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AN ARRAY OF GERMANIUM DETECTORS FOR NUCLEAR SAFEGUARDS*

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ABSTRACT

Our gamma-ray spectrometer system, designed for field use, offers high efficiency and high resolution for safeguards applications. The system consists of three 40% high-purity germanium detectors and a LeCroy 3500 data-acquisition system that calculates a composite spectrum for the three detectors. The LeCroy 3500 mainframe can be operated remotely from the detector array with control exercised through modems and the telephone system. System performance with a mixed source of ^{125}Sb, ^{154}Eu, and ^{155}Eu confirms the expected efficiency of 120% with an overall resolution that is between the resolution of the best detector and that of the worst.

INTRODUCTION

High-resolution gamma-ray spectra usually provide the best characterization of radioactive material. However, the time required to acquire these spectra is often unacceptably long in many safeguards applications because the efficiency of a single, large, high-purity germanium detector with good resolution is typically only 40% of that of a NaI(Tℓ) detector 7.6 cm in diameter by 7.6 cm long. To improve the efficiency, we built a gamma-ray spectrometer system that consists of an array of three 40% high-purity germanium detectors and a computer to sum the three spectra without significant loss of resolution. The resulting high efficiency promotes the use of high-resolution gamma-ray systems for safeguards applications.

EQUIPMENT

The three detectors in the array (Fig. 1) have relative efficiencies of 43.8, 44.5, and 46.8% and resolutions of 1.77, 1.76, and 1.71 keV (FWHM) at 1332 keV, respectively. Each detector, supplied by Princeton Gamma-Tech, has its own all-attitude dewar so that it can be used separately. In the array, the three detectors are held in position by a styrofoam and aluminum frame of low mass to minimize scattering and absorption. Figure 2 shows a setup with the array for studying a radioactive sample.

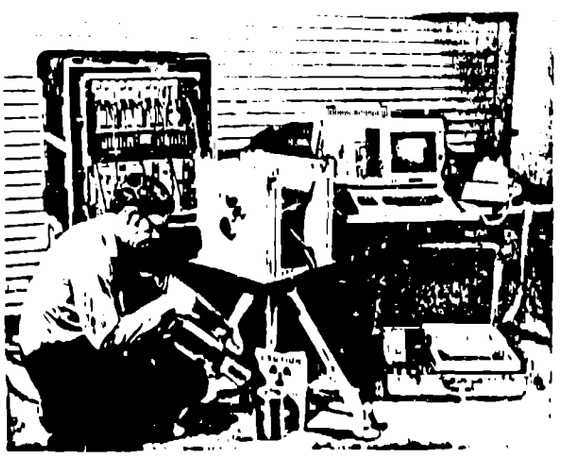

Fig. 1.
Three-detector array and associated electronics. As shown, the detectors can be used individually. The LeCroy 3500 is the unit on the right with the video display. The large box on the left contains a CAMAC crate and a NIM bin. A modem is near the telephone. The case on the chair contains a Tektronix and a PEGASUS computer with a floppy disk for communicating with other computers.

Although all-attitude dewars are portable because of their light weight, the short, 16-hour holding time is inconvenient for long-term usage. We solved this problem by connecting the dewars to an automatic filling system (Fig. 3), which refills each dewar every 8 hours. An overflow sensor terminates the fill cycle.

A LeCroy 3500 data acquisition system acquires the three individual spectra and calculates a composite spectrum. The LeCroy 3500 is equipped with a video display and light pen, bubble memory, printer/plotter, and a CAMAC crate. A separate box, which can be remote from the LeCroy 3500 mainframe, contains another CAMAC crate and a NIM bin for the analog electronics. In remote operation, this box communicates with the LeCroy 3500 mainframe via a serial highway using 600 m of twisted pair cable or 3000 m of fiber optic cable, by tying into the telephone network

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Fig. 2.
Setup for looking at a radioactive sample with the array. For a better view of the detectors, one has been removed from the array.

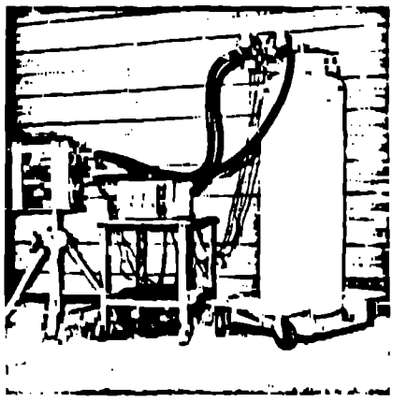

Fig. 3.
The automatic liquid-nitrogen filling system for the three-detector array.

with modems, operating distances can be extended worldwide. All system equipment is designed for measurements in the field and is packaged for easy shipment.

