Peak Efficiency of NaI

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SCINTILLATION COUNTERS are ideally suited for the measurement of absolute gamma-ray intensities since they have a well-defined sensitive volume. The problem is to relate the counting rate observed to the intensity of gamma rays. The shapes of the full-energy peaks are not greatly affected by scattering or by other gamma radiation as is the lower-energy Compton distribution. It is therefore practical to relate the intensity of the incident radiation to the area under these peaks.

This approach to the measurement of gamma-ray intensities is very powerful since the efficiencies as defined are independent of variations in resolution and surrounding scatterers. Thus, curves of efficiency should prove useful for many applications.

We define the peak efficiency, $\epsilon_p(E)$, of a scintillation spectrometer as the probability that a gamma ray of energy E will cause a pulse that will fall in the full-energy peak if it strikes the crystal. Thus, the intensity of gamma radiation of energy E is related to the area under the full energy peak by the peak efficiency and solid angle. We have developed a method of determining ϵ_p over the range 0.150–2.76 Mev for 1½- × 1-in. and 3- × 3-in. NaI(Tl) cylinders and a 3- × 3-in. cylinder with ½ in. bevelled off the radius and height.

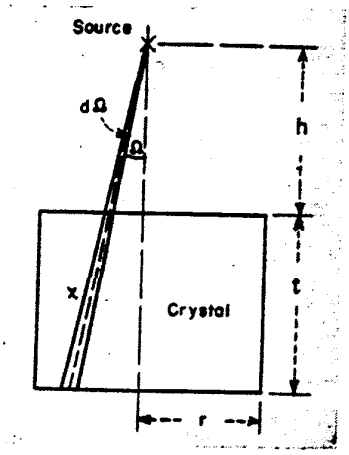

FIG. 1. To calculate ϵ_i, consider geometry above. If I_0 is total intensity of γ-rays leaving the source, $I_0 d\Omega$ will be number of γ-rays striking crystal in solid angle $d\Omega$; $I_0 d\Omega(1 - e^{-\tau x})$ will be the number detected by crystal (τ is total absorption coefficient for NaI and x is path length in crystal, a function of Ω). Thus, $\epsilon_i \Omega = \int_{\text{crystal}} (1 - e^{-\tau x})\, d\Omega$ where integral extends over crystal face

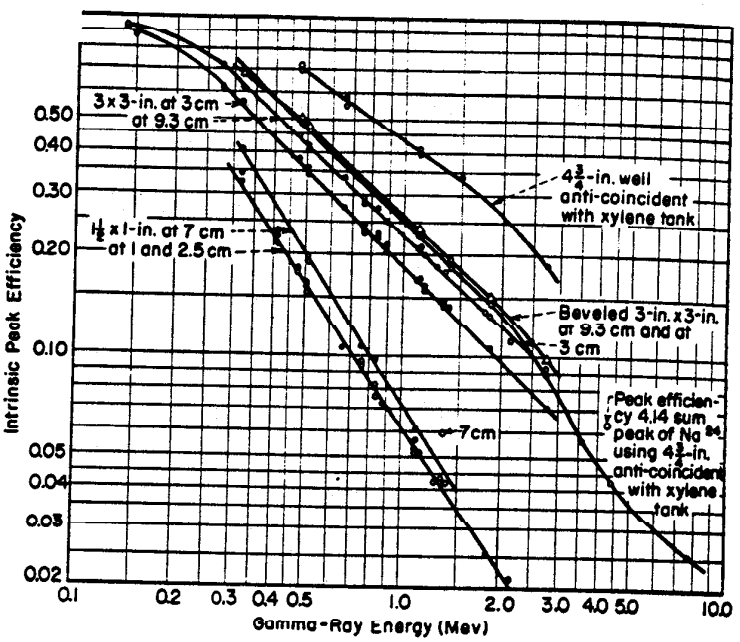

FIG. 2. Peak efficiency vs energy for NaI crystals

Because of the high probability for multiple collisions in the crystal, it is difficult to calculate ϵ_p directly. However, it is a relatively simple matter to calculate $\epsilon_i(E)$, the total efficiency of the crystal for a gamma ray of energy E (see Fig. 1).*

Our approach has been to determine ϵ_p by a measurement of R, the ratio of the area under the full-energy peak to the area under the total spectrum, for several sources that emit only one or two gamma rays; then $\epsilon_p = R\epsilon_i$.

We measured R at two distances from each of the crystals. Single gamma rays could be used from 0.145 Mev (Ce^{141}) to 1.114 Mev (Zn^{65}), but at 1.85 and 2.76 Mev only sources that emitted two gamma rays were available. The contribution to the total area from the lower-energy gamma rays in Y^{88} and Na^{24} were determined by fitting a Gaussian shape to the full-energy peaks observed for these radiations and using the value of R that already had been determined for that energy. Above 2.76 Mev, gamma rays from (p,p'), (p,γ) and (p,α) reactions were observed with the 3- × 3-in. cylinder at 3.57, 4.43 and 7.48 Mev. The peak-to-total ratio was obtained from other similar reactions at 2.14 and 1.78 Mev and agreed excellently with the curve determined from sources.

The curves of ϵ_p vs. E are shown in Fig. 2. Note that points fit curves for the 3- × 3-in. crystals within 5% to 2.76 Mev. Agreement is almost as good for the smaller crystal.

To reduce scattering, crystals were suspended in an empty room in which the nearest walls were ≥4 ft away. Bremsstrahlung was reduced by suitable choice of sources and the introduction of a minimum amount of polystyrene absorbers to stop the beta rays.

These values of efficiency have been checked at several energies by a β-γ coincidence experiment using sources in which it is known that essentially all beta rays are in coincidence with gamma rays. The values agreed with the curve obtained by the method described above, in every case, to better than 3%.

In addition, the intensities of several gamma rays have been compared to the disintegration rates measured for certain isotopes by 4π β-counting techniques and the agreement was always within 5%.

* This has been done for all of our crystals. Wolicki of the Naval Research Laboratory has extended these calculations to include all standard cylindrical crystals.