## The Effect of Magnetic Fields on the Response of Gamma-Scintillation Counters

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A MARKED change in the response of scintillation detectors has been observed with their use in magnetic fields. The extent of this effect has been determined for several conditions.

A 1P21 photo-multiplier tube and a phosphor were mounted in a light-tight brass cylinder and the cylinder was placed in a long, stationary solenoid. Variable direct current through the solenoid windings was used to produce axial magnetic fields, and a constant voltage was applied to the photo-multiplier. Radium was used as the source of gamma-radiation. Two phosphors, a $CaWO_4$ crystal, $\frac{1}{4}$ inch in diameter and 1 inch long, and a NaI(Tl) aggregate approximately $\frac{3}{8}$ inch$\times\frac{1}{2}$ inch were used.[1] Magnetic fields of the magnitude used here had no apparent effect upon the light output of the phosphors.

In Fig. 1, curves I and III show a maximum counting rate at a magnetic field strength of about 12 gauss directed from the base through the photo-multiplier. Curves II and IV for fields directed toward the base, show a diminishing counting rate with increasing magnetic field.

Figure 2 shows integral bias curves taken for the two phosphors without the applied magnetic field, and with 11.7 gauss applied axially and directed from the base. With both phosphors the percentage change in counting rate between the two field strengths decreased with decreasing discrimination level. It appears that for a given phosphor, extrapolation of these curves will result in a common ordinate intercept for both field strengths. The effect of the magnetic field appears as a simple change in amplification of the photo-multiplier, as evidenced by the constant percentage change in the discrimination level at the two field strengths for any one counting rate.

Figure 3 shows that the maximum total anode current occurs at approximately 12 gauss directed from the base. The current is seen to drop rapidly with increasing fields directed toward the base. Curves similar to those in Figs. 1–3, with the exception of a shifting of the field strength for maximum response, were obtained for several photo-multiplier tubes. A variation in shape and position of the curves with applied voltage was observed.

Nearly exponential integral bias curves of the form

$$N_1 = N_0 \exp(-s_1 v)$$

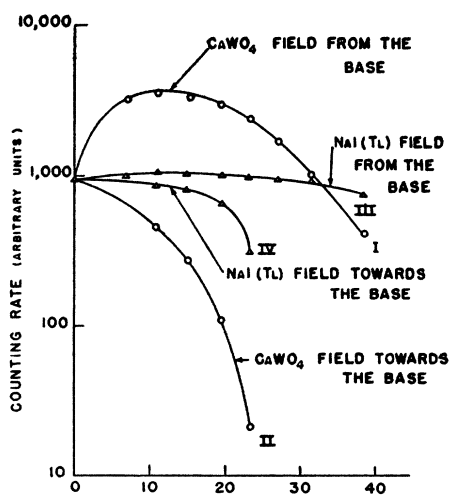


FIG. 1. Fixed discrimination level counting rate from scintillation counters as a function of axial magnetic field strength. Radium gamma-field adjusted to give equal counting rates at zero applied field for the two materials.

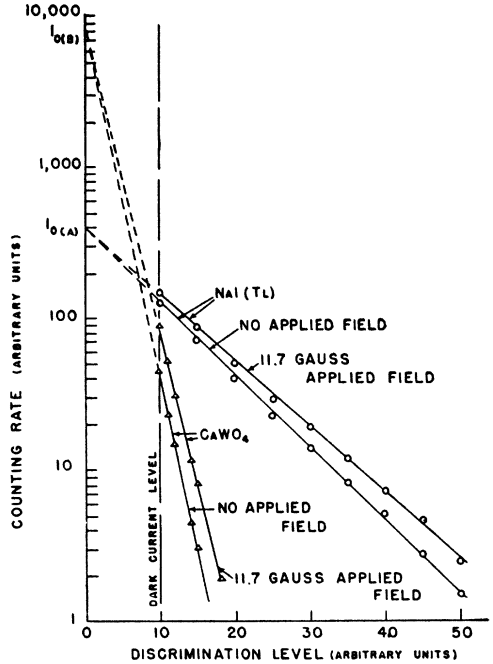


FIG. 2. Integral bias curves for the sintillation counters at zero applied field and 11.7 gauss directed axially from the base.

were observed, where $N_1$ is the counting rate, $N_0$ the total number of scintillations occurring, $-s_1$ the slope, and $v$ the discrimination level. This distribution was due in part to the energy distribution of the Compton and photo-electrons, statistical variations within the tube, and edge effects and optical transmission properties of the phosphor.

