLEDGEMENTS

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