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Performance Test of BF3 Neutron Detection System

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1. Introduction

BF3(Boron Tri-Fluorides) gas filled neutron detector is widely used in nuclear reactors as a startup channel neutron flux monitoring tools due to its high neutron sensitivity at a very low power level. Especially, the neutron detecting system of First-of-a-kind plant such an APR1400 at Shin Kori should have been verified in the condition of low operating temperature and pressure of the primary coolant system before receiving the operation license. Auxiliary Ex-core Neutron Flux Monitoring System (AENFMS) is supposed to be installed using BF3 neutron detector in Shin Kori plant. The performance test of AENFMS was conducted to measure neutron sensitivity, moderation ratio and count rate in the same condition with Ex-core Neutron Flux Monitoring System (ENFMS) of APR1400 to verify its detection characteristics in compliance with the functional requirement.

2. BF3 Neutron Detection System

2.1 AENFMS Configurations for Test

AENFMS for test consists of three parts, BF3 detector, pre-amplifier and measuring circuit, as illustrated in Figure 1. Actually, four(4) BF3 detectors, four(4) pre-amplifiers and measuring circuit 1 set are a full set of AENFMS.

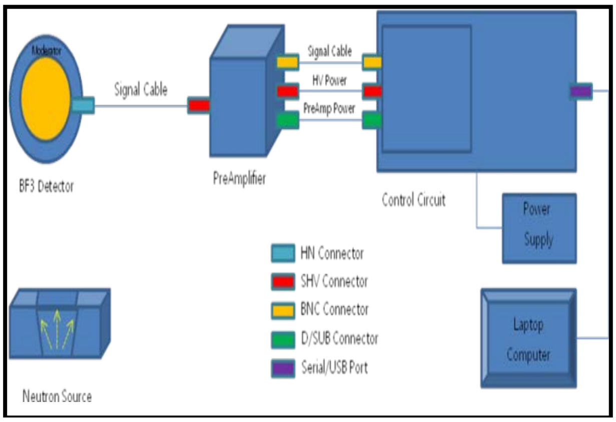

Fig. 1 Schematic Configuration of Test

A neutron source, Cf-252, was located under the BF3 detector with flux level of 3.9E+07 nv, activity of 0.32 TBq. Distances from BF3 detector to pre-amplifier and neutron source were set 3m and 78cm, respectively. The reference measuring circuit and fission chamber were also installed at the laboratory.

2.2 Test Procedure

The purpose of the test is to verify the reliance of AENFMS by measurement test in laboratory. As follows are objectives to confirm by several stepwise.

1) Confirm the reliance all parts used in the test
2) Identify white noise signal without neutron source
3) Calibrate with optimum gain, operating voltage, bias voltage(LLD) with neutron source
4) Measure BF3 detector sensitivity
5) Measure moderation ratio
6) Measure AENFMS and ENFMS count rate
7) Measure white noise along with various distances between BF3 detector and pre-amplifier.

In order to fulfill with those objectives above, test matrix were prepared to measure sensitivity, moderation ratio and count rates at various conditions. Test items the first through third had been checked and set straightforward.

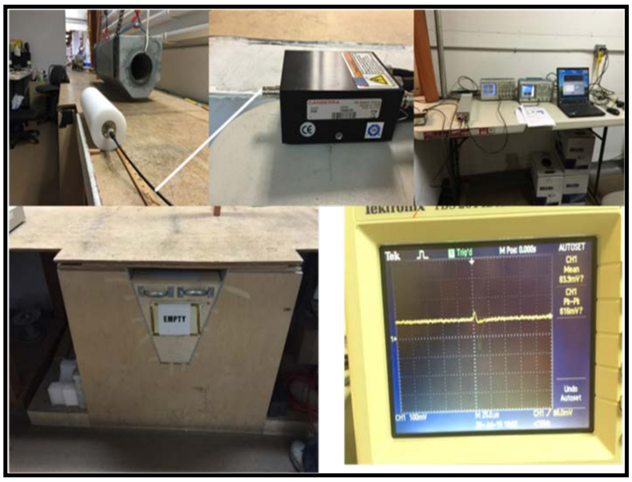

Fig. 2 Test Equipments

3. Test Methods and Results

3.1 BF3 Detector Sensitivity Measurement

The reference count rate was measured in order to determine the neutron flux level at the detecting position, 78cm above on the neutron source drawer, by reference detector that already has known its neutron sensitivity. Neutron flux at the testing position was determined as

