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Enhancement of Detection Efficiency on Tritium Detection Part using Plastic Scintillation Chamber

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1. Introduction

Decommissioning of nuclear power plant in South Korea becomes important issue. The development of technology to secure public safety from dispersion of radioactive materials on decommissioning sites also becomes important issue. Tritium is one of the hazardous radioactive nuclides existed in underwater on decommissioning sites. When tritium enters to inside of human body by respiration or intake, cell deoxyribonucleic acid (DNA) can be damaged by ionization. Therefore, the development of underwater tritium detection technology is important research issue in decommissioning research field. In this study, tritium detection is focused on real-time underwater tritium detection

2. Methods and Results

For detection of real-time underwater tritium, proton exchange membrane (PEM) electrolyzer was used. And photomultipliers and plastic scintillators were used to detect tritium. To increase the detection efficiency on detection system, plastic scintillation chamber is covered with teflon tape and light guide.

2.1 Electrolysis System

When the water (H_2O) is entered to PEM electrolyzer, Hydrogen ion and electron are generated by oxidation reaction of the water molecule on the anode of PEM cell. Hydrogen ion passes proton exchange membrane and moves to cathode. electron also moves to cathode through circuit line of PEM cell. In the cathode, hydrogen ion is reduced by electron and hydrogen gas (H_2) is generated by the combination of hydrogen ion and electron. Using same principle, the gaseous tritium (HT) is generated by electrolysis of the tritiated water (HTO).

Electrolysis system consists of water container, water pump, PEM electrolyzer, power supply, water trap as seen in Fig. 1. Water pump control the flow rate of water from water container to PEM electrolyzer. Flow rate of water by water pump is 600 mL/min. The power supply provides the current of 7 A to PEM electrolyzer. When the tritiated water is poured in water container and supplied to PEM cell, gaseous tritium and small amount of water is generated by electrolysis reaction. However, water is confined to water trap. Gases (HT or H_2) is moved to detection system. Although there is not an air pump to increase mass flow rate of gaseous tritium generated from electrolysis system, mass flow rate was enough to move to detection part, 490 mL/min.

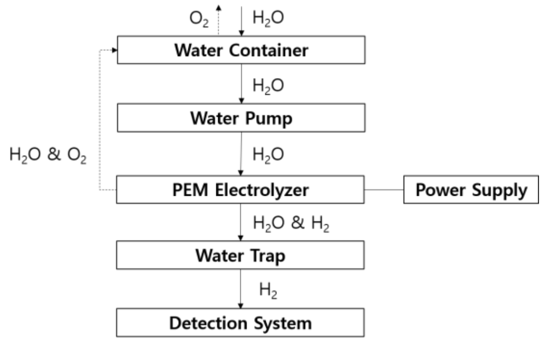

Fig. 1. Flow of liquid and gas in electrolysis system.

2.2 Detection System

Detection system consists of detection part based on photomultipliers system based on timing coincidence method [1-2]. Photomultiplier of detection part react with the light generated from the reaction between plastic scintillator and gaseous tritium.

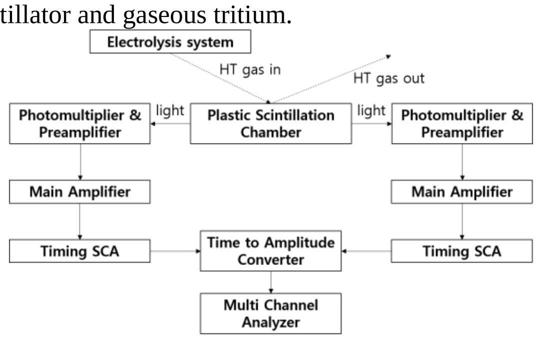

Fig. 2. Detection signal processing system configuration.

Plastic scintillation chamber was made by the combination of acrylic case and seven plastic scintillators (1x76x76 mm^3) with thin card shape. Plastic scintillators were inserted in acrylic chamber slots. And gaseous tritium generated from electrolysis system flows from inlet to outlet. The volume of acrylic case is (86x76x106 mm^3). To prevent leakage of gaseous tritium, plastic scintillation chamber was shielded by optical cement. When the mass flow rate of gaseous tritium generated from electrolysis and the radioactivity concentration of the tritiated water are constant, the radioactivity concentration of gaseous tritium in plastic scintillator chamber is constant.

