LA-DC-6397 (Full Paper)

JAN 15 1965

A SEMICONDUCTOR ANTICOINCIDENCE DETECTOR SYSTEM*

by

CONF-641001-54
83550

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I would like to describe an anticoincidence detector system. I will orient you by briefly describing the equipment used to obtain the data to be presented, and try to show how the technique can be applied to many problems.

We are developing molten plutonium nuclear reactors, and believe that knowledge of the fission product distributions in the fuel element aids in analysis of the element's performance. Therefore we have attempted to make an instrumental radiochemical analysis of the fuel elements as a function of position. Figure 1 shows the equipment. The fuel element is moved in front of a collimator by stepping motors with 0.001" increments in one of six degrees of freedom.

Data is taken with an anticoincidence detector system. Continuous scans are taken to locate regions of change in fission product distributions, and these are examined in detail by taking complete spectra which are analysed on a computer using a combination of Gaussian and exponential curves.

A block diagram of the circuitry is shown in Figure 2. I would like to point out one feature which we have used in a few different applications. This is the subtraction circuit which is used in conjunction with two single channel analyzers. It makes a first order subtraction of the Compton distribution that is due to a higher energy gamma-ray. One single channel analyzer is set on the full energy peak of interest and the other is set on the gamma-ray that contributes the major portion of effective background. This technique is important because it provides an automatic correction which is proportional to the gamma ray intensity. It is valid if the shape of the pulse height distribution does

*Work done under the auspices of the Atomic Energy Commission.

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not change with counting rate. The circuit consists of a few resistors and has been used for very high effective backgrounds. I have data with me to demonstrate this but will not present it at this time. This technique can be used with either NaI or semiconductors.

We are now using a 3 mm x 2 cm² lithium drifted germanium detector in place of a NaI detector. Figure 3 shows how we have been able to keep it cold and still effect the very great advantages of anticoincidence. The important features are:

- (1) The detector is cooled by conduction down a "cold finger";
- (2) The large liquid nitrogen reservoir, in conjunction with high vacuum in the walls of the Dewar keeps the detector cold for days with one filling;
- (3) Thin aluminum materials are used inside the anticoincidence annulus to reduce the scatter and absorption in structural parts;
- (4) A vacuum of about 10^{-6} mm Hg is maintained with molecular sieve;
- (5) The signal lead capacitance is about 10pf because we use a 0.005" wire inside a large cylinder.

Some data taken with this system is shown in Figure 4. Note the approximately five-fold reduction in the Compton distribution. The resolution of 1 % is quite reasonable for the electronics used. Figure 5 shows a comparison of an anticoincidence spectrum taken with a 2.3" x 6" NaI crystal and two spectra taken with the lithium drifted germanium detector. One of the latter was taken with anticoincidence and the other was taken without the aid of anticoincidence. The tantalum full energy peaks are the same in either case. I do not mean to imply equal efficiency between the scintillator and semi-conductor - the normalization was done at approximately 1.12 MeV. The effect of higher energy resolution is remarkable and the anticoincidence make the Cs^{137} peak much easier to measure because of the reduction in the Compton distribution.

Ten different spectra are shown in Figure 6. These were taken at various positions along a fuel element. They show how it is possible to do good instrumental radiochemical analysis with good spacial resolution. The spectra have been displaced upward one decade from the one below for ease in presentation.

Note how the distributions of isotopes vary with position. Some of these data were taken with a 0.020" high x 0.5" wide x 8" long lead defining collimator. However, an additional 14" of lead shielding was provided that did not define the beam. These latter collimators are called beam scrapers. Pin hole beam defining collimators 0.031" dia. and 8" long have also been used.

A set of anticoincidence spectra taken with NaI are shown in Figure 7. Computer reduction of these data is necessary in order to unfold the component parts for identification. However, these are easily resolved in Figure 6 without computer data reduction.

The semi-conductor anticoincidence system as described is applicable for collimated gamma-ray beams with energies below about 1.6 MeV. For higher energies the annular crystal should be split along the axis and data taken with triple coincidences. This is necessary to take advantage of the large pair-production cross-section. The double escape peak is the dominant peak observed and there are two 0.51 MeV gamma-rays which escape the detector in opposite directions. If these are all detected separately, the event is accepted as a triple coincidence. This method results in higher peaks relative to the continuous part of the distribution.

In summary, I would like to call your attention to: (1) the great improvement in the quality of spectra taken with anti-coincidence counting, regardless of the analyzing detector used, (2) semi-conductors offer advantages that often outweigh their lower efficiency, and (3) these techniques will be used because of the demand for better data to do harder jobs. Very few people would have proposed in 1950 that accelerators would be used as an analytical laboratory instrument in 1964. I submit that the cost of the detector systems which I have described will be reduced due to the demand by you for these instruments, as has already occurred with accelerators and multichannel analyzers.

FIG. 1

GAMMA SCANNING CAVE

FIG. 2

ANTI-COINCIDENCE GAMMA SCANNER BLOCK DIAGRAM

ANTICOINCIDENCE LITHIUM DRIFTED GERMANIUM DETECTOR SYSTEM

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7