Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Design of Adsorption Module and Air-sampling System for ^{85}Kr Analysis

Young Gun Ko *, Hyuncheol Kim, Hajin Song, Jeonghyeon Ryu, Sang-Do Choi, Jong-Myoung Lim, Wanno Lee
Nuclear Energy & Environment Research Laboratory, Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea
**Corresponding author: ygko@kaeri.re.kr*

1. Introduction

The radioactive noble gas ^{85}Kr (beta emitter, E_{max}: 687 keV, half-life: 10.76 years) distribution in the atmosphere can be used as an indicator of clandestine separation of plutonium for the preparation of nuclear weapons [1]. A Budesamt für Strahlenschutz - Institute of Atmospheric Radioactivity (BfS-IAR) system is the only commercialized system developed by the Budesamt für Strahlenschutz (Germany) to analyze the radioactivity of ^{85}Kr in the atmosphere [2]. However, the BfS-IAR system is operated manually, and requires 1 week air-sampling period. For those reasons, continuous and reliable data with a high level of accuracy have not been obtained by using the system. The analysis system consists of several steps of air sampling, first concentration, second concentration, purification and determination of radioactivity.

In this study, design of adsorption module and air-sampling system for automatic ^{85}Kr analysis has carried out. Temperature distribution in the adsorption module was analyzed using an ANSYS FLUENT CFD software. Automatic air sampler was newly developed with a hollow-fiber membrane module.

2. Materials and Methods

The distribution of temperature in the adsorption module was analyzed with an ANSYS FLUENT CFD software. Numerical simulations of air flow into the module was presented. Two cases were modeled to select the optimum structure design of the adsorption module (^{85}Kr sampling module) (Fig. 1).

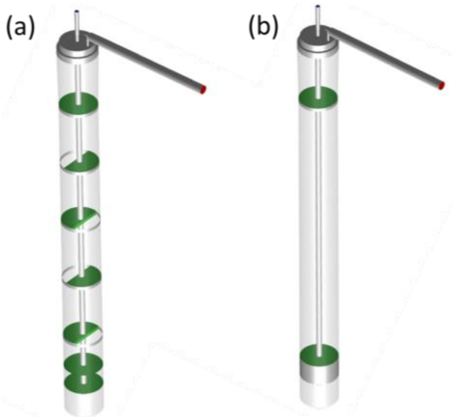

Fig. 1. Basic 3D model for the simulation by using ANSYS FLUENT CFD; Adsorption module (a) with and (b) without baffles.

The sampling step of the BfS-IAR system was automated with an air compressor, a heat exchanger, a hollow-fiber membrane module, a multi-position valve (MPV) system, several adsorption modules and a cooling chamber (Fig. 2).

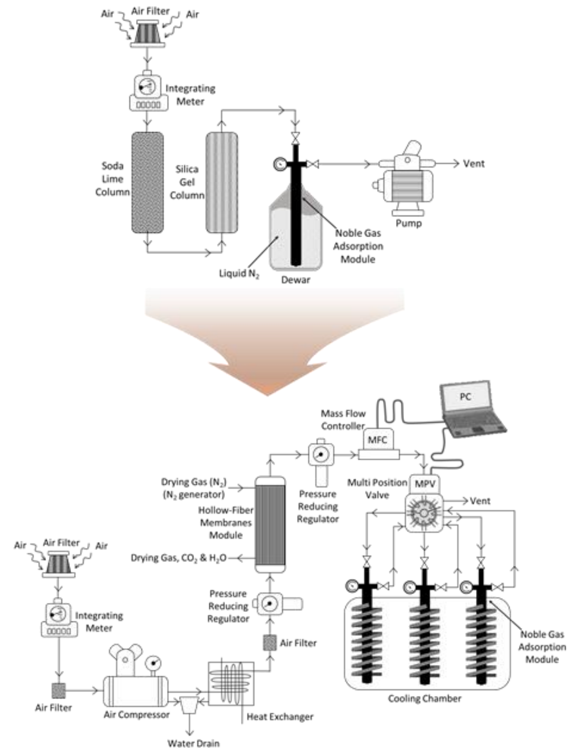

Fig. 2. The schematic diagram of the novel KAERI air-sampling system.

Attenuated total reflectance Fourier transform infrared spectroscopy (ATR FT-IR) was performed using a Frontier spectrometer (PerkinElmer) equipped with a diamond coated KRS-5 crystal (PerkinElmer, Universal Diamond ATR) to analyze the hollow-fiber membrane. The morphologies of the activated charcoal and the hollow-fiber membrane were examined using a field emission gun scattering electron microscopy (FEG-SEM) (Inspect F50, FEI) at 10 kV.

