Design and fabrication of the xenon emission mitigation system for the fission Mo-99 production process

Suseung Lee*, Seung-Kon Lee, Won-Je Cho, Taewoon Kim, Sung-Soo Nam, Kwon Mo Yoo, Jun Sig Lee
Division of Radioisotope Research, Korea Atomic Energy Research Institute, 989-111 Daedoek-daero, Yuseong-gu, Daejeon, 305-353 Republic of Korea
**Corresponding author: ssl1863@kaeri.re.kr*

1. Introduction

Technetium-99m (Tc-99m) is one of the most important radioisotopes which are frequently used for the diagnoses of the metastases, cerebrovascular and cardiovascular diseases. Tc-99m can be easily obtained by the conventional Mo-99/Tc-99m generator with the molybdenum-99 (Mo-99), the mother nuclide of Tc-99m. Mo-99 has been commonly produced from the fission of U-235 in order to achieve the high specific radioactivity. However, numerous residual fission products are generated as the impurity by considerable from the fission Mo-99 production process. [1] Among them, radioactive gases such as radioiodine and radioxenon are needed to be treated with the off-gas treatment system before release into the environment.

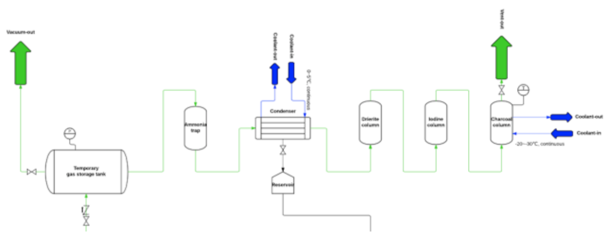

Fig. 1. Off-gas treatment system from the fission Mo-99 production process.

Especially, mitigation of radioactive xenon emission is recently emerging as a major issue because it can cause not only harmful effects on environment but also critical interferences on the nuclear test monitoring activities. In Korea, fission Mo-99 production facility (which is being constructed in Kijang, Busan) aims 2,000 Ci/week (8 days after EOB) Mo-99 productions, and radioxenon emission from the facility should be maintained under the limit (5 GBq/day) suggested by CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization) in accordance with the radioxenon emissions pledge. [2]

On the assumption that Mo-99 can be produced successfully and operated routinely as planned, it is expected that about 13,000 Ci of radioxenon (24 hrs after EOB) can be contained within the off-gases.

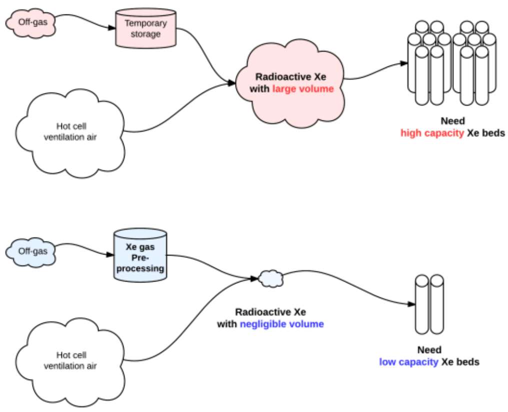

Fig. 2. Conventional (upper) and newly developed system (lower) for mitigating of xenon gas emission at fission Mo-99 production facilities.

In order to meet the above mentioned criteria, radioxenon should be decayed for more than 80 days before release into the environment. With the conventional mitigation system, however, operation of the huge equipment such as delay beds or decay tanks is required and causes economic hardship to the Mo-99 producers. In this research we proposed and developed the compact and efficient xenon emission mitigation system, which can assist in reducing the scale of the conventional huge equipment as playing a role of a pre-processing system.

2. Methods and Results

In order to mitigate the radioxenon emission, the combination of decay tanks and delay beds is widely used as a conventional system. However, xenon has a poor adsorption characteristic due to its properties as inert gas. In general, activated charcoal has been widely used as the adsorbent for the radioxenon delay bed, but that does not show so high adsorption efficiency with the typical operating conditions, too.

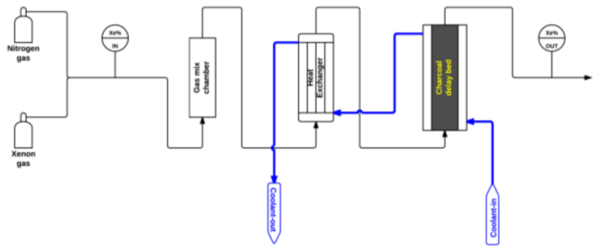

Fig. 3. Lab-scale test module of xenon pre-processing system.

As previously reported [3], adsorption performance of the activated charcoal for inert gases can be dramatically increased with decreasing the bed operating temperature. On the basis of above research studies, we fabricated the compact charcoal delay bed system which can be operated with low temperature condition. Delay bed was designed with a double-jacketed column, which can chill the packed activated charcoal continuously by circulating the cooling medium through the jacket. And heat exchanger was connected with the charcoal bed column to cool down the temperature of incoming gases prior to the delay bed. Fabricated lab-scale module was tested with different operating temperature varied from -25℃ to 20℃, and the system with 707 g of activated charcoal could show about 3.8 L xenon trap capacity for 142 hours without release of xenon gas at -25℃ operating temperature.

Furthermore, some mathematical models for xenon adsorption phenomena in the xenon delay bed system were built up and computational modeling was carried out to optimize the operating conditions of the xenon delay bed. As a result of the process modeling based on the experimental results above, parameters of the xenon adsorption process were estimated and verified.

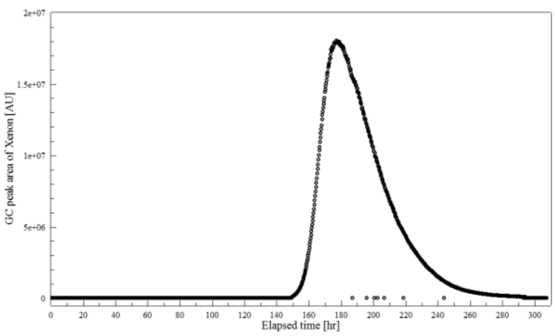

Fig. 4. Result of the xenon gas adsorption experiment at -25℃ operating temperature.

3. Conclusions

The mitigation of radioxenon emission from the radiopharmaceutical production facilities is an important issue as a point of both environmental and political aspects. In here we proposed the efficient xenon emission mitigation system from optimizing the operating condition. As a result of the optimization research, a compact xenon delay bed system which can be operated at low temperature was fabricated and the performance was estimated. It showed the advanced xenon delay performance although reducing the scale of the equipment as compared with the conventional huge equipment.

REFERENCES

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[2] CTBTO, Breakthrough in mitigating radioxenon emissions, (www.ctbto.org/press-centre/press-releases/2013/breakthrough-in-mitigating-radioxenon-emissions)
[3] W. F. Kenney, and A. M. Eshaya, Adsorption of Xenon on Activated Charcoal, Brookhaven National Laboratory, 1960.