In any distribution, if $N_0$ is independent of the tube amplification, the ratio of counting rates at any two amplifications is dependent only upon some function of the discrimination level. In this case the ratio is exponential with $v$, or

$$R = N_1/N_2 = \exp[(s_2 - s_1)v].$$

Since the slope of the integral bias curve is a function of the efficiency of the crystal as well as of the tube amplification, the

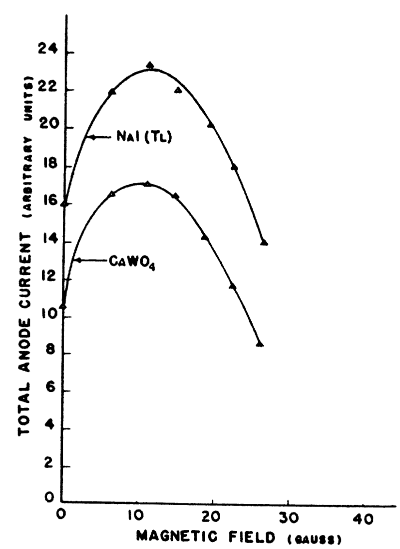


FIG. 3. Total current output for the scintillation counters as a function of axial magnetic field strength directed from the base.

relative effect of tube amplification on $R$ for phosphors of different efficiencies is of interest. The relation between slopes $(-s_1)$ and $(-s_2)$ at two amplifications for phosphor $A$ and slopes $(-s_3)$ and $(-s_4)$ for phosphor $B$ can be shown to be

$$s_1/s_3 = s_2/s_4 = n.$$

Hence the relation between the counting rate ratios $R_A$ and $R_B$ is

$$R_A = R_B{}^n.$$

From Fig. 2,

$$R_{\mathrm{CaWO_4}} = R^5{}_{\mathrm{NaI(Tl)}}. \quad (1)$$

If the time constants of the pulse are independent of the pulse amplitude, the percentage change in anode current resulting from a change in magnetic field would be constant for both phosphors.

In the case of $CaWO_4$ a 40 percent change in counting rate was observed when the field was changed from 0 to 1.5 gauss through the tube. Discrimination took place just above the dark current level. This corresponds roughly to the change that would result from positioning the tube axially with and against the earth's field. The 3 percent change predicted from expression (1) for this same field change with NaI(Tl) was not detectable with the experimental accuracy observed. The change in total current for the 1.5 gauss change was about 9 percent.

[1] The NaI(Tl) sample was obtained through the courtesy of R. Hofstadter, Princeton University, and the $CaWO_4$ sample was obtained from the Linde Air Products.

## Radioactive Decay of the Neutron*

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EXPERIMENTAL evidence concerning the instability of the neutron[1] has been obtained with the apparatus shown in Fig. 1. A beam of neutrons from the Oak Ridge uranium-graphite reactor passed longitudinally (perpendicular to paper) through an evacuated tank shown in section. An electric field was applied between an open-sided cylindrical electrode (+) and a plane electrode (−) such that positive particles appearing in this region of the beam would be accelerated upward through 8 kv and would be focused upon the enlarged first plate of a secondary electron multiplier situated behind an aperture in the negative electrode. The aperture and the multiplier plates were 7.3 cm long in the direction parallel with the beam. The two-celled beta-proportional counter placed below the beam had an effective length of about 11 cm.