6.73 nv. Then, by measuring the AENFMS, BF3 detector sensitivity was determined as a value of 34.246±0.168(95% Confidence Interval)cps/nv from Table 1. Expecting value is above 25 cps/nv.

3.2 Moderation Ratio Measurement

PE(Polyethylene) is a moderator material installed in AENFMS while Resin in ENFMS. Moderation ratio was derived from Table 1. A moderation ratio was directly calculated, moderated count divided by un-moderated count rate. Then, measured moderation ratio was 11.343±0.039(95% Confidence Interval). Expecting value is about 10 times.

Table 1. Measurement of Count Rate

BF3 No. 1 with 3m Cable, Test Circuit
Gain : 2.0
LLD : 0.54 volt

No	Un-moderated		Moderated	
	Counts	CPS	Counts	CPS
1	13775	229.58	155223	2587.05
2	13690	228.17	156221	2603.68
3	13830	230.50	156584	2609.73
4	13832	230.53	156562	2609.37
5	13760	229.33	156370	2606.17
6	13949	232.48	157740	2629.00
7	13826	230.43	156840	2614.00
8	13754	229.23	157513	2625.22
9	13979	232.98	157848	2630.80
10	13936	232.27	158280	2638.00
Avg. CPS	13833.1	230.55	156918.1	2615.30

3.3 Neutron Count Rate Comparison

To estimate how AENFMS amount times larger than ENFMS, neutron signals were measured in the same geometric condition. As a result, Table 2 was obtained. As shown in Table 2, 17.8 times larger neutron count rate are expected when AENFMS are measuring neutron signals. Expecting value is above 10 times.

Table 2. ENFMS and AENFMS Count Rate(cps)

	Un-moderated	Moderated
ENFMS	15.90	146.48
AENFMS	230.55	2615.30

3.4 White Noise Measurement in extending distance from BF3 detector to Pre-amplifier

Neutron signal Peak heights and Noise signal heights were measured with various distances between BF3 detector and pre-amplifier. As shown in Table 3, AENFMS could selectively detect the neutron signal discriminating white noises in case within 20m distance between BF3 detector and pre-amplifier.

Table 3. Noise Signal Measurement in Various Cases

Distance	3m	20m
Neutron signal, Volt	1.2	1.0
Noise signal,Volt	0.02	0.2

4. Conclusion

Performance test has been conducted for AENFMS of APR1400 to verify BF3 neutron sensitivity, moderation ration of PE, expecting neutron signal count rate from AENFMS, possible extending cable length from detector to pre-amplifier. As a result of measurement, the neutron sensitivity of 34.246±0.168(95%CI)cps/nv, moderation ratio of 11.343±0.039(95%CI) and AENFMS expecting count rate related to ENFMS of 17.8 times are acceptable in compliance with functional requirement, respectively.

In order to reduce radiation exposure time for worker replacing and repairing pre-amplifier in a reactor cavity, the extending distance from detector to pre-amplifier should be more considered in the future works.

Reference

[1] “DOE Fundamentals Handbook Instrumentation and Control,” DOE-HDBK-1013/2-92, Vol. 2, 1992.
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[4] Y.S. Choi et al, “Application of Temporary Neutron Monitoring System for Subcriticality Monitoring during Initial Fuel Loading of OPR1000,” Trans. Of KNS Spring Meeting, Jeju, May 17-18, 2012