Letters to the Editor

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Use of a Ring Source in a Homogeneous Field Ring Focusing Beta-Ray Spectrometer. II

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We would like to revise our previous estimates[1] of the theoretical performance of a ring source in a homogeneous magnetic field beta-ray spectrometer. A comparison of ring and disk sources is now possible from the results[2] of a calculation of the disk source line profile using a Hubert[3] slit system, and the thin ring line profile has a low energy tail that was not considered in I.

The discussion given in I is correct for $d \leqslant 1$, but for thin ring electrons which were overlooked in I, can get to the receiver for $1 \leqslant d \leqslant 2$. Using the notation and analysis given in I, the cutoff-property of the Hubert diaphragms for $1 \leqslant d \leqslant 2$ is given by the condition

$$\frac{\partial y}{\partial D}(\Delta D-\Delta D_p)=\tfrac{1}{2}\frac{\partial^2 y}{\partial \varphi^2}\Delta\varphi^2. \tag{1}$$

The solid angle available from the ring source is then given by

$$\Omega=\frac{4\,\sin\alpha}{4\pi}\int_{\Delta\varphi_m(d-1)^{\frac{1}{2}}}^{\Delta\varphi_m}\epsilon_m[d-(\Delta\varphi/\Delta\varphi_m)^2]^{\frac{1}{2}}d\Delta\varphi,\quad 1\leqslant d\leqslant 2, \tag{2}$$

where the integrand results from the inner diaphragm at the ring focus and the lower limit is given by Eq. (1). This profile is obtained on the assumption that the range in φ can be limited to $\pm\Delta\varphi_m$ around a value of $\varphi=\varphi_0=\pi-\psi_i$ where ψ_i is the value of ψ at the ring focus. Since $\partial y/\partial\alpha$ is zero at a point near the source as well as at the ring focus, an annular diaphragm placed at this axial position will limit φ but not α. The axial positions of these diaphragms are given approximately by

$$z=S\cos\varphi[\tan\alpha+(S/D)\sin\varphi\cos\alpha(\sec^2\alpha+\tan^2\alpha)]^{-1}, \tag{3}$$

where

$$\varphi=\varphi_0\pm\Delta\varphi_m \quad\text{and}\quad \Delta\varphi_m=[(D_0\Gamma/S)\sin\psi\csc\alpha]^{\frac{1}{2}}\epsilon_m.$$

The resulting thin ring profile is given in Fig. 1, curve a. This profile may be compared with the right triangular profile erroneously given in I and shown in Fig. 1, curve b. If we had included the effect of the trace change in slope with φ near the Hubert diaphragms the peak intensity for the example given would have been reduced 10% and the half-width slightly increased. This effect will be treated in greater detail in a later paper.

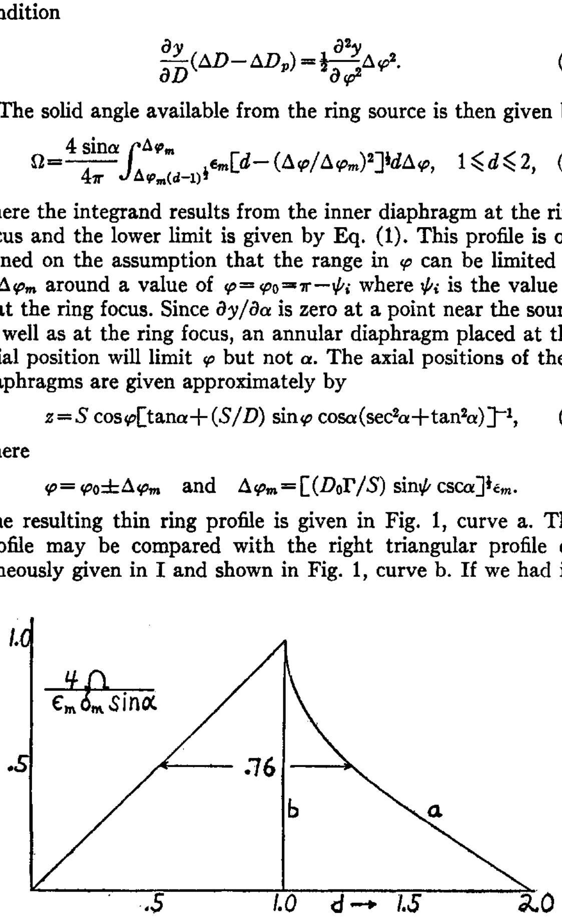

Fig. 1. Line profiles from a thin ring source. Case a refers to the corrected profile previously reported as case b.

