Calibration for the Liquid Monitoring System of a NaI(Tl) scintillator

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1. Introduction

The main acceleration parts of the proton accelerator use coolant to properly manage the heat generated by the collision of accelerating particles. Since this cooling water circulates inside the parts that generate high radiation, proton beams and secondary particles react with the cooling water itself, or with impurities in the cooling water or corrosive substances in the piping, so that radioactive is exist in the cooling water. Most of the radio-nuclides are removed on the ion exchange resin. During the operation period of an accelerator, the level of generation of these radioactive materials is being monitored. One of the important things in measurement using a measuring instrument is to know how much statistical fluctuations we are measuring, but it is more important to measure accurately. Usually, we know the efficiency concerned about the measuring target of the measuring instrument in advance and reflect this efficiency in the measurement result. There are several factors that affect this efficiency and efforts are being made to control those. However, in terms of the correcting efficiency, whenever the measurement object (geometric structure) is changed, determining the efficiency of the measurement object increases the effort consumption too much. As representative correction factor (Geometry factor, G), the efficiency ratio of the reference nuclide that comes from the difference in the two geometries to be measured, the efficient was corrected from the different geometry that we can obtain practically and easily by obtaining the correction factor.

2. Methods and Results

The detector to be calibrated is a NaI(Tl) detector with a diameter of 2 inches and a length of 3 inches. The cooling water to be measured is continuously flowing in and out of the chamber with a capacity of 25L where the detector is placed. Energy calibration and efficiency calibration are performed once every 5 years, and it is confirmed that integrity is maintained by performing a performance test using the built-in Cs-137 source every year.

2.1 Target Isotope for the monitoring

Among the nuclides estimated to be generated in the cooling water of the 100 MeV particle accelerator, the most frequently mentioned and considered important nuclides are shown below in Table I. [1]

Due to the characteristics of the detector installed for the continuous monitoring in the cooling water circulation loop, a Be-7 emitting gamma rays was selected as the indicator nuclide.

Table I: Radioisotopes produced in a cooling water of a proton accelerator

Isotope	Half-life, ($T_{1/2}$)	Decay mode	Gamma energy [MeV] (emission probability)
^{15}O	122.24 sec	β^+-decay (0.10 % EC)	- 0.511(1.998)
^{13}N	9.965 min	β^+-decay (0.20 % EC)	- 0.511(1.998)
^{11}C	20.39 min	β^+-decay (0.24 % EC)	- 0.511(1.995)
^{7}Be	53.29 day	EC	0.477(0.1052)
^{3}H	12.33 yr	β^--decay	-
^{14}C	5730 yr	β^--decay	-
^{16}N	7.13 sec	β^--decay	- 6.13(0.69)

The specification of NaI(Tl) detector is shown in Table II and Figure 1 shows installation.

Table II: Specification of the NaI(Tl) liquid monitoring system

Detector	2" x 3" NaI(TI)
Detector Endcap Material	0.5mm Aluminum
Resolution	Cs-137≤8%
Energy Range	50 keV ~ 1.7 MeV
Measurement Range	$550Bq/m^3$~$5.7x10^9Bq/m^3$(Cs-137)
	$910Bq/m^3$~$9x10^9Bq/m^3$(Co-60)
Vessel	25L, SUS304, Water tight
Lead shield	50mm(Top:100mm)
Flow rate	$3m^3/h$
Check source Actuator	Cs-137 10kBq

Fig. 1. Liquid monitoring system using a NaI(Tl) detector

2.2 Efficiency for each Isotope

In order to obtain and use the efficiency of a detector for all nuclides within a specific geometry, it is practically impossible to obtain a source suitable for its geometry. Therefore, in this paper, we used a method to obtain the efficiency in the chamber where the actual detector is installed which is divided the detector efficiency using the multi-source of the marinelli beaker structure by the geometrical efficiency correction factor (G). The geometry factor (G) is the ratio of the efficiencies in different structures, which is obtained using one reference source. Here, Co-60 was selected as the reference source.

An overview of the efficiency calibration is as follows.

1) Obtain the efficiency of the reference nuclide using a multi-source in the form of a marinelli beaker.
2) Determines the efficiency of the reference nuclide in the chamber.
3) Calculate the geomety factor (G) as the ratio of the efficiency of the reference nuclide in the chamber to the efficiency of the reference nuclide in the Marinelli beaker
4) The efficiency of the target nuclide in the chamber is calculated by multiplying the efficiency of the target nuclide in the Marinelli beaker by the geometrical efficiency correction constant (G).

$$E = \frac{cps_{source} - cps_{background}}{Activity_{source} \times G} \quad \cdots\cdots\cdots (1)$$

where, $$G = \frac{Efficient(Co-60)_{Marinelli}}{Efficient(Co-60)_{Vessel}}$$

2.3 Future Work (Apply the geometry factor)

In this paper, we introduced the process of selecting the nuclide for monitoring in the facility and calculating the geometry factor (G) to correct the measurement of the nuclide in the equipment. By applying the geometry factor (G) to the efficiency of the standard source included in the marinelli, the efficiency in the actual geometry in which is measured is going to be evaluated in the second quarter. For example, if the efficiency of the detector for Co-60, 1173keV gamma rays in the vessel is 2% and 9% in the marinelli beaker, the G value is 0.9/0.5 = 4.5. The correction efficiencies for nuclides other than Co-60 are shown in Table 3. Figure 2 shows the relative efficiency for Cs-137 according to energy.

Table III: Absolute efficient in vessel (example)

Isotope	Energy [MeV]	Absol. eff. in vessel	Deviation [%]	Rel. eff. [%]
Co-57	0.122	0.081	5.6	231.4
Cs-137	0.662	0.035	7.1	100.0
Co-60	1.173	0.019	6.5	54.29
Co-60	1.332	0.017	7.0	48.57

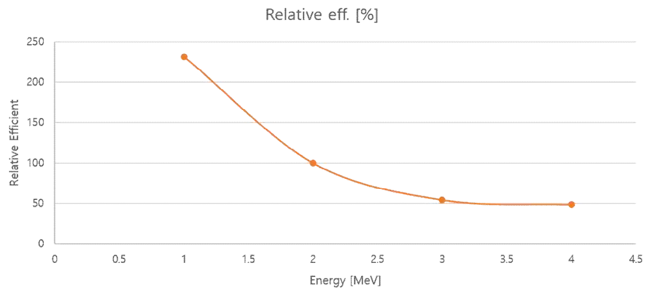

Fig. 2. Linearity of relative efficient curve dependent with energy (example)

3. Conclusions

By applying the geometry factor (G), it was possible to obtain the efficiency in a state with different geometrical structures. As representative correction factor, the efficiency ratio of the reference nuclide that comes from the difference in the two geometries to be measured, the efficient was corrected from the different geometry that we can obtain practically and easily by obtaining the correction factor.

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