Nal spectrometers for indirect detection of neutrons

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1. Introduction

Due to the worldwide shortage of ³He, alternative methods to detect neutrons are actively studied. One alternative approach for neutron detection is to use high-energy gamma-rays produced in β⁺γ-reactions [1]. In addition to the neutron capture gamma-rays, neutron sources also emit high-energy gamma-rays by themselves (Fig. 1).

Figure 1. Origins of high-energy gamma-rays.

2. Objectives

The objectives were to optimize the neutron response of the Nal detector system and to compare Nal and ³He detectors in evasive scenarios.

3. Methods

The neutron induced gamma-rays up to 8 MeV were measured with a 4 x 4 x 16" Nal portal monitor in the radiation metrology laboratory of STUK. The employed neutron signal (gamma-rays between 3.5 and 8 MeV) can be enhanced by covering three sides of the detector with moderators and converters (Figs. 1 and 2). One side was left uncovered for normal gamma spectrometry, a Thermo Fisher ³He counter of comparable dimensions was also used.

Figure 2. Nal portal monitor (left), moderated ³He-tube (back right) and a cylindrical borated polyethylene (BPE) neutron shield (front).

4. Results

Figure 3 presents typical gamma spectra generated by ²⁵²Cf and AmBe sources. The AmBe source was shielded with Pb to attenuate the 60 keV peak.

Figure 3. Spectra recorded using PVC/PPE converter/moderator showing the increased count rate at high energies due to the ²⁵²Cf and AmBe sources.

Figure 4. Absolute detection efficiency per emitted neutron with converter/moderator structures of various thicknesses. Measurements were performed with ²⁵²Cf source at source-detector distance 2 m.

A 10 cm-thick sandwich converter/moderator composed of 2 cm-thick PVC and PE slabs was chosen as a compromise between performance and size (Fig. 4). This configuration was compared to the ³He-tube with and without neutron shielding around the sources. Table 1 presents minimum detectable activities (MDA) with 1 s acquisition time and 100 s background measurement time in these conditions.

Table 1. MDA with source-detector distance 2 m [2]. The AmBe source was shielded with 4 mm Pb.

<table>
<thead>
<tr>
<th>Source</th>
<th>MDA (Nal) [Bq]</th>
<th>MDA (³He) [Bq]</th>
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<tbody>
<tr>
<td>²⁵²Cf</td>
<td>3.9 x 10⁹</td>
<td>2.5 x 10⁹</td>
</tr>
<tr>
<td>²⁵²Cf23 cm PE*</td>
<td>4.1 x 10⁹</td>
<td>6.3 x 10⁹</td>
</tr>
<tr>
<td>²⁵²Cf50 cm BPE**</td>
<td>1.5 x 10⁹</td>
<td>2.0 x 10⁹</td>
</tr>
<tr>
<td>AmBe</td>
<td>4.9 x 10⁹</td>
<td>5.3 x 10⁹</td>
</tr>
<tr>
<td>AmBe23 cm PE*</td>
<td>1.8 x 10⁹</td>
<td>5.3 x 10⁹</td>
</tr>
<tr>
<td>AmBe50 cm BPE**</td>
<td>3.4 x 10⁹</td>
<td>8.9 x 10⁹</td>
</tr>
</tbody>
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* PE = Polyethylene
** BPE = Borated polyethylene

5. Conclusions

By utilizing the high-energy gamma-rays induced and emitted by neutron sources, the Nal detector is superior to the ³He-counter in evasive scenarios. In addition, the characterization of neutron sources is possible.

Acknowledgements

This project was supported by the Finnish Scientific Advisory Board for Defence (MATINE). The authors would also like to thank Dr. A. Hakanen (STUK) for assisting with the measurements.

References