Experimental Characterization on Accuracy of Multi-Detector Boron Meter

Si Hyeong Sung[a),*] Jin Bok Cho[b)], and Hee Reyoung Kim[a)]

[a)] *Ulsan National Institute of Science and Technology, 50, UNIST-gil, Eonyang-eup, Ulju-gun, Ulsan, Republic of Korea*

[b)] USERS Incorporated Company, 65, Techno3-ro, Yuseong-gu, Daejeon, Republic of Korea

*shlove912@unist.ac.kr

1. Introduction

Accurate measurement of the concentration of boric acid can improve the safe operating environment by preventing dilution accident of PWR. The boron meter, which is a boron concentration measurement technique, is capable of on-line measurement but has a high error (2%). Therefore, a study was conducted to solve the error by measuring the stable count regardless of the concentration using the selective detector measurement method. The previous MCNP simulation studies show that the accuracy of the multi detector boron meter is improved (0.4%) [1] and the accuracy improvement is 65% compared with the single detector boron meter through experiments which based on simulation [2]. The accuracy of the multi - detector boron meter was confirmed through previous studies and the system was constructed for the experiment in the actual cooling water circulation environment. In this paper, a study was conducted to measure and analyze the accuracy of 0 to 5000 ppm boric acid concentration measurement of a multi-detector boron meter in a real reactor environment through a coolant circulation system.

2. Method

Fig. 1 shows the design of a multi-detector boron meter. The fast neutrons emitted from the source (Eckert & Ziegler, N20 capsule, 1 Ci) inserted in the central. The internal detector uses four LND 20292 BF_3 detectors (11.3 cps/nv) and two LND 2528 ^3He detectors (28 cps/nv).

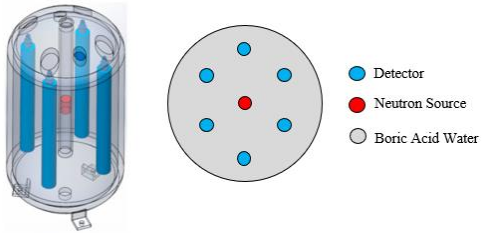

Fig. 1. Design of Boron Meter.

Fig. 2 shows the boron water circulation system including the boron meter.

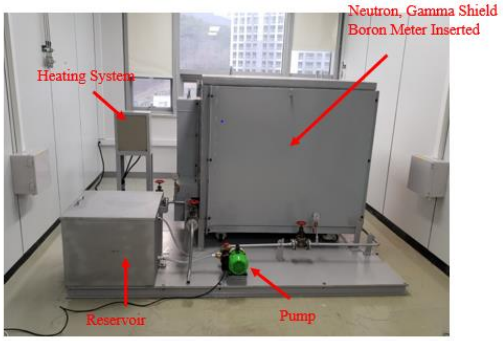

Fig. 2. Boric Acid Water Circulation System.

A circulation system creates a reactor coolant circulation environment (60 psig). A temperature of 49℃ is set through the heating system, and 18 concentrations (0 ~ 5000 ppm) of boric acid are prepared and inserted into the circulation system. Based on the measured values, boron concentration conversion equation shown as Eq. (1) was produced.

$$P = \frac{1}{c_1X^4+c_2X^3+c_3X^2+c_4X+c_5} \quad (1)$$

The coefficients C_{series} of the fitting function were obtained by using least square fitting, and the boron concentrations X were obtained from the curve with the known coefficients and the count rate P were measurement values. The accuracy of the fitting function was confirmed by a repeatability test of seven concentrations.

3. Result and discussion

The measured count rate and the fitting curve which obtained by 18 concentrations are shown in Fig. 3.

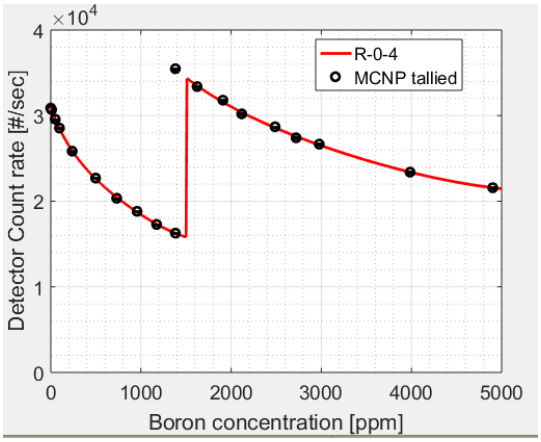

Fig. 3. Measure count rate and rational-0-4 fitting curve.

The accuracy of the boron concentration conversion equation was verified by comparing the boron concentration calculated by the fitting curve with the boron concentration value used in the actual experiments. A standard error of 6.964 ppm was observed in the range of less than 1500 ppm using the low sensitivity detector and a standard error percentage of 1.131% was observed in the range of 1500 ~ 5000 ppm. Therefore, it is possible to confirm the improved accuracy compared to the single-detector boron meter which generates 2% standard error percentage in 0 ~ 5000 ppm range.

Table 1 shows the comparisons and errors between manufactured concentration values and fitting curve calculation values.

Table 1. Experimental value and theoretical value

Boron concentration [ppm]	Rational-0-4 equation calculation [ppm]	Error [ppm]
98.212	105.075	6.863
488.865	490.270	1.405
933.040	944.806	11.766
1418.220	1338.500	-79.720
1418.220	1341.710	6.510
1903.190	1892.160	-11.030
2825.790	2887.570	61.780
3753.500	3777.110	23.610

The standard error of 19.91 ppm was observed in the range of less than 1500 ppm and standard error percentage of 1.76% was observed in the range of 1500 ~ 5000 ppm. which means that accuracy is 12% improved when the multi-detector boron meter method is introduced.

4. Conclusion

Accuracy analysis of multiple detector boron meter in actual coolant circulation environment was performed and the results were analyzed Compared to conventional single-detector boron meters, 43.45% improved accuracy is achieved. For the repeatability test, the re-measured count rate was used to evaluate the accuracy and the performance was improved by 12%. The introduction of a new concept of boron meter is expected to improve the stability of the nuclear power plant operation.

ACKNOWLEDGMENTS

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