ANALYSIS

The computer program (Fig. 4) that combines the distributions calculates a highly accurate calibration of each distribution. The gains for the distributions can be quite different. First the program locates several

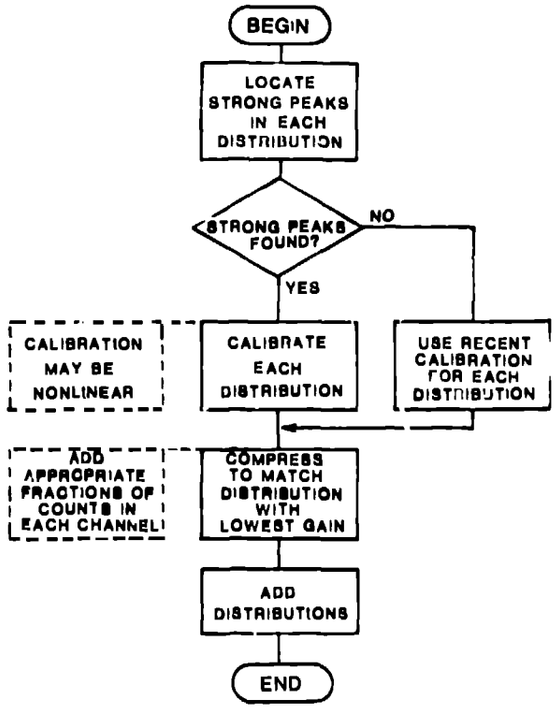

Fig. 4.
Flowchart of the computer program that adds the pulse-height distributions.

strong peaks with accurately known energies using an automatic peak-search routine; then it fits the peaks. Manual intervention is possible. The program calculates a least squares fit to determine the calibration. The calibration curve can be any function; however, tests showed that a straight line was adequate with our analog-to-digital converters. If the spectra do not contain enough strong peaks, the program uses recent calibrations with another source.

The program then compresses the two distributions with the highest gains to match the distribution with the lowest gain. The compression of each distribution requires summing functions of the number of counts in each channel to generate a new distribution. The calibrations are required to calculate these functions.

To calculate the final composite distribution, the program performs a channel-by-channel sum of the two compressed distributions and the distribution with the lowest gain. The composite distribution is then further analyzed with standard gamma-ray analysis programs such as FITEK,[1] which originated at the University of Munich.

RESULTS

To test the system, we used a mixed source containing ^{125}Sb, ^{154}Eu, and ^{155}Eu from the US National Bureau of Standards. Figure 5 compares a

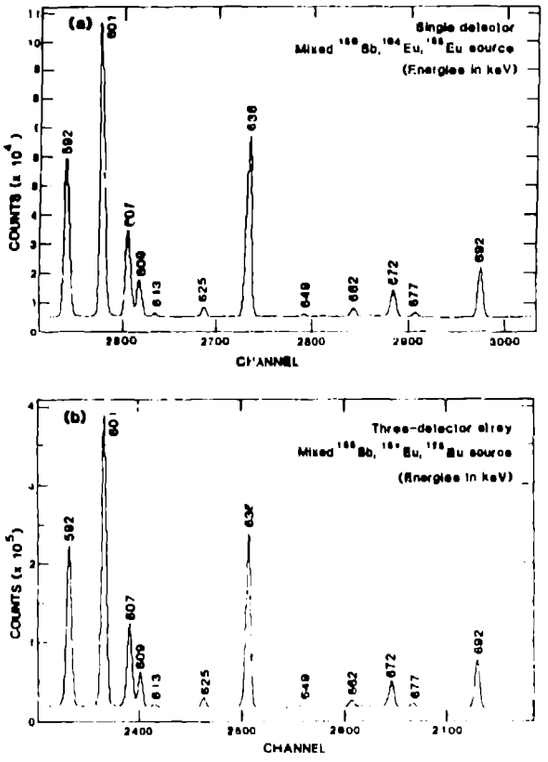

Fig. 5.
(a) A section of a pulse-height distribution taken with a single 40% efficient germanium detector. (b) The corresponding composite distribution obtained by combining the distributions from the three detectors.

section of the distribution from one detector with the corresponding section in the composite distribution. There is no significant difference over all 8000 channels of the distributions except that the composite distribution contains more counts.