To compare the CO_2 and water sequestration performance of the KAERI air-sampling system with other air-sampling systems, one subunit of the two parallel subunits in the air-sampling part of the Swedish Automatic Unit for Noble gas Acquisition (SAUNA) system was fabricated (Fig. 3) [3].

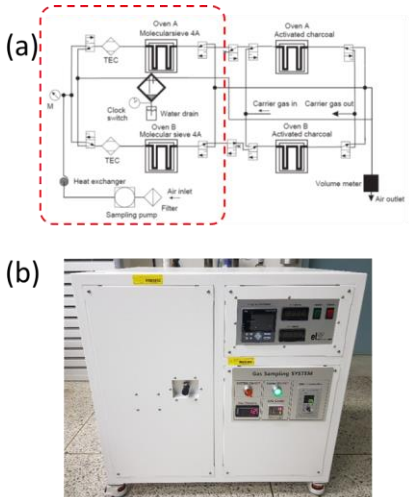

Fig. 3. (a) The schematic diagram and (b) an imitated product of the air sampling part of SAUNA.

3. Results and Discussion

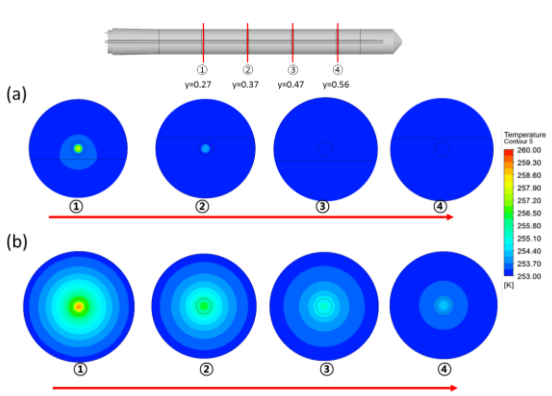

Fig. 4. Sectional heat-transfer analysis by using ANSYS FLUENT CFD; Adsorption module (a) with and (b) without baffles.

Table I: Comparison of Water and CO_2 Sequestration Capacities between Various Air-sampling Systems (Concentration of Their Sequestration)

	Water sequestration capacity (ppm)	CO_2 sequestration capacity (ppm)
BfS-IAR	< 40 (measured at a process toward the adsorption module	< 10
SAUNA	< 20	< 10
KAERI system	< 40 (measured at a process toward the transfer process into a silica gel column connected mini-can	< 10

The heat-transfer simulation of adsorption module showed that baffles in the module clearly operated the temperature drop of char coal particles in the adsorption module. Fig. 4 shows the sectional heat-transfer analysis of two-types (with/without baffles) of adsorption modules by using ANSYS FLUENT CFD.

The ATR FT-IR and FEG-SEM analyses demonstrate that the used hollow-fiber membrane is polysulfone with 60 μm of wall thickness and 240 μm of inner diameter.

The comparison of water and CO_2 sequestration capacities between BfS-IAR, SAUNA and the KAERI system is summarized in Table I. The values for BfS-IAR and SAUNA are obtained after 30 min operation of their systems while the values for KAERI system are after 6 hrs. The novel KAERI system exhibits high water and CO_2 sequestration capacities.

4. Conclusions

In this study, the sampling step was automated by using a membrane module, a heat exchanger, an automatic air-flow distribution system, a thermostat bath and newly designed modules. In addition, the distribution of temperature in the adsorption module was analyzed with an ANSYS software to design new adsorption modules and showed that baffles in the module clearly operated the temperature drop of char coal particles in the adsorption module. The developed air sampling system was well operated automatically, and demonstrated high sequestration efficiency of moisture and CO_2 in the air sample.

REFERENCES

[1] M. Aoyama, K. Fujii, K. Hirose, Y. Igarashi, K. Isogai, W. Nitta, H. Sartorius, C. Schlosser, W. Weiss, Establishment of a Cold Charcoal Trap-Gas Chromatography-Gas Counting System for ^{85}Kr Measurements in Japan and Results from 1995 to 2006, Technical Reports of the Meteorological Research Institute No. 54, Meteorological Research Institute, Japan, 2008.

[2] C. Schlosser, A. Bollhöfer, S. Schmid, R. Krais, J. Bieringer, and M. Konrad, Analysis of radioxenon and krypton-85 at the BfS noble gas laboratory, Applied Radiation and Isotopes, Vol. 126, pp. 16-19, 2017.

[3] A. Ringbom, T. Larson, A. Axelsson, K. Elmgren, and C. Johansson, SAUNA - a system for automatic sampling, processing, and analysis of radioactive Xenon, Nuclear Instruments and Methods in Physics Research A, Vol. 126, pp. 16-19, 2017.