Verification of Gamma-ray Sensitivity for BF3 Neutron Detection System

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1. Introduction

The BF3(Boron Tri-Fluorides) gas filled neutron detector(hereafter BF3 Detector) is commonly used for nuclear reactor's startup channel due to its relatively high neutron efficiency and good discrimination against gamma-ray backgrounds. In order to measure how much this gamma-ray will affect on BF3 neutron detector performance in view of gamma noise discrimination, Multi-Channel Analyzer(MCA) is utilized for spectrum based signal analysis. The pre-test of BF3 Detector should be performed in an area where the ionization does not exceed 2.5 micro Gy/Hr(Ref.1). In this paper, the discrimination level (Voltage Unit) is verified by experimentally measurement if that discrimination level is acceptable within the criteria or not before installation.

3. Methods and Results

In general, the instrumentation for gamma-ray sensitivity of BF3 neutron detector consists of Pre-amplifier, Amplifier, High-Voltage Bias Supplier and Multi-Channel Analyzer. The oscilloscope is used to see a pulse shape. Plateau curve and Integral bias Curve are commonly a way to find out the optimal discrimination voltages for Lower Level and Upper Level according to the fuel loading procedure (Ref.2&3). In order to verify an acceptable gamma sensitivity for BF3 detector, the Plateau and Integral bias curves are measured by using Am-Be neutron sources. After that lower level discrimination (LLD) is determined to cutoff background noise signals, the LLD shall be verified whether the LLD is within acceptable voltage level under the various signal levels of gamma-ray induced.

2.1 BF3 Detector Performance Test by Neutron Source

The objective of the Plateau Curve Measurement is to confirm that the operating high voltage is within the range that vendor recommended.
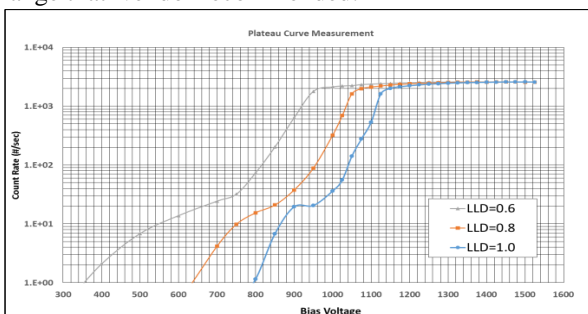

Fig. 1. Plateau Curve Measurement

The vendor's specification recommends that the operating voltage is about 1,250V. As shown in Fig.1, the suitable operating range shall be from 1,200V to 1,400V. It is shown that an enough count rates are expected even at 1.0V.
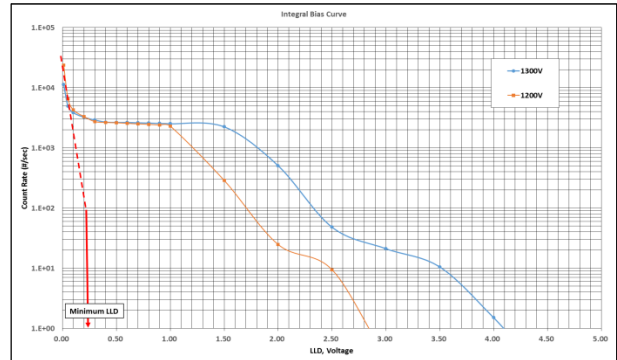

Fig. 2. Integral Bias Curve at Various Bias Voltage

As shown in Fig. 2, the suitable LLD shall be determined at about 0.25V. As the measuring window is 0V~10V, a bias voltage of 1,300V is suitable for the BF3 Detector performance pre-tests.

2.2 Determination of Maximum Acceptable Gamma Rate

The objective of the insensitivity test of BF3 Detector is to determine LLD that equivalent to the LLD by only neutron source. Figure 3 shows that the gamma source(Cobalt 60) is located in an shielding container box and BF3 Detector shall be move its position against the gamma source container box linearly. While BF3 Detector moving, gamma rate is decreasing with distance from 0.54 mGy/Hr to 2.0 Gy/hr.

Fig. 3. Position of BF3 Detector at Gamma Source

Table 1 shows that 0.54 mGy of gamma source is comparable with the noise signal level induced from neutron source. This means that 0.17 V of LLD at 0.54

mGy/Hr is acceptable LLD for gamma insensitivity of BF3 Detector.