If a finite ring width is used, the resulting line profile may be obtained by integrating over the source area as was done in I. The optimum counting rate for a given resolution occurs if the ring source width is approximately equal to the ring focus width. The profile is a pure parabola, as given in I, up to $d=1$; but if the ring source width is reduced to 0.3 of the ring focus width the profile becomes linear for $0.3\leqslant d\leqslant 1$ with a concomitant sacrifice of about 40% in peak intensity.

If the predicted intensity using a Hubert slit system and an optimum disk source[2] is used for comparison at a given half-width of line profile, the following ratio of peak intensities is predicted for case a.

$$\frac{I_{\text{ring}}}{I_{\text{disk}}}=1.4\left(\frac{S/D_0}{\Delta D_{\frac{1}{2}}/D_0}\right)^{\frac{1}{2}}.$$

If $\epsilon_m=1.0°$, $\Delta D_{\frac{1}{2}}/D_0=1/1700$, $\Delta\varphi_m=9.5°$ for $\alpha=23.5°$, and if $S/D=0.04$ the ratio given above is 15. Since the φ selecting diaphragms actually limit $\cos\varphi$, electrons with initial negative φ's as well as those with positive φ's will traverse the slit system. The resulting low-intensity, flat-topped profile is distinct from that for positive φ in d value. If troublesome, negative φ electrons may be eliminated with a slight reduction in intensity for the example given by azimuthal baffles which make use of the opposite sense of rotation about the axis that positive φ electrons have relative to negative φ electrons in the source region.

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[1] J. A. Jungerman and D. B. Beard, Rev. Sci. Instr. 27, 56 (1956). This paper will hereafter be referred to as I.
[2] D. B. Beard in an article on disk sources to be submitted soon to the Rev. Sci. Instr.
[3] P. Hubert, Ann. phys. 8, 662 (1953).

Measurement of Tritium as Water Vapor

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When Geiger or proportional counters are used for the assay of tritiated water, the sample is usually converted into hydrogen or methane which is included in the counter filling. Measurement of the sample itself as water vapor would appear to be a more direct method which avoids possible uncertainties in the chemical conversion, and this technique has been used recently.[1,2] It will be shown, however, that although counters containing water vapor may have satisfactory characteristics, adsorption effects can introduce large errors.

The presence of water vapor tends to impair the operation of a counter because pulses may be reduced or lost due to electron attachment. The probability of attachment depends on electron agitation velocity, length of drift, and partial pressure of water, while the attachment coefficient itself varies rapidly with electron agitation velocity,[3,4] and has a minimum of less than 10^{-6} near the value of 1.5×10^7 cm/sec. An approximate calculation from the available data suggests that the agitation velocity may be brought into this region throughout the major part of a proportional counter by using a suitable mixture of argon and methane as the filling.

In order to check this, pulse-height distributions of the 2.8-kev K peak and 240-ev L peak from an A^{37} source in a proportional counter have been measured with different pressures of water vapor present, and some of the spectra are shown in Fig. 1. The voltage on the counter was adjusted to make the mean pulse height the same in each case. The broadening caused by the water is due partly to the varying probability of attachment for secondary electrons originating at different distances from the wire,

