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Active Neutron Interrogation Package Monitor

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Abstract

An active neutron interrogation package monitor is being developed for the purpose of rapidly searching containers, packages, and luggage for special nuclear materials (SNM). The technique uses a pulsed neutron generator to interrogate the container or package with neutrons, inducing fission in any SNM that may be present. Arrays of ^{3}He-filled neutron proportional counters are used to detect neutrons produced by these fissions. Both calculations and experiments with a prototype device have shown active neutron interrogation to be a very effective technique for detecting SNM, even in the presence of shielding.

I. INTRODUCTION

The increased threat of nuclear proliferation and nuclear material smuggling has resulted in many efforts to develop new technologies to monitor and safeguard against these activities. One technique that is being investigated at the Los Alamos National Laboratory (LANL) is using active neutron interrogation to rapidly search containers, packages, and luggage for special nuclear materials (SNM). The SNM of interest includes uranium, plutonium, and any other fissionable isotope.

Passive techniques, which measure gamma-ray and neutron emissions from spontaneous decay, work well for some SNM materials, but have been mainly designed for applications involving specific containers and well controlled geometry. In addition, passive techniques may involve substantial measurement times, depending on the configuration of the SNM and materials between the source and detectors. As a result, active interrogation is currently the best non-destructive method to rapidly search containers for SNM (ranging from luggage to large shipping containers).

Active neutron interrogation has been used for many years for assaying the quantity of SNM in waste containers and drums [1], [2], [3]. This technique has also shown promise for assaying SNM in the presence of other radioactive materials [4], [5].

To study active neutron interrogation for monitoring packages for SNM, a prototype system was constructed. This prototype system is shown in Figure 1. It has been used to study the effects of detector-package arrangement on detection efficiency, detector saturation, and background decay in a pulsed neutron environment. In addition, the prototype, along with calculations from MCNP, has been used in detector design and the optimization of an active interrogation device.

II. METHODOLOGY

The technique being studied uses a pulsed neutron generator, sometimes referred to as a zetatron. Neutrons produced by this pulsed generator are used to interrogate the container or package at both epithermal and thermal energies. These neutrons induce fission in any SNM within the container or package that is being interrogated. Detector
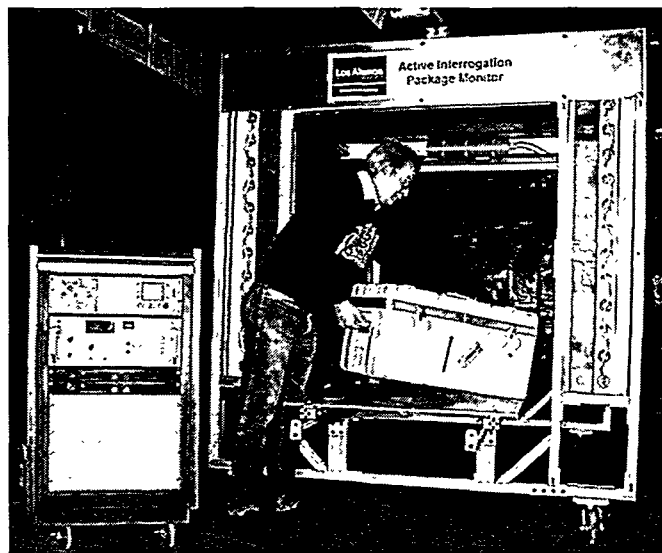

Figure 1. Active neutron interrogation package monitor prototype built at the Los Alamos National Laboratory.

packages containing arrays of ^{3}He-filled neutron proportional counters are used to detect neutrons produced by these fissions, indicating the presence of fissionable material. This active interrogation is accomplished with low levels of neutron flux, such that neutron activation is not a concern in the package being interrogated.

A. Pulsed Neutron Generator

The generation of neutrons is accomplished with a portable pulsed neutron generator. The neutron generator is a small pulsed ion accelerator that utilizes the deuterium-tritium (D-T) reaction to produce 14-MeV neutrons [6]. The neutron generator used in this study was a laboratory system, model A-210, manufactured by MF Physics Corporation. This neutron generator produces approximately 10^6 neutrons per pulse with a pulse width of 10 to 15 µs. It is capable of running at a pulse rate of up to 100 pulses per second [7].

