Gaseous Tritium Measurement Using Plastic Scintillator

Jun Woo Bae* and Hee Reyoung Kim
Ulsan National Institute of Science and Technology, 50, UNIST-gil, Eonyang-eup, Ulju-gun, Ulsan, Republic of Korea
*skypia12@unist.ac.kr

1. Introduction

Tritium is one of concerning radioactive nuclide during operating or decommissioning of nuclear power plant. Tritium is difficult to detect because it only emits beta ray with very low energy (~18.6 keV). In general, radioactivity of tritium is analyzed using liquid scintillation counter (LSC) [1]. Tritium detection using LSC has merit of high accuracy, but it generates organic waste which is harmful to the environment. Therefore, analysis of huge amount of sample using LSC is not preferred. For this reason, studies to measure the tritium using vaporization or gasification have been conducted for routine monitoring of tritium [2–3]. Detection efficiency of the beta ray emitted from the tritium in liquid state is extremely low due to self-absorption. So that, detection of gasified tritium has a merit of increase of detection efficiency without using liquid scintillation cocktail.

In this study, two types of gaseous tritium detector based on the plastic scintillator were designed. The detectors were designed suitable for the continuous and waste-less detection of gaseous tritium. Estimation of detection efficiency was carried out for those detectors.

2. Materials and Methods

2.1 Design of detectors

Two types of detector design were proposed: one was pellet-filling type and the other one was reflector type. All scintillators were polystyrene based plastic scintillator with maximum emitted wavelength of 415 nm. For pellet-filling type, 200 of small cylindrical plastic scintillators (5 mm (H) × 5 mm (Φ)) were filled in a detection chamber (20 mm (H) × 50 mm (Φ)). Two circular plastic scintillators (1 mm (H) × 50 mm (Φ)) were used to seal the detection chamber. For reflector type, there was no pellet scintillator in the chamber. Otherwise, Teflon tape was coated inside the detection chamber to increase light collection efficiency.

The detection chamber was same to the both type. The detection chamber was fabricated by processing 60 mm × 60 mm acrylic bulk. There were holes for two facing sides with diameter of 51 mm to fix the photomultiplier tubes (PMTs).

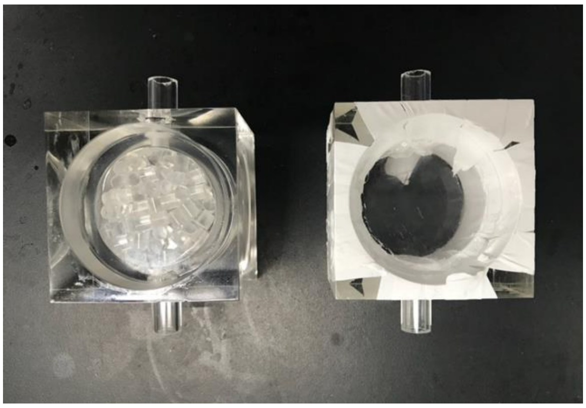

Fig. 1. The pellet-filling type detector (left) and the reflector type detector (right).

2.2 Light detecting apparatus

The light detecting apparatus was used to detect the light produced by interaction between beta ray and the scintillator. The apparatus consisted PMT and sockets, and nuclear instrument modules(NIMs) for coincidence measurement of the signals from two PMTs. The photomultiplier tubes were optically coupled with the plastic scintillators which were attached to the detection chamber.

2.3 Hydrogen gas preparation

The detection efficiency of each detector was estimated by using self-produced tritiated hydrogen gas through electrolysis. 10-stack of proton-exchange membrane electrolysis cell was used and 7A of current was applied to the electrolysis cell. The tritium concentration of the produced gas was quantified using a fractionation factor [4]. The tritium concentrations of self-produced hydrogen gas were 1,600 and 1,020 kBq/m^3, respectively. Fig. 2 shows the conceptual diagram of the experimental process.

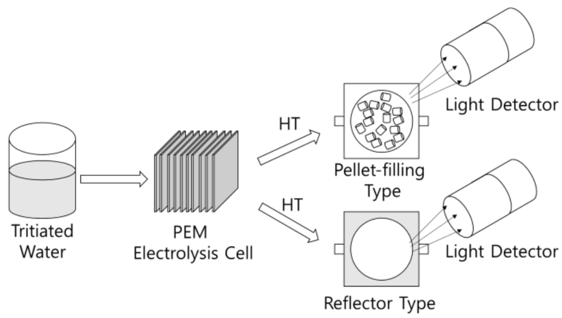

Fig. 2. Conceptual diagram of the experimental process.

3. Results

The detection efficiency of each detector was estimated using the self-produced tritiated hydrogen gas. Net counting rates for pellet-filling and reflector type detector were 0.56 and 1.7 cps, respectively. The tritium activity in the chamber was calculated taking into account the volume reduction of the detection chamber by the pellets. Detection efficiencies for the detectors were 1.78 and 4.25%, respectively. The reflector type showed 2.4 times higher detection efficiency than the pellet-filling type.

Table 1. Detection efficiency estimation according to the type of detector

Detector	Pellet-filling	Reflector
Net Counting Rate (cps)	0.56	1.7
Tritium Concentration (kBq/m^3)	1,600	1,020
Volume of the Chamber (m^3)	1.96×10^{-5}	3.93×10^{-5}
Tritium Activity in the Chamber (Bq)	31.4	40.1
Detection Efficiency (%)	1.78	4.25

4. Conclusion

Two designs for the gaseous tritium measurement using plastic scintillator were proposed. One was designed to increase the area of the interaction with tritium, and the other was designed to increase the light collection efficiency. It was confirmed that the light intensity after the interaction with the tritium was very low, so that it was effective to increase the light collection efficiency. For future works, detector designs to increase both light collection efficiency and interaction area with tritium will be considered. Also, increasing the size of the detection chamber without loss of detection efficiency will be further studied to allow more tritium into the chamber and lower the detection limit.

ACKNOWLEDGEMENT

This work was supported by the Industrial Technology Innovation Program (Real-Time Underwater Tritium Monitoring Technology by Electrolysis) through the Korea Institute of Energy Technology Evaluation and Planning under Grant 2016520101340.

REFERENCES

[1] S, Yoon, W.H. Ha, and S.S. Lee, “Tritium analysis of urine samples from the general Korean public.”, Applied Radiation and Isotopes, 81, 276–278 (2013).

[2] E. Furuta, Y. Kato, and S. Fujisawa, “Measurement of tritium with plastic scintillators in large vials of a low background liquid scintillation counter: an organic waste-less method”, Journal of Radioanalytical Nuclear Chemistry, 314, 701–708 (2017).

[3] A.M. SOREEFAN and T. A. DEVOL, “Proportional Counting of Tritium Gas Generated by Polymer Electrolyte Membrane (PEM) Electrolysis”, Journal of Radioanalytical Nuclear Chemistry, 282, 517 (2009).

[4] J.W. Bae, U. Lee, and H.R. Kim, “Development of continuous inflow tritium measurement in water technology using electrolysis and a plastic scintillator”, Journal of Radioanalytical and Nuclear Chemistry, 314(2), 689–694 (2017).