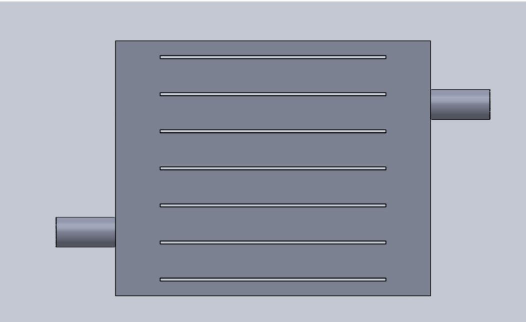

Fig. 3. The schematic of plastic scintillation chamber (left : inlet of gaseous tritium, right : outlet of gaseous tritium).

If the volume of plastic scintillators used in detection part and the volume of acrylic chamber is largely increased, the radioactivity concentration of gaseous tritium on plastic scintillation chamber can be increased. However, it cannot be used in decommissioning sites due to large volume and heavy mass. Therefore, the methods that increase detection efficiency are to increase collection efficiency of the light generated by the reaction between plastic scintillator and gaseous tritium.

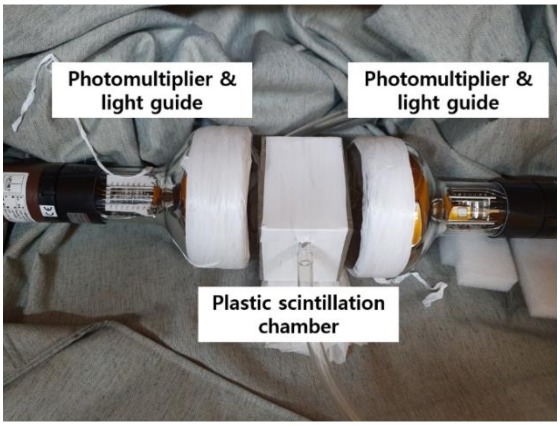

Fig. 4. Plastic scintillator chamber covered by taflon tape and light guide.

2.3 Data Analysis

When there are cover by light guide and teflon tape and there are not cover, detection efficiency and minimum detectable activity (MDA) were compared. Detection efficiency and MDA were calculated by Eq. (1) and Eq. (2).

$$\varepsilon = \frac{C_{net}}{R_{net}} \quad (1)$$

ε : Detection efficiency (%)
C_{net} : Net counting rate (counts per second, cps)
R_{net} : Net radioactivity (Bq)

$$\text{MDA (kBq/m}^3\text{)} = \frac{2.71+4.65\sqrt{C_B \times t}}{t \times \varepsilon \times V \times 10^{-2}} \quad (2)$$

V : Volume of the sample (6.52×10^{-4} m^3)
C_B : Background counting rate (cps)
t : Counting time (s)

Table I: Detection efficiency with and without the teflon tape and light guide

Teflon tape and light guide	Detection efficiency (%)	MDA (kBq/m^3)
With	11.6±0.8	24.8±1.8
Without	5.5±0.2	54.2±2.0

As shown in Table I, the detection efficiency and the MDA with the taflon tape and light guide are 2.1 times higher and 2.2 times lower than those without it, respectively. It means that when the teflon tape and light guide was covered to plastic scintillation chamber, detection efficiency was increased and MDA was decreased. Because the mass flow rate of gaseous tritium and current supplied to PEM cell was constant, the real-time radioactivity concentration of gaseous tritium flow through plastic scintillation chamber was also constant. Because the number of plastic scintillators in acrylic chamber slot was constant as 7, the light generated from the reaction between gaseous tritium and plastic scintillators was almost constant. However, the increased collection of light due to coverage of teflon tape and light guide made the light possible to be better transmitted to photomultiplier. Therefore, the light was better transmitted to photomultiplier. As a result, more transmission of light from scintillation chamber to photomultiplier is thought to increase the detection efficiency.

3. Conclusions

When the radioactivity concentration of gaseous tritium in plastic scintillation chamber was constant, the increase on detection efficiency was confirmed by coverage of the teflon tape and light guide. Plastic scintillator has a small volume. Although there is increase on the number of plastic scintillators, there is little change in the inner volume of acrylic chamber except for volume of plastic scintillators. By increasing the number of scintillators, the generation rate of light, which leads to enhance the extraction of radioactivity concentration of detected gaseous tritium, is expected to be increased. In the future, generation rate of light will be also expected to be increased by increasing the volume of plastic scintillators, and acrylic chamber.

REFERENCES

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[2] Lino M, A plastic scintillator detector for beta particles, Radiation Measurement, 35(4):347-354, 2002.