CONF-761006--2P

Lawrence Livermore Laboratory

A FAST-NEUTRON DETECTOR FOR USE AS A CRITICALITY MONITOR

Richard D. Friesen

September 21, 1976

This paper was prepared for submittal to the Proceedings of the 1976 Nuclear Science Symposium of the IEEE Nuclear and Plasma Sciences Society, October 20-22, 1976, New Orleans, Louisiana.

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

A FAST-NEUTRON DETECTOR FOR USE AS A CRITICALITY MONITOR *

Richard D. Priesen†

Abstract

To increase the reliability of the criticality monitoring system in a diagnostic chemistry area and to reduce the number of false alarms, a new monitoring system was built using a fast-neutron detector. This paper outlines the design requirements, describes the system as it was built, and reports on the results of several months of operation. The new monitor has proven much more useful than the gamma-detector system it replaced.

Introduction

Federal regulations require that areas in which fissionable materials are handled be monitored for criticality accidents. Specifically, any location where the maximum foreseeable dose to man could exceed 25 rem must be monitored. The Lawrence Livermore Laboratory's Diagnostic Chemistry Building falls into this category. Should a criticality accident occur, the building would have to be evacuated within seconds to avoid serious injury to workers. The alarm system must therefore be extremely reliable.

In the past, the building was monitored using a gamma-detection system. However, scientists working in the building felt that a gamma detector was not the best choice for a criticality monitor because gamma-active materials routinely handled in the building posed a constant threat of false alarm. It was felt that a neutron-detector system would be a much more reliable choice. Thus, when the building was expanded recently, the Electronics Engineering Department was asked to design and install a neutron-detection criticality-monitoring system (a survey had shown that a suitable commercial neutron-monitoring system was not available).

Monitor Selection

Several different types of neutron detectors were considered for the criticality-monitoring system.

First the boron trifluoride (BF_3) tube was examined. This tube — the most common type of neutron detector used today — generates a charged particle when a neutron interacts with a molecule of BF_3 gas. The charge is then amplified by a sensitive amplifier. The BF_3 tube has reasonable neutron sensitivity with low gamma sensitivity, but its high input impedance makes it too sensitive to radio-frequency and spark interference.

Next, a depleted-uranium secondary-electron mixed-radiation dosimeter (Semirad)** was considered. Here,

* This work was performed under the auspices of the U.S. Energy Research & Development Administration, under contract No. W-7405-Eng-48.

Lawrence Livermore Laboratory, University of California, Livermore, California 94550.

** Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research and Development Administration to the exclusion of others that may be suitable.

NOTICE
This report was prepared as an account of work sponsored by the United States Government. While the United States was the United States Energy Research and Development Administration, no copyright claim is made by the Government. This report is available to the public without charge. However, the Government is not responsible for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

a charged particle is liberated when a neutron interacts with the uranium on the wall of the detector. Like the BF_3 tube, Semirad requires a sensitive amplifier, but it is smaller and more easily shielded. Semirad has good linear response to high neutron fluxes, but it is not very sensitive to low neutron fluxes. It would be impractical, therefore, to test this type of monitoring system with anything less than criticality-level fluxes.

System-testing problems also ruled out a third type of detector, an organic scintillator combined with a photodiode operational amplifier. Such scintillators emit light when hit by a neutron, and they can be manufactured such that the light emitted matches the spectral response of the photodiode. This offers the advantages of simple construction and obviates the need for a high-voltage power supply. However, currently available organic-scintillator/photodiode combinations are not sensitive enough to allow safe, reliable testing.

The detector finally selected was a plastic scintillator combined with a photomultiplier. This detector operates like the organic-scintillator/photodiode combination except that the color of the light emitted is tuned to the spectral responses of a photomultiplier. This detector has good neutron sensitivity, is small enough to be shielded easily, and has good long-term reliability.

System Description

Ten neutron detectors are used to monitor the Diagnostic Chemistry Building, two in each of the five areas where fissionable materials are handled. The detectors are cabled to a central equipment rack, where each detector has its own line-receiver module. Two of the detectors must register above-normal activity before the alarm-control module will trip the building-evacuation alarm.

System status is indicated by three colored lights on each detector and its corresponding line receiver. Green indicates that everything is alright, yellow indicates a unit failure, and red signals a high-level alarm. The alarm-control module has an additional red criticality-alarm light. This module supplies a relay contact closure for the building-evacuation alarm and the building supervisory alarm system, which is tied to the fire department by telephone line. There are also relays in each module power regulator to signal unit failure should there be a power failure (high or low) that does not otherwise trip the unit-failure alarm.

Several design features were included to make the detector system easy to monitor, test, and maintain. A small light with enough current to give a small background signal is installed in the side of the scintillator. A low-level discriminator is set to trip if this background signal is lost. The light can be switched off to test the monitor. There is also a switch (a run-turn potentiometer) and a pushbutton to allow the light to be pulsed to a calibrated high level. This makes it easy to set the high-level discriminator and to test the criticality alarm without a neutron source. Or, by raising the gain of the preamp (using another switch), a small neutron source

can be used to test the system. While these features do not completely eliminate the need for testing high-level neutron fluxes, they do enable fast spot-checks and easy and safe maintenance.

The circuit is primarily made up of integrated-circuit operational amplifiers, and it requires ± 15 V for power. This is supplied from a ± 24 -V power supply. Each module and detector has its own 24-to-15-V regulator to facilitate power-supply and power-line noise rejection. Power for each detector is fed into the same cable that carries the alarm signal. Each detector also has its own dc-to-dc inverter for the photomultiplier-tube high voltage.

Conclusions

The decision to use a fast-neutron detector as a criticality monitor is wise for several reasons. First, high-energy (i.e., fast) neutrons are the first fission fragments emitted in a criticality event; thermal (i.e., low-energy or slow) neutrons and gamma rays are secondary events. Secondly, in a facility where high-level gamma-active materials are handled, a criticality monitor based on gamma detection will have a poor signal-to-noise ratio. That is, it must distinguish a criticality-level signal from an already high gamma background noise. This naturally leads to a greater probability of false alarms and to testing

Fig. 1. Detector efficiency.

Fig. 2. Response of the detector to a pulsed neutron source. The neutron pulse width was 9 μ s, and the energy was 15.1 MeV. The flux density at the detector was 1.3×10^3 n/cm².

procedures requiring high-level radiation sources. Of course, the facility must still have a gamma monitor, but a high-level gamma alarm and a criticality alarm are two very different problems. In response to a high-level gamma alarm, personnel must leave the immediate area and notify the health and safety technician, who surveys the area to determine appropriate action. In response to a criticality alarm, the entire building must be evacuated in a matter of seconds.

The type of detector used in the new criticality-monitoring system and the shielding around it (1/8-in. tantalum) ensure against false alarms caused by signals from fission products or by electrical interference. As shown in Fig. 1, the scintillator used in the detector has a low sensitivity to thermal neutrons (the type produced in a reactor), thereby providing a good signal-to-noise ratio for criticality detection, even in the neutron-rich environment around a power reactor.

Tests on the detector show it to be meeting all requirements. The gamma sensitivity was not measurable with a 1-R/h gamma source. A 1-R/h fission neutron source next to the detector will not trip it. A high-intensity pulsed neutron generator was used to simulate a criticality event. The test pulse used 15.1-MeV neutrons with a duration of 9 μ s and a flux density of 1.3×10^3 n/cm² (see Fig. 2). The detector was set at about -10 V and was tripped in approximately 100 μ s. A 15-mg Californium source, emitting 3.2×10^{10} 2.5-MeV neutrons per second also tripped the set point alarm.