Table 1. LLD of Various Gamma Rate

Gamma rate	LLD	Remarks
2,000.0 mGy/Hr	1.71 V	High
110.8 mGy/Hr	0.60 V	High
11.7 mGy/Hr	0.26 V	Similar
0.54 mGy/Hr	0.17 V	Acceptable

* Operating Voltage is at 1,200V.

2.3 BF3 Detector Performance Test by Gamma Source

The objective of this test is that how much gamma ray induces the LLD higher than those of neutron source. The previous measurement of only background signal was about 0.1V for LLD at 1,200V bias voltage. As shown in Fig. 4, the suitable LLD rage is from 0.25V at 1,200V to 0.35V at 1,300V in condition of gamma rate of 540 micro Gy/Hr that is about 200 times larger than that of the test requirement. This means that BF3 detector is more insensitive to gamma ray than that of requirement.
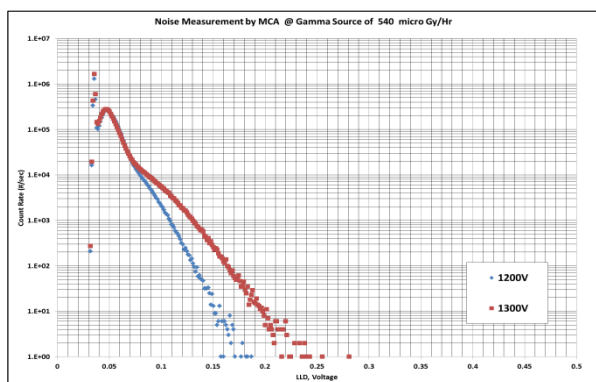

Fig. 4. Spectrum measurement under gamma source

2.4 Determination of Optimal LLD Range

The Fig. 5 shows BF3 Detector's Integral Bias Curves by neutron and gamma sources at proper operating voltage that recommended from detector vendor. The suitable LLD against ionization radiation is above 0.3V at bias voltage of 1,300V as shown in Fig. 5.
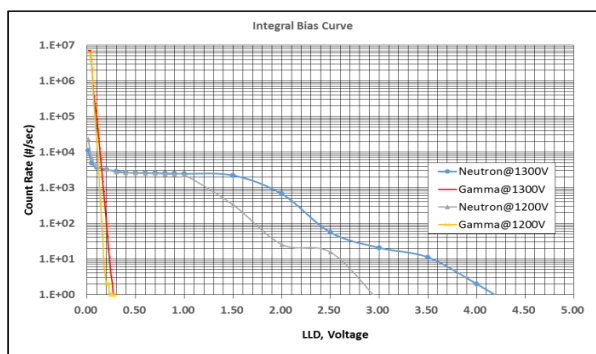

Fig. 5. Comparison of Integral Bias Curves in condition with Neutron and Gamma Source at various Bias Voltages

The determined values of pre-test for BF3 detector in laboratory are recommended as LLD=0.3V, Bias Voltage=1,300V. After BF3 Detector system shall be installed at plant, LLD level shall be experimentally re-determined due to the difference of signal cable length and geometrical configuration (Ref.4).

3. Conclusion

The maximum discrimination level, so called LLD, is determined by experimentally measurement as following Table 2. As shown in Table 2, this BF3 Detector (LND20372) is insensitive under 540 micro Gy/Hr of gamma ray and 0.3V of LLD could cut off a background and gamma induced signal in a laboratory.

Table 2. Recommended LLD & Bias Voltage of BF3 Detector

Insensitive maximum Gamma ray	Acceptable LLD	Bias Voltage (Vendor recommend)
540 micro Gy/Hr	0.3V	1,300V (1,250)

MCA could be a convenient tool for spectrum analysis of signals that induced from gamma ray and a time saving tool rather than oscilloscope investigation due to its function to integrate all input signals at a sudden duration.

It is expected that the installation of BF3 Detector at plant could be made more harsh condition than a laboratory. The experimentally re-calibration for BF3 detector at factory test must be performed to confirm the LLD and Bias Voltage are acceptable at plant condition.

Reference

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