The neutrons produced in each pulse are emitted nearly isotropically with an initial energy of approximately 14 MeV. The neutrons scatter inside the chamber, slowing down to thermal energies very quickly. After a couple hundred microseconds, only thermal neutrons remain in both the package monitor and the container being interrogated. It is these thermal neutrons that induce fission in any SNM that may be present. The fissions result in higher-energy neutrons being produced, which are then detected by the ^{3}He detector cells.

B. Detector Cells

The active neutron interrogation package monitor prototype incorporates detector cells, which are optimized to detect neutrons emitted from the fission process. Each detector cell is made up of three ^{3}He filled proportional
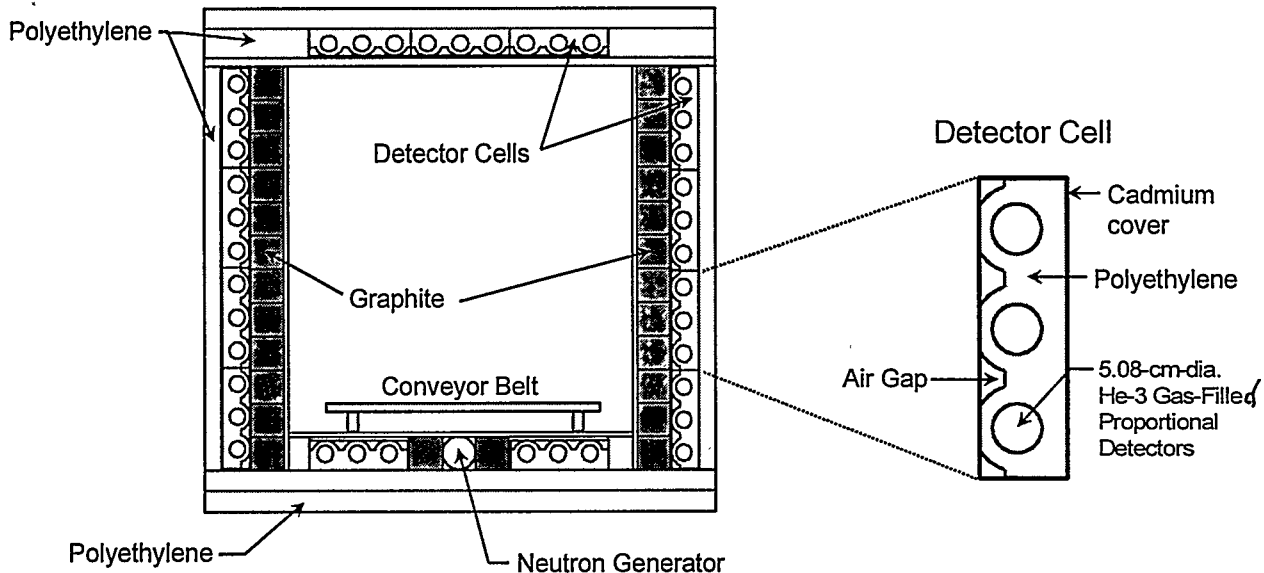
Figure 2. Diagram of new active neutron interrogation package monitor prototype being built at Los Alamos National Laboratory.

counters, 5.08 cm in diameter by 152 cm long with a fill pressure of 2 atm. The ^{3}He detectors are surrounded by polyethylene and then covered with a 40-mil-thick cadmium sheet. Cadmium has a very high absorption cross section for thermal neutrons. This results in the detector cell being efficient for only those neutrons above thermal energies. Since the time region of interest occurs after the faster flux from the pulse has died away (>400 μs), leaving only thermal neutrons in the package monitor, the detector cell must be sensitive to only those non-thermal neutrons. The polyethylene in each detector cell moderates the higher-energy neutrons from fission energies to thermal energies. Thermal neutron energies are required within the detector cell for efficient detection by the ^{3}He-filled proportional counters.