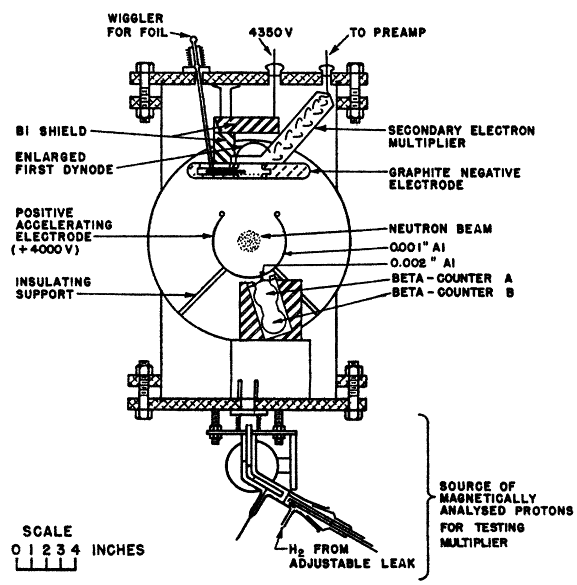


FIG. 1. Apparatus used for seeking beta-proton coincidences arising from neutron decay. The neutron beam is indicated in section at the center. A vertical electric field accelerates the protons upward and focuses them upon the secondary electron multiplier; the beta-particles register in the double beta-proportional counter below.

Triple coincidences were sought; namely, coincidences between discharges of counter $A$ and counter $B$ resulting from beta-particles emitted from neutrons in the beam, and pulses in the multiplier caused by the focused product protons.

Because of stray radiation the single counting rates were high (~75,000 per minute in $A$ and $B$, and 1500 per minute in the multiplier). With an effective resolution time of 1.3 μsec., the random coincidence rate was almost equal to the expected genuine rate. Genuine coincidences were nevertheless observed. They could be divided into two classes:

(1) Coincidences which appeared when no special delays were were introduced in the circuits. These coincidences did not depend upon the presence of the electric field. They were probably caused by fast secondary electrons in the background radiation, which traversed the three detectors. They do not concern us further.

(2) Coincidences which appeared when 0.25 μsec. delay was inserted in the $AB$ counter channel. These coincidences depended upon the presence of the electric field across the beam. A field plot had shown that 0.25 μsec. was approximately the minimum time required for a recoiling proton to be collected upon the multiplier.

TABLE I. Coincidences with 0.25 μsec. delay.

| Conditions | Transverse electric field | Genuine coincidence rate cpm | Field-sensitive genuine coincidence rate cpm | Remarks |
|---|---|---|---|---|
| Normal | on<br>off | 0.74 ±0.05<br>0.08 ±0.04 | 0.66 ±0.07 | Conditions would allow neutron decay coincidences to appear. |
| Boron interrupting slow neutron beam | on<br>off | 0.13 ±0.03<br>0.03 ±0.03 | 0.10 ±0.04 | $B^{10}$ shutter known to leak about 10% of the slow neutrons through thin spots. |
| Cadmium in beam, eliminating slow neutrons and substituting strong source of capture gammas | on<br>off | 0.18 ±0.08<br>0.17 ±0.10 | 0.01 ±0.13 | Pile power reduced until individual counting rates about equal to those in other tests. (Factor 1/7.) |
| 3 sq. ft. Cd wrapped around vacuum tank | on<br>off | 0.73 ±0.08<br>0.19 ±0.07 | 0.54 ±0.11 | Neutrons again present in beam. Local captures increased many fold. |
| 0.0002 in. Al foil covering multiplier aperture | on<br>off | 0.05 ±0.04<br>0.05 ±0.04 | 0.00 ±0.06 | Reassuring check; contributes little new. |
| $H_2$ gas in vacuum tank to 5 times base pressure | on<br>off | 0.73 ±0.05<br>0.06 ±0.04 | 0.67 ±0.07 | No more field-sensitive coincidences than in 1, 4 or 8. |
| 0.051 in. Al over $AB$ counter window | on<br>off | 0.11 ±0.04<br>0.12 ±0.03 | −0.01 ±0.05 | Sufficient Al to stop betas of expected energy (0.8 Mev). |
| Repeat 1 | on<br>off | 0.75 ±0.04<br>0.08 ±0.03 | 0.67 ±0.05 | |

Table I gives some observations made with the 0.25 μsec. delay in the $AB$ channels. Random coincidence rates which have been subtracted were about 0.9 counts per minute throughout. A field-sensitive effect was present (column 5) which was the same under conditions 1, 4, 6, and 8, but which essentially vanished under conditions 2, 3, 5, and 7. Tests were also made with the reactor off, using a pure gamma-source ($Co^{60}$) to actuate the detectors to approximately the same individual rates as prevailed when the