Sensitivity Evaluation of Boron Meter Model

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1. Introduction

The boric acid plays a crucial role in maintaining the reactor at the critical state. So, it is highly recommended to continuously monitor the boron concentration in the reactor coolant. Many boron meters have been used for this and various attempts have been made to improve accuracy of the boron meters. In 2011, Pirat presented a new boron meter, Boronline, showing 1% of accuracy [1]. Lee et al. did sensitivity test for one-dimensional slab thickness [2]. In this paper, more diverse sensitivity tests are performed using cylindrical boron meter model.

2. Sensitivity Case Description

2.1 Reference Model

The reference model is composed of the reactor coolant, four BF_3 detectors, and *Am-Be* neutron source at the center. Fig. 1 shows the top view of the model. The coolant, BF_3 detectors, and source are surrounded by stainless steel 304 marked red lines as in Fig. 1. Table I shows geometry of the reference model.

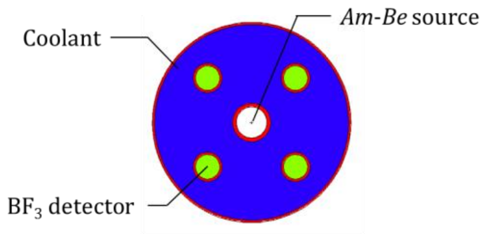

Fig. 1. Top view of the boron meter reference model.

Table I: Geometry of Reference Model

Structure	Size [cm]
Radius of boron meter	12.7
Height of boron meter	55
Radius of detectors	1.588
Radius of source	2.0
Stainless steel thickness	0.317

2.2 Sensitivity Case for Detector Size

To check the effect of BF_3 detector size about the boron meter accuracy, three different cases are designed as listed in Table II.

Table II: Sensitivity Case for Detector Size

Case	Radius of detectors [cm]
Size-down	1.191
Reference	1.588
Size-up	2.382

2.3 Sensitivity Case for Detector Location

To check the effect of BF_3 detector location about the boron meter accuracy, four different cases are designed as listed in Table III.

Table II: Sensitivity Case for Detector Location

Case	Distance from center of source to center of detectors [cm]
Closest	6.241
Close	7.193
Reference	8.146
Far	9.098

2.4 Sensitivity Case for Detector Number

To check the effect of the number of BF_3 detectors about the boron meter accuracy, two different cases are designed as listed in Table IV.

Table IV: Sensitivity Case for Detector Number

Case	Number of detectors
Reference	4
8-detectors	8

3. Estimation Method of Boron Concentration

Several forms of fitting function were tested by Kong et al. [3]. Among them, it was observed that Eq. (1) showed lowest error.

$$\text{Count Rate} = \frac{a + b \times C_b}{1 + c \times C_b + d \times C_b^2}, \qquad (1)$$

where C_b is the boron concentration and *a*, *b*, *c*, and *d* are the coefficients of the equation. In this work, Eq. (1) is used.

The estimation method of the boron concentration is as follows: First, tally detector count rates about 18 different boron concentrations using MCNP6 [4].

Second, get the coefficients of Eq. (1) from the tallied count rates by least square fitting. Third, obtain the boron concentration about corresponding count rates using the completed fitting curve. Finally, get the boron concentration error compared with the reference boron concentration.

4. Results

Fig. 2 shows the tallied count rates of the reference model according to boron concentrations. Here, 18 set of points were used to be fitted by Eq. (1). The boron concentration was estimated from the equation.

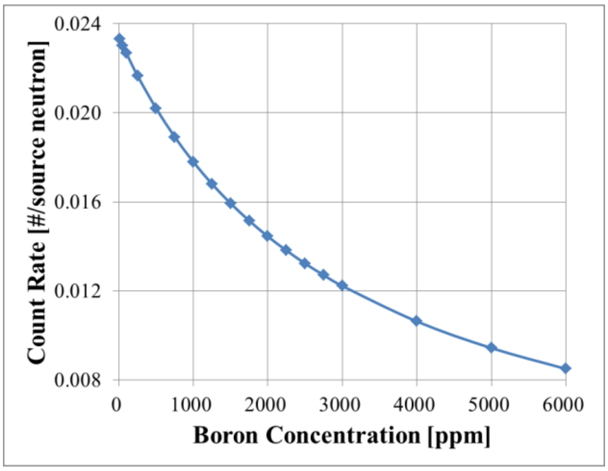

Fig. 2. Tallied count rate according to boron concentration.

Table V shows the root-mean-square (RMS) of 18 sets of the boron concentration errors obtained from the boron concentrations estimated by Eq. (1).

Table V: root-mean-square error of each case

Case	RMS error [ppm]
Size-down	4.909
Reference	3.282
Size-up	2.659
Closest	1.911
Close	2.503
Reference	3.282
Far	4.718
Reference	3.282
8-detectors	2.988

Three trends are observed from Table V: (1) as the detector size increases, (2) the detector is located close to the neutron source, and (3) the number of detectors increases, the boron concentration RMS error decreases. From these results, it was confirmed that the boron meters can be designed with improved accuracy.

5. Conclusions

Sensitivity test was performed for the boron meter model about (1) the detector size, (2) distance from the center of the neutron source, and (3) the number of detectors. As a result, it was confirmed that (1) as the detector size increases, (2) the detector is located close to the neutron source, and (3) the number of detectors increases, estimated boron concentration error decreases. Therefore, it is concluded that the boron meter model can be optimized in terms of detector size, location, and number to improve their measurement accuracy.

ACKNOWLEDGMENTS

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