These detector cells surround the package monitor chamber, resulting in an absolute efficiency of between 5% and 10%, depending on the materials being used between the detector cells and the SNM. A combination of graphite and polyethylene inside the chamber has been demonstrated to significantly improve the thermal neutron interrogating flux within the package. However, this combination reduces the absolute detection efficiency. The final configuration of materials is still being determined. Furthermore, current design allows for an opening on two sides of the cavity to permit the installation of a track or conveyer belt for rapid screening of packages or luggage. A new package monitor prototype is currently being built based these new detector cells. A diagram of the new prototype is shown in Figure 2.

Experiments conducted with the previous prototype, shown in Figure 1, have shown that the detector cell design can affect the sensitivity of the neutron interrogation and subsequent detection of fission neutrons. Optimizing for the decay of the thermal flux in the detector package aids in the detector recovery from the neutron pulse, but reduces detection efficiency. As a result, a study of various detector cell configurations was conducted involving both calculations using MCNP and measured data. Several measurements made with different detector cell configurations are shown in Figure 3. These detector responses show the saturation of the detector as a result of the neutron generator pulse and the subsequent die-away of the neutrons in the detector cell. A desirable detector cell is one that recovers rapidly, since the

early time period involves a higher rate of fissions if SNM is present. However, a sacrifice of detector efficiency is usually the result of a fast-recovery detector cell. As can be seen in Figure 3, detector-cell design can greatly influence neutron die-away, thus influencing the regions of interest for data analysis. For the new prototype device, a moderate-to high-efficiency design was selected. Furthermore, the polyethylene around the ^{3}He detectors was modified to optimize the recovery and decay. This resulted in the shape of polyethylene in the detector cell shown in Figure 2.

III. DATA ANALYSIS

A. Differential Die-Away Technique (DDT)

In addition to the prototype evaluation, different data analysis techniques are being studied for use with active
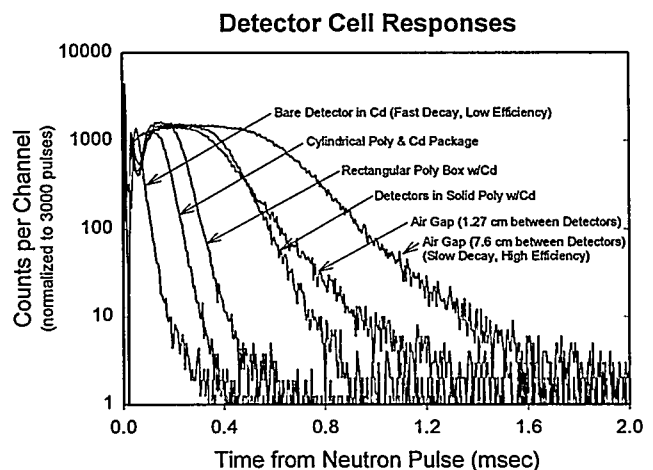

Figure 3. Measured detector response data for various detector cell configurations using the pulsed neutron generator.

neutron interrogation. The most sensitive method of analyzing data obtained by active neutron interrogation is the differential die-away technique (DDT) [8], [9], [10], [11]. The DDT, developed at the Los Alamos National Laboratory, has been used for over 10 years to assay the level of transuranic nuclear waste in 55-gallon storage drums down to the 100 nCi/g level.

The DDT primarily relies on the fact that thermalized neutrons in the cavity die away at a much slower rate than epithermal and fast neutrons. Since the detector packages are cadmium covered and thus sensitive only to epithermal and fast neutrons, any neutrons detected (above background) after the non-thermal neutrons have died-away must be from fission-induced events. The active measurement sequence for the DDT is given in Table 1. This DDT technique has been demonstrated to work even if the SNM is heavily shielded by lead, since thermal neutrons easily penetrate lead.

