MULTI-ENERGY NEUTRON DETECTOR FOR COUNTING THERMAL NEUTRONS, HIGH-ENERGY NEUTRONS, AND GAMMA PHOTONS SEPARATELY

M. M. Chiles
S. A. McElhancy

Instrumentation and Controls Division
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, TN 37831-6006

To be presented at
Health Physics Society
34th Annual Meeting
Albuquerque, N.M.
June 27, 1989
MULTI-ENERGY NEUTRON DETECTOR FOR COUNTING THERMAL NEUTRONS, HIGH-ENERGY NEUTRONS, AND GAMMA PHOTONS SEPARATELY

M. M. Chiles and S. A. McElhaney

The need for an improved, compact, wide-energy neutron detector for neutron monitoring and surveillance in nuclear facilities and weapons storage, where a possibility of fission excursion exists, led to development of a single detector that is sensitive to thermal neutrons, high-energy neutrons, and gamma radiation. Previously, separate detectors have been required to count these three different radiations separately. This development is a great advantage when experimental space is limited.

This scintillation detector is composed of two scintillators optically coupled and mounted on a single photomultiplier tube as shown in Fig. 1. The first scintillator is a *Li-loaded glass that has high efficiency for thermal neutrons because of its high neutron capture absorption coefficient for thermal neutrons by the following equation:

\[ ^{7}\text{Li} + ^{1}\text{H} \rightarrow ^{4}\text{He} + ^{1}\text{H} + 4.78 \text{ MeV} \]

The second scintillator is a liquid (BC501) that has fairly high efficiency for higher energy neutrons by neutron elastic proton recoil scattering as diagramed below:

\[ E_p = E_n \cos^2 \theta \]
Fig. 1. Dual-scintillator (Li glass + BC501 liquid) neutron detector.
The BC501 scintillator also emits scintillations from electrons scattered by gamma Compton interactions:

\[ E_\theta = \frac{(1 - \cos \theta) E_\gamma / MC^2}{1 + (1 - \cos \theta) E_\gamma / MC^2} \cdot E_\gamma \]

The \(^6\)Li glass scintillator emits light with a characteristic time constant of \(~60\) ns, whereas light emitted in the liquid scintillator by proton recoil from energetic neutrons has a time constant of \(~30\) ns and the time constant for scintillations occurring from gamma-scattered Compton electrons in the liquid scintillator is \(3.7\) ns. These differences in light decay time constants make this detector conducive to electronic separation of pulses generated by the three different radiations. Figure 2 shows the photomultiplier tube voltage divider and buffer preamplifier circuit, which is the first stage of separating the pulses according to their rise time. Pulse-shaping electronics\(^5\) have been used with this detector to demonstrate that one can count thermal neutrons, high-energy neutrons, and gamma radiation separately. Figure 3 is a block diagram of the experimental setup.

Figure 4 is a plot of data acquired by a multichannel analyzer and shows the separation of pulses from thermal neutrons, high-energy neutrons, and gamma photons.

CONCLUSION

This dual scintillator detector and pulse-shaping electronics system demonstrates a method to effectively count thermal neutrons, high-energy neutrons, and gamma photons separately. It is conceivable that this detector can be used to estimate neutron dose, to monitor criticality, or to continuously monitor neutrons of all energies. We are now investigating the possibility of developing a lighter weight, portable survey instrument incorporating this multi-energy detector to replace the heavier neutron monitors (such as the REM ball type) for health physics monitoring.

---

Fig. 2. Diagram of photomultiplier tube voltage divider and buffer preamplifier.
Fig. 3. Block diagram of experimental setup.
Fig. 4. MCA display of the separation of pulses from thermal neutrons, high-energy neutrons, and gamma photons.