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Scintillation Spectrometer with Improved Response

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THE physical electronics group at the Oak Ridge National Laboratory has constructed an improved scintillation spectrometer that is one step closer to the ideal gamma-ray spectrometer, namely, one that would give one single peak in its response for a monoenergetic gamma ray and would have nearly 100-percent efficiency.

The usual scintillation counter produces a pulse distribution for a monoenergetic gamma ray that includes, in addition to a peak representing the full energy of the gamma ray, a continuous distribution of pulses from zero size to a well-defined upper limit lower than the principal peak. This continuous distribution is caused by gamma-ray quanta that interact with the phosphor by the Compton process wherein an electron and a scattered gamma-ray photon share the energy of the original quantum. The scattered photon may escape from the phosphor; if it does, only the smaller pulse caused by the electron is recorded. A similar escape of energy often follows a pair-production process, wherein the created electron pair shares the energy left over in the original quantum above the amount (1.02 Mev) required to produce the electron and positron of the pair. After both members of the pair are stopped in the phosphor, the positron combines with some nearby electron to produce by annihilation two photons of 0.511-Mev gamma ray. One or both of these photons might escape from the phosphor without absorption.

The response of an ordinary scintillation counter to gamma rays is shown in Figs. 1*a* and 2*a*. The phosphor in the ordinary counter was a right circular cylinder of sodium iodide activated with thallium, 1½ in. in diameter and 1 in. high. Figure 1*a* shows the response to the radiations from Zn^{65} which gives a gamma ray of 1.114 Mev and a very weak positron emission (resulting in a small amount of annihilation radiation). The peak at 640 pulse-height divisions is produced by complete absorption of the 1.114-Mev gamma ray. The peak at 300 pulse-height divisions is produced by the 0.511-Mev annihilation photons from the β^+ emission. The broad continuum extending up to about 500 divisions is the Compton electron-pulse distribution where the scattered photons have escaped.

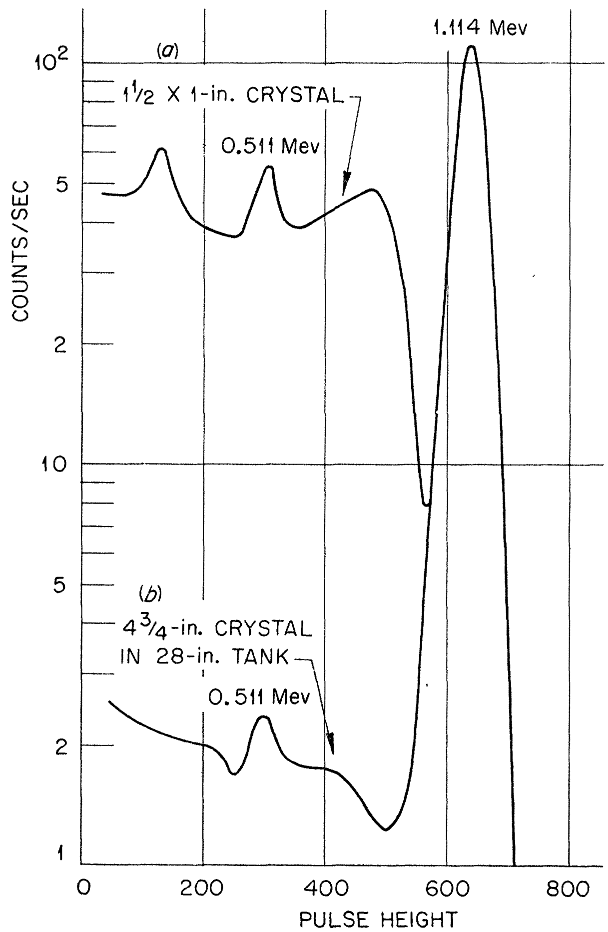

Fig. 1. Response of large and small crystals to the gamma rays of Zn^{65}.

The peak at 130 divisions is produced by radiation scattered from the surrounding objects.

Figure 2*a* similarly shows the response of the small phosphor to the gamma rays of Co^{60} (1.16 Mev and 1.32 Mev).