A similar experiment was conducted where a sample of HEU was placed in a lead pig. Using DDT analysis, the presence of HEU was clearly distinguishable. The measured data for one experiment are shown in Figure 5. These data were taken for 300 seconds to clearly show the difference between an empty cavity and with HEU present. Additional experiments conducted with the active neutron interrogation prototype have clearly shown that small quantities of [235]U can be detected with a measurement time of less than 30 seconds. Additional optimization of the prototype is expected to improve the sensitivity and required counting time even further.

Table 1
Active measurement sequence following each pulse of neutrons.

Time Interval (μsec)	Interrogating Flux	Detector Response
0-20	14 MeV Neutrons emitted from generator	Detectors becomes saturated
20-400	Fast and Epithermal neutron interrogation	Detectors remains saturated
400-800	Thermal neutron interrogation	Detectors start to recover
800-10000	Thermal neutron interrogation	Detects both prompt and delayed fission neutrons

B. Delayed Neutrons

Another method of analyzing the data produced by active neutron interrogation is using the delayed neutrons emitted after prompt fission. Since the interrogating flux is comprised of only thermal neutrons after a couple hundred μs in the package, there may be difficulty in using thermal neutron DDT in the presence of specific combinations of neutron shielding. However, since the neutrons emitted from the pulse generator start at 14 MeV, they easily penetrate any shielding that may be present. In this situation, calculations have shown that there are an adequate number of epithermal neutrons penetrating the shielding which induce fission and result in a sufficient number of delayed neutrons that can be detected by the ^{3}He proportional counters. Initial experiments with the prototype device have confirmed the ability to measure this delayed neutron effect.

IV. RESULTS

One of the advantages of active neutron interrogation is that it is extremely difficult to hide the SNM. Monte Carlo calculations using MCNP have clearly shown that gamma-ray shielding has little effect on the detection of [235]U. One such calculation is shown in Figure 4, where a sample of highly enriched uranium (HEU) was surrounded with 2.54 cm of lead.
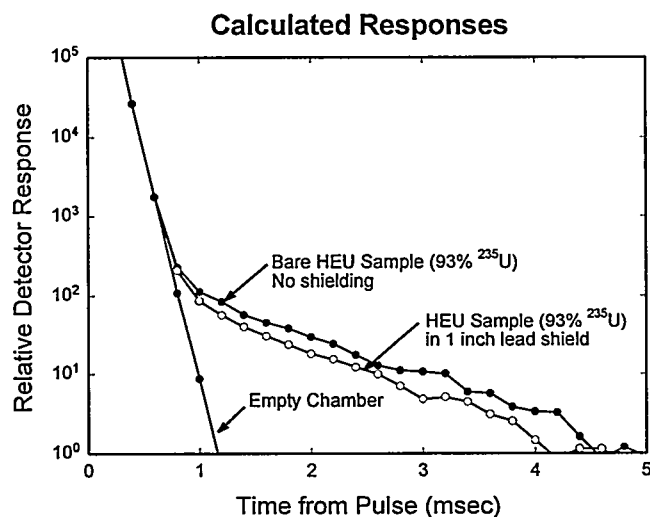

Figure 4. Calculated response data for highly enriched uranium (HEU) sample with shielding and without shielding.
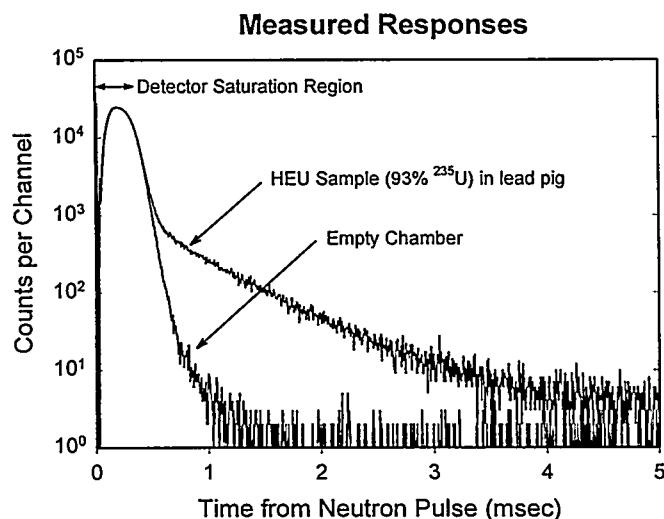

Figure 5. Measured response data for empty chamber and highly enriched uranium (HEU) sample in a lead pig.