For this mixed source, we determined the resolutions for representative peaks in the distributions from the individual detectors and in the composite distribution. As shown in Fig. 6, the resolution in the composite distribution lies between the resolution for the best detector and that for the worst detector. We also performed a separate experiment with ^{60}Co, which is the standard source for measuring resolution. The resolution in the sum distribution at the 1332-keV line was 1.78 keV (FWHM) when the resolutions of the individual distributions were 1.78, 1.79, and 1.73 keV.

To demonstrate the capabilities of our system for nuclear safeguards, we used a 2.03-g sample of plutonium metal containing 8% ^{240}Pu. The distance was 30 cm from detector face and the acquisition time was 25 minutes. Figure 7 shows the 640-keV complex. This complex is often used to determine the isotopic percentage of ^{240}Pu in shielded material.[7] For the weak peak at 642 keV from ^{240}Pu the number of counts is inadequate for the distribution from an individual

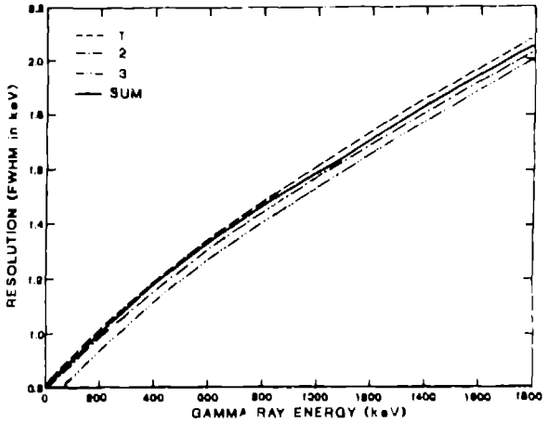

Fig. 6.
Resolutions as a function of energy for the mixed source containing ^{125}Sb, ^{154}Eu, and ^{155}Eu. Curves 1, 2, and 3 are calculated from individual detector distributions; the sum curve is calculated from the composite distribution.

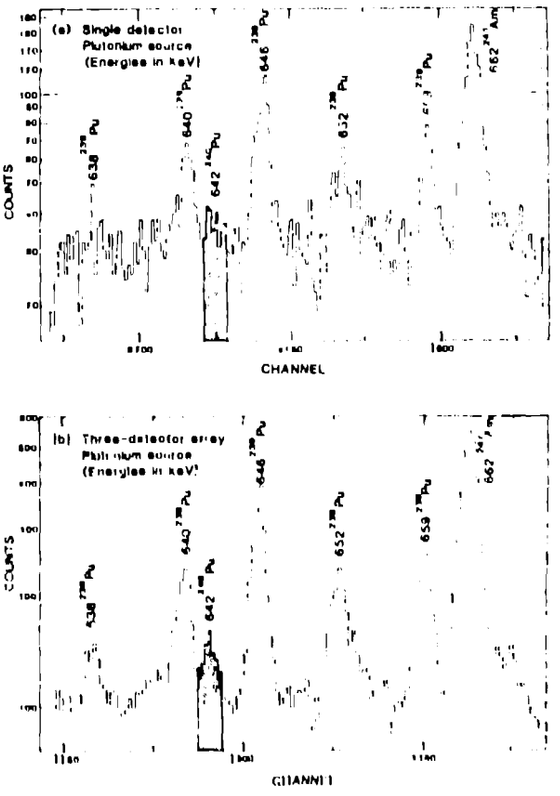

Fig. 7.
(a) A section of a pulse-height distribution taken with a single 20% efficient germanium detector. The weak peak at 642 keV from ^{240}Pu highlighted is used to calculate the isotopic percentage of ^{240}Pu. (b) The corresponding composite distribution in which the 642 keV peak is much more prominent.

detector (Fig. 7a) but is adequate in the composite distribution (Fig. 7b).

CONCLUSIONS

It is possible to achieve high efficiency and high resolution by combining pulse-height distributions from germanium detectors. Our three-detector array has an efficiency of 120%, but higher efficiency can be obtained with more detectors. The detailed information provided in a reasonably short time can be used in many safeguards applications. The portability of our system facilitates deployment in any location to investigate suspicious activities involving nuclear material. Because the spectrometer system can be operated by remote control, home base can receive timely information and reduce travel costs.

REFERENCES

1. Wolfgang Stoeffl, private communication.

2. R. Gunnink, J. E. Evans, and A. L. Prindle, "A Re-evaluation of the Gamma-Ray Energies and Absolute Branching Intensities of ^{237}U, $^{238,239,240,241}Pu$, and ^{241}Am," Lawrence Livermore Laboratory report UCRL-52139 (October 1976).