Statistical Analysis of Fission Chamber Signal

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1. Introduction

Fission Chamber (FC) is widely used at power range of commercial power reactors to measure neutron flux due to its longer life time than other detectors. However, detecting neutron counts from fission chamber during fuel loading is normally very low counting number. Fission chamber sensitivity is determined by experimental test to validate sensitivity on design specifications and linearity of neutron counts have been verified at fine range from 0.03 to 0.1 cps.

2. Methods and Results

Sensitivity of 5 fission chambers have been measured and analyzed to reconfirm the sensitivity of design specifications before statistic determination how much numbers of neutron counts are enough for monitoring of core alteration at fueling loading.

2.1 Measurement of Sensitivity

Five fission chambers that are candidates for use in commercial power reactor are tested. For each detectors plateau and integral bias curve are measured to determine optimal operating voltage and discriminator level. Research reactor could provide power levels corresponding to neutron fluxes as shown in Table 1. Therefore, Neutron flux levels could be maneuvered by reactor power level.

Average sensitivity of fission chamber was measured to 0.0268 cps/nv, standard measurement uncertainty was 0.0000723 cps/nv corresponding to average value of ±2.7%. Final sensitivity value is 0.0268 cps/nv±8.1% with 95% confidence level. All fission chambers are satisfied with design specifications. It is a value of 1/100 order of BF3 detector sensitivity. One of five fission chambers are selected for test fission chamber because of fission chamber have a same characteristics in view of statistics for measurement uncertainty.

As shown in Fig.1, neutron signal, CPS, is a linear function of reactor power levels. It is possible that increasing a power level continuously can make maneuver the neutron flux level correspondingly.

Table 1. Measurement of FC Sensitivity

Power	Flux	FC1	FC2	FC3	FC4	FC5	AVG	S.D.
1.0E-05	2.265E+00	0.0166	0.0191	0.0169	0.0184	0.0221	0.0186	0.0022
4.0E-05	1.812E+01	0.0206	0.0317	0.0286	0.0290	0.0314	0.0282	0.0045
4.0E-04	1.812E+02	0.0265	0.0306	0.0275	0.0320	0.0284	0.0290	0.0023
4.0E-03	1.812E+03	0.0265	0.0309	0.0301	0.0326	0.0282	0.0297	0.0024
4.0E-02	1.812E+04	0.0244	0.0281	0.0267	0.0300	0.0249	0.0268	0.0023
4.0E-01	1.812E+05	0.0259	0.0291	0.0277	0.0313	0.0264	0.0281	0.0022
4.0E+00	1.812E+06	0.0243	0.0271	0.0270	0.0304	0.0268	0.0271	0.0022

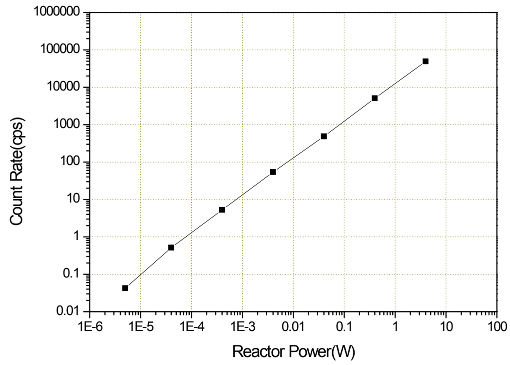

Fig1. Reactor Power vs. Count Rate for Coarse Range

2.2 Statistical Error Analysis

To obtain neutron count rate from 0.03 to 0.4 cps, Test Fission Chamber (TFC) and Reference Fission Chamber (RFC) were allocated at symmetric channels in research reactor except TFC was positioned far from the center of core than that of RFC.

Experimentally, the TFC positions in a channel were selected where 0.038, 0.076, 0.155, 0.320 and 0.380cps are measured. As a measuring results shown in Fig. 2, TFC count rate have a proportional trend with that of RFC. It means that fine range flux maneuvering can be provided from 0.03 to 0.4 cps.

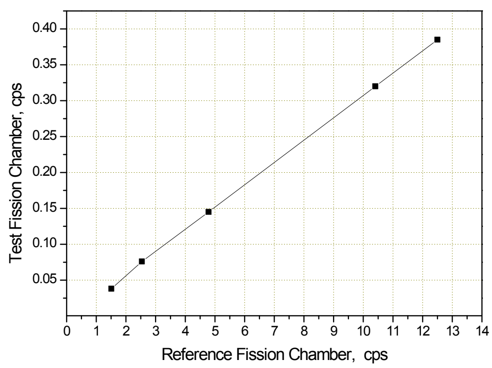

Fig. 2 Linearity Test for TFC and RFC

At fuel assembly loaded in reactor core, very low neutron count rate would be predicted below 0.4 cps that give rise to a large measurement uncertainty because of small neutron numbers from detection.

2.2.1 Data Acquisition

Neutron counts are obtained every second by fine reactor power maneuvering. At very low counting rate such 0.04cps, average count is relatively large value to sample variance due to very small number of neutrons detected from TFC.

Table 2. Measurement at Low Counting Rate

Measuring Time (Second)	Measured Count Rate (CPS)	Standard Deviation	Relative Error (%)
10,311	0.038	0.0183	48.0
5,400	0.076	0.0074	9.7
2,500	0.155	0.0125	8.1
1,800	0.320	0.0431	13.5
1,200	0.380	0.0390	10.3

$$\text{Relative Error (\%)} = \frac{\text{(Measured Count-Average Count)}}{\text{Average Count}} \times 100$$

2.2.2 Acceptable Counting Number Selection to Stable Relative Error

The neutron count rate measured at the beginning of fuel loading is very low. The statistical meaningful counting numbers could be obtained by extending measurement time. However, it is spent a seriously long period to measure data. As shown in Fig. 3, relative errors are decreasing after 300 counts within ±*5%.*

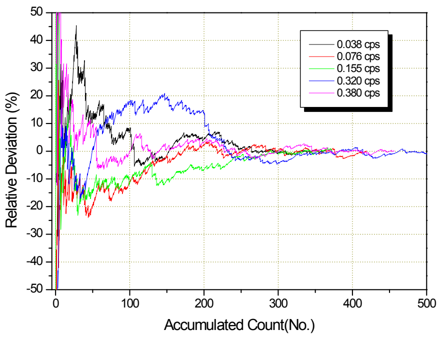

Fig. 3 Relative Error at Each Count Rates of TFC

Table 3 Measurement data obtained by 300 counts

RCF	TCF	(TCF-RCF)/RCF,%
0.1206	0.1000	-17.1
0.2030	0.2000	-1.5
0.3830	0.4079	6.5
0.8326	0.8421	1.1
1.0	1.0000	0.0

3. Conclusion

In this study, sensitivity of fission chamber was measured and summarized to verify detector sensitivity and linearity. It is confirmed that test fission chambers could have a monitoring capability for reactor core alteration from the first fuel assembly loading. And stable count rate could be obtained this system by 300 counts above within 10% relative error.

Reference

[1] LND, Inc., Design Specificaitons-30773 Fission Counter.
[2] Y.S. Choi and H.S. Lee, “Technical Support for Temporary Neutron Monitoring System pre-test,” 2012-50003339-Jeon-0081TC, Feb. 2012.
[3] KHNP SWN, “Initial Fuel Loading,” 9S-L-422-01, Test Procedure 2012.