V. CONCLUSION

The active neutron interrogation prototype has undergone initial experimental evaluation with excellent results. Further optimization using the prototype device is continuing. In addition to making the package monitor as sensitive as possible, we are striving to make it compact, simple, and economical. Efforts have also focussed on design of a data-acquisition system that will fit inside a desktop computer, eliminating the need of CAMAC crates or NIM bins. Different analysis techniques, including differential die-away and delayed neutron activity are being further investigated for optimizing the technique even more.

Active neutron . interrogation represents a safeguard technology that will improve the ability to rapidly monitor for SNM and aid in the prevention of nuclear material smuggling. Both calculations and experiments with a prototype device have shown active neutron interrogation to be a very effective technique for detecting SNM, even in . the presence of shielding material.

VI. REFERENCES

[1] J. T. Caldwell, R. D. Hastings, G. C. Herrera, W. E. Kunz, and E. R. Shunk, "The Los Alamos Second-Generation System for Passive and Active and Active Neutron Assays of Drum-Size Containers," *LANL Report LA-10774-MS*, September 1986.

[2] R. J. Estep, K. L. Coop, T. M. Deane, and J. E. Lujan, "A Passive-Active Neutron Device for Assaying Remote-Handled Transuranic Waste," *LANL Report LA-UR-89-3736*, November 1989.

[3] R. Estep, S. Melton, and D. Miko, "Real Waste Measurements with the Combined Thermal-Epithermal (CTEN) Prototype," *LANL Report LA-UR-98-70*, 1998.

[4] J. T. Caldwell, W. E. Kunz, H. F. Atwater, J. D. Atencio, G. C. Herrera, R. E. Morgado, J. C. Pratt, A. G. Blasewitz, J. M Davis, M. R. Smith, "Experimental Evaluation of the Differential Die-Away Pulsed-Neutron Technique for the Fissile Assay of Hot Irradiated Fuel Waste," Treatment and Handling of Radioactive Wastes, American Nuclear Society Topical Meeting, Richland, WA., 19-22 April 1982.

[5] J. Romeyer Dherbey, G. Bignan, L. M. Deidier, Y. Beroud, R. G. Post, "Active Neutron Interrogation Devices for Gamma Irradiating Solid Alpha Wastes," Waste Processing, Transportation, Storage and Disposal, Technical Programs and Public Education. Proceedings of the Symposium, 25 Feb.-1 March 1990, Tucson, AZ.

[6] M. L. O'Neal, "MA165C Zetatron Neutron Generator Operating Manual," *Sandia Report SAND85-0152*, August 1990.

[7] "Instruction Manual for Pulsed Neutron Generator, Model A-210," MF Physics Corporation.

[8] K. L. Coop, "Neutron Die-Away Methods for Criticality Safety Measurements of Fissile Waste," *LANL Report LA-UR-89-2104*, 1989.

[9] P. M. Rinard, K. L. Coop, N. J. Nicholas, H. O. Menlove, "Comparison of Shuffler and Differential Die-away Technique Instruments for the Assay of Fissile Materials in 55-Gallon Waste Drums," JNMM; July 1994; vol.22, no.4, p.28-38.

[10] B. Milicic, H. Wurz, and T. Zoltowski, "The Differential Die Away Time Method: An Attractive Method for the Assay of Alpha -Waste from LWR Fuel Reprocessing," Nuclear Materials Management; 1986; vol.15 procissue, p.421-6.

[11] N. J. Nicholas, K. L. Coop, and R. J. Estep, "Capability and Limitation Study of the DDT Passive-Active Neutron Waste Assay Instrument," LA-12237-MS, May 1992.