The largest sodium iodide crystal that we have is equivalent to a sphere 5¼ in. in diameter. This crystal with its 5-in. photomultiplier was placed in a reentrant thin-walled tube in the center of a large iron tank containing a solution phosphor (Fig. 3). Four 5-in. photomultipliers look at the solution phosphor, and the reentrant tube is stoppered with a small tank of solution phosphor looked at by a fifth photomultiplier. The pulse spectrum from the sodium iodide counter was examined by a multichannel analyzer with the output from the solution phosphor counter in anticoincidence so that no pulse from the central detector would be counted if there were also a scintillation in the liquid.

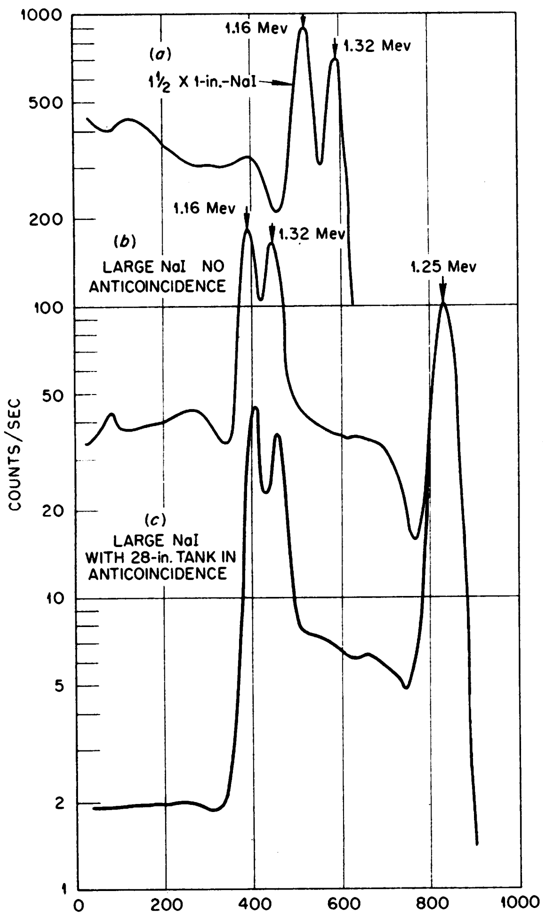

Fig. 2. Response of large and small crystals to the gamma rays of Co^{60}.

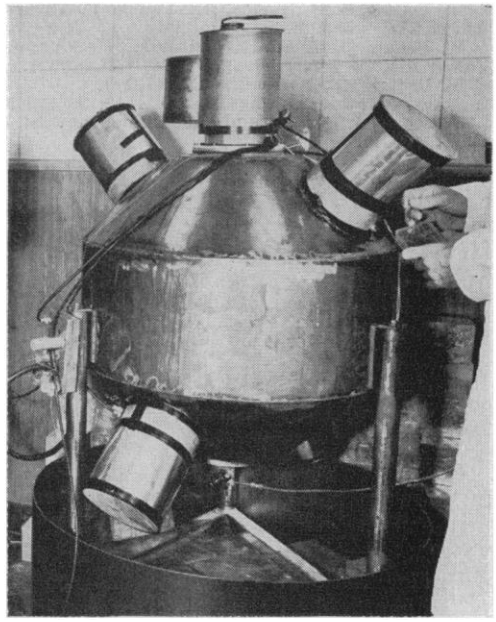

Fig. 3. Coincidence tank counter.

The solution phosphor is so large that most of the secondary photons that escape from the sodium iodide crystal are detected in the solution and the smaller pulse in the NaI counter is not recorded.

Figure 1*b* shows the response of the large crystal to the Zn^{65} gamma rays from a source placed in a hole drilled to the center of the crystal. Note the great reduction of the Compton distribution. Figure 2*b* shows the response of the large crystal to the Co^{60} radiation when the tank is not in anticoincidence. The larger crystal alone gives considerable reduction of the Compton distribution. The two gamma rays of Co^{60} are in cascade and are produced with negligible delay so that very frequently both gamma rays are completely detected, giving rise to a pulse representing the *sum* of the gamma-ray energies (2.5 Mev).

The lower curve (Fig. 2*c*) shows the effect of adding the anticoincidence circuit. The Compton distribution is greatly reduced, and the two peaks representing the single gamma rays, with the other member of the cascade escaping entirely, are also strongly reduced because of the detection of the escaping member in the tank.

A somewhat larger tank would absorb essentially all the radiation escaping from the central crystal, and only those pulses would be recorded that represent complete absorption in the crystal of all radiation from each event.