§4. Performance Evaluation of a High Sensitivity Tritium Gas Monitor Using a Pulse-Shaping Analyzer

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The exhaust gas at radiation facilities is regularly monitored for the purpose of certifying that the concentrations of radioisotopes in the exhaust gas do not exceed their legal limits. Thus, the monitor employed for this purpose must have sufficient sensitivity to be able to detect the concentration limits of the radioisotopes that are handled at the facilities. The legal concentration limits depend both on the kind of radionuclide and on its chemical form. For example, in the case of tritium, the legal concentration limit according to Japanese law for tritiated hydrogen is 70 Bq/cm^3, while that for tritiated water vapor is 5×10^{-3} Bq/cm^3. This legal concentration limit for tritiated water vapor is very low compared with the tritium sensitivity of a conventional gas monitor. For this reason, several monitors dedicated to monitoring tritium are being developed at various laboratories.

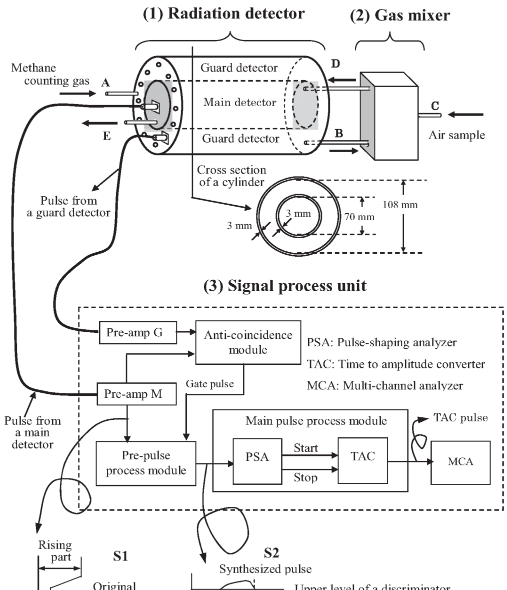

Fig.1 Schematic of the tritium gas monitor.

The tritium gas monitor developed at our laboratory is shown in Fig.1, employing several ingenious methods. First, a proportional counter is employed and methane gas is used as the counting gas for reducing the influence of radon in the exhaust air. This proportional counter is bicylindrical; the inner and outer cylinders are referred to as the main detector and the guard detector, respectively. Exhaust air is sent into the main detector and its tritium concentration is measured. The guard detector completely surrounds the main detector and it is used to detect external incident radiation such as cosmic rays. Cosmic rays have large energies and arrive at the main detector after passing through the guard detector. Such radiation produces a noise signal that reduces the detection limit of the monitor. The monitor shown in Fig.1, such incident radiation is eliminated by applying the anticoincidence method between the guard and main detectors. The entire proportional counter is also surrounded by lead blocks that shield against cosmic rays. Thus, the anticoincidence method is used for eliminating signals due to cosmic rays that pass through the blocks. Moreover, our monitor differs from conventional ones in that a pulse-shaping analyzer (PSA) is used to distinguish signals due to tritium from other signals.

The first step of the present study involved examining the optimum values for parameters such as the counting gas flow rate, the mixing ratio of air to the counting gas and the applied voltage by using a 5-kBq enclosed tritium wide-area reference source. The following values were determined: Bias = 2.9 kV, Counting gas flow rate = 930 ml/min, and Air sample gas flow rate = 70 ml/min. Applying these parameters, both rise-time spectra with and without application of the anti-coincidence method were inspected. No significant difference was found between the spectra. These results indicate that the anti-coincidence method was not effective for further reduction of noise when the present system employed the PSA method. So, the anti-coincidence module was detached.

Then a conversion factor, which could be used to convert count rate to tritium concentration, was examined using tritiated methane gas (CH_3T) mixed into the methane counting gas (CH_4). The conversion factors were determined to be 1.8×10^{-3}, 2.0×10^{-3}, and 2.1×10^{-3} for tritium concentrations of 0.51, 1.09, and 2.15 Bq/cm^3, respectively. The average value was 2.0×10^{-3}. Using the conversion factor, the detection limit of the monitor was determined as shown in Fig.2.

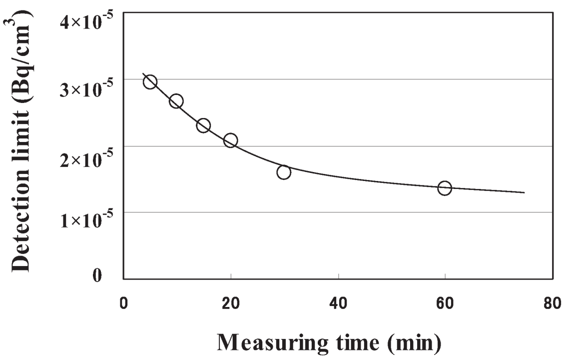

Fig. 2 Dependence of detection limit on measurement time.

In addition, the detectable concentration of tritium in an actual exhaust air sample was examined. Results indicated that the detector can measure as low as 2.0×10^{-4} Bq/ cm^3 and 4.3×10^{-4} Bq/ cm^3 in exhaust gas for 60 min and 5 min measurements, respectively. These results were obtained without consideration of the influence of the air on the measurements. Therefore, a follow-up study is needed to examine this effect in the future.