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Development of Fission Mo-99 Production System for Hot Irradiation Test at HANARO

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1. Introduction

Molybdenum-99 (^{99}Mo) has been one of the most important isotopes for more than 50 years. Since its daughter isotope ^{99m}Tc is the most commonly used medical radioisotope which covers 85% of overall nuclear diagnostics. [1–2] More than 95% of ^{99}Mo is produced through fission of ^{235}U because, ^{99}Mo generated from the fission (fission ^{99} Mo) exhibits very high specific activity (~10^4Ci/g). These days, worldwide ^{99} Mo supply is not only insufficient but also unstable. Because, most of the main ^{99}Mo production reactors are more than years old and suffered from frequent and unscheduled shutdown. Therefore, movement to replace old reactors to keep stable supply is now active. Under these conditions, KAERI (Korea Atomic Energy Research Institute) is developing LEU-based fission ^{99}Mo production process which is connected to the new research reactor (Kijang New Research Reactor, KJRR), which is being constructed in Gijang, Busan, Korea. [3]

Historically, the most fission ^{99}Mo producers have been used highly enriched uranium (HEU) targets so far. However, to reduce the use of HEU in private sector for non-proliferation, ^{99}Mo producers are forced to convert their HEU-based process to use low enriched uranium (LEU) targets. Economic impact of a target conversion from HEU to LEU is significant. Overall cost for the production of the fission ^{99}Mo increases significantly with the conversion of fission ^{99}Mo targets from HEU to LEU. It is not only because the yield of LEU is only 50% of HEU, but also because radioactive waste production increases 200%. [4–7] To evaluate the efficiency and yield of the LEU-based fission ^{99}Mo production process, we developed pilot-scale production system. By using the system, test hot production will be performed with depleted uranium (DU) target irradiated in HANARO. The hot production system will be installed in a hot cell in the Irradiated Material Examination Facility at HANARO. The experimental result will be applied to the development of full-scale fission ^{99}Mo production systems of KJRR.

2. Methods and Results

Target: In KAERI's fission ^{99}Mo process, plate-type LEU target with UAlx meat and Al-6061 cladding is used. Compared with general pulverized UAlx powders, KAERI's powders prepared by the unique centrifugal atomization technology have spherical shape with small surface area. And, those differences may lead to different dissolution behavior during the chemical process. To be used in the pilot-scale hot production system, DU target with same specification will be used. (Fig. 1)

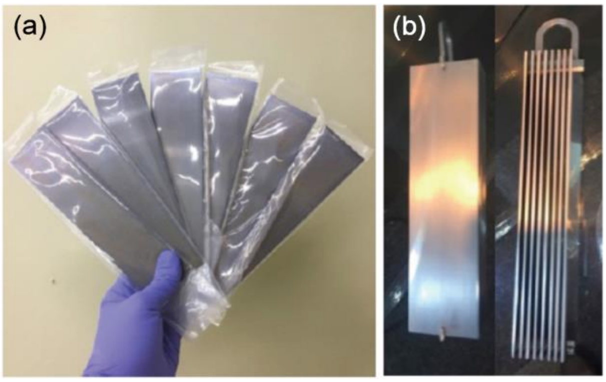

Fig. 1. (a), (b) Commercial grade LEU target and target assembly for fission Mo-99 production.

Process: Targets with atomized UAlx powders are dissolved in sodium hydroxide solution to extract ^{99}Mo into the solution. Other fission products including unreacted uranium and actinides are removed from the solution. Medical-grade ^{99}Mo can be extracted after proper chemical treatments and multi-step separation and purification process. During the process, undesired dissolved aluminum is removed by sedimentation forming sludge-type precipitates. The overall scheme of the KAERI's fission ^{99}Mo process is presented in Figure 2.

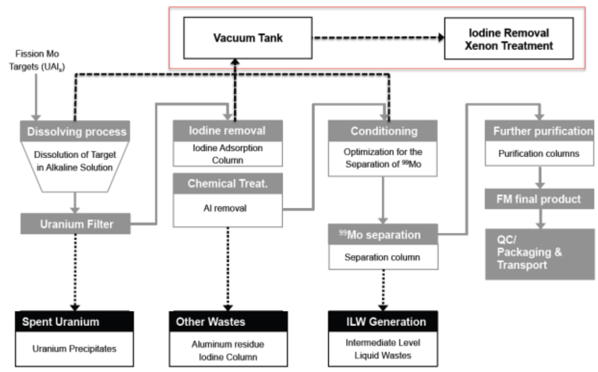

Fig. 2. Scheme of fission Mo-99 production process.

Irradiation: For the hot test production, we aimed 10 Ci total activity with ~1 Ci ^{99}Mo. To find optimized irradiation condition for the desired radioactivity, combustion analysis was performed as shown in the figure 3a. 10.84 Ci of total radioactivity is expected from two DU targets when they are irradiated for 7 days in the IP5 irradiation hole at HANARO.

Production System: To evaluate the efficiency and yield of the LEU-based fission ^{99}Mo production process, pilot-scale production system was developed as shown in the figure 3b. By using the system, test hot production will be performed with depleted uranium (DU) target irradiated in HANARO. The hot production system will be installed in a hot cell in the Irradiated Material Examination Facility at HANARO.

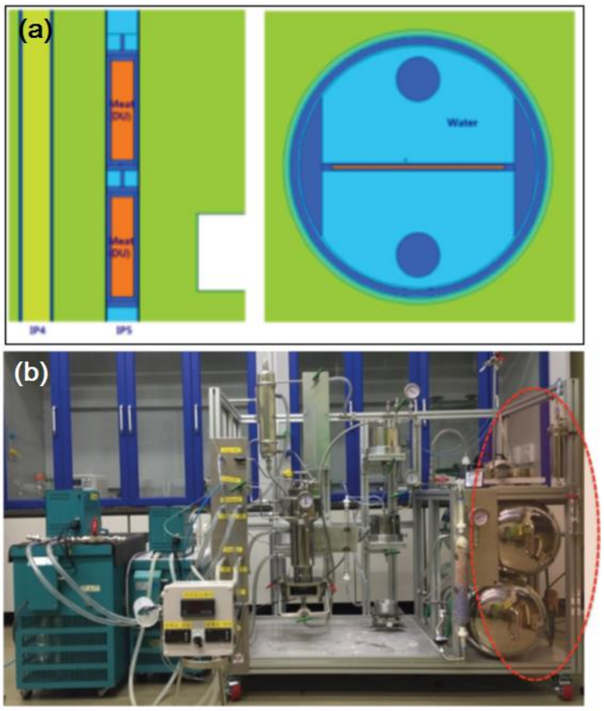

Fig. 3. (a) Irradiation calculation at HANARO, (b) fission Mo-99 production equipment designed and fabricated for hot test at HANARO.

3. Conclusions

In this study, development of pilot-scale fission ^{99}Mo production system was presented. By using the system, test hot production of 1 Ci ^{99}Mo will be performed with depleted uranium (DU) target irradiated for 7 days in the IP6 hole of HANARO. The hot production system will be installed in a hot cell in the Irradiated Material Examination Facility at HANARO. And, the experimental result will be applied to the design of full-scale fission ^{99}Mo production systems for KJRR. The KJRR is aiming weekly production of 2000 Ci fission ^{99}Mo to cover 100% Korean domestic demand (~150 Ci/wk) as well as 18% of the international ^{99}Mo market (International market: 10,000–12,000 Ci/wk in 2015).

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