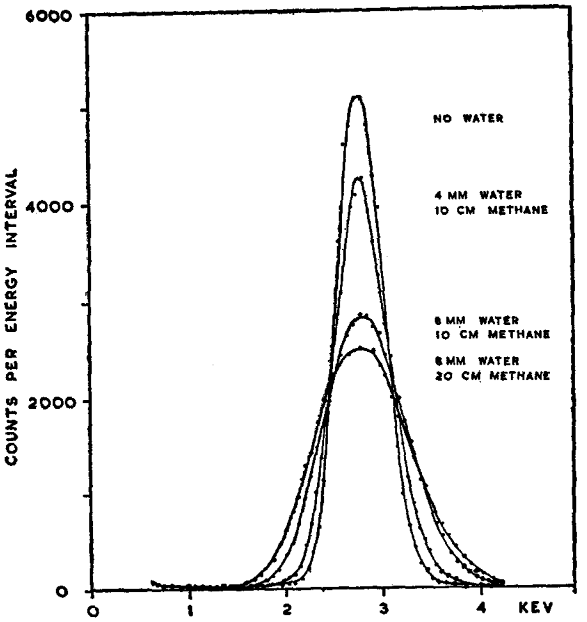

FIG. 1. Spectrum of A^{37} K peak obtained in a proportional counter of diameter 10 cm with different pressures of water vapor and methane.

and also to statistical fluctuations in attachment. The curves show that although energy resolution deteriorates as water is added, the pulses would all be counted provided the bias on the scaler were low enough.

The pulse spectra in the region of the L peak showed similar broadening. The measurements extended down to 50 ev and indicated the absence of spurious pulses.

The conclusion that activity measurements are not affected by the presence of water was verified independently by taking the counting rate from a solid C^{14} source mounted inside the counter facing the wall at different pressures of water vapor.

However, when tritiated water was being measured, the observed activity decreased with time as shown in Fig. 2. This may be explained by adsorption of the source on the wall of the counter, the effective counting geometry changing from 4π to approximately 2π in the process. The curve shown was obtained with a brass counter, but similar decays were observed in external cathode counters made of soda glass, glass treated with a water repellent silicone, and polythene. After pumping out, an activity of about 1% of the initial counting rate remained in the counters.

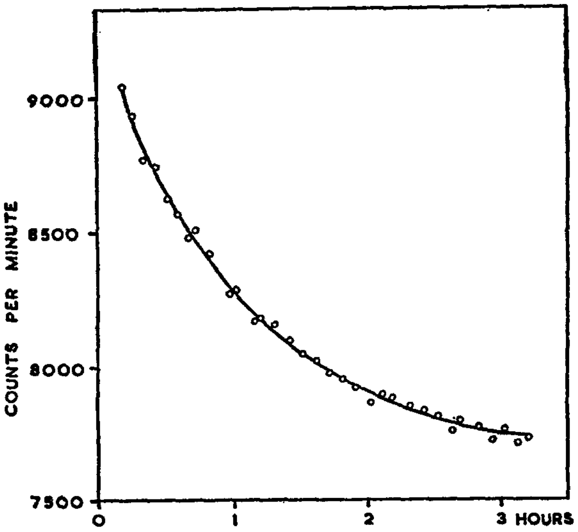

FIG. 2. Decrease of tritium counting rate after filling.

The deposition of the source on the wall involves complex adsorption phenomena which depend on the previous history of the surface and also tritium-hydrogen exchange effects. Mere extrapolation to find the initial activity cannot give the correct value for the source strength.

We would like to thank Dr. S. C. Curran for his encouragement and valuable discussions. This work was begun following a request by R. C. Hawkings of Chalk River for an independent assay of a standard source.

[1] E. B. Butler, Nature 176, 1262 (1955).
[2] J. F. Cameron, Nature 176, 1264 (1955).
[3] V. A. Bailey and W. E. Duncanson, Phil. Mag. 10, 145 (1930).
[4] N. E. Bradbury and H. E. Tatel, J. Chem. Phys. 2, 835 (1934).

Experimental Test of the Fixed Field Alternating Gradient Principle of Particle Accelerator Design*

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THE possibility of accelerating particles in an annular ring machine with a magnetic guide field which is constant in time,[1] using alternating gradient focusing, has been verified by the achievement of an accelerated beam in an electron model. This model[2] (Fig. 1) uses the simplest method of achieving alternating gradient focusing with a fixed guide field, the so-called radial sector method, in which the median plane field at any azimuth is of the form $H=H_0(r/r_0)^k$, but has opposite sign in successive magnets. The value of k for this model is 3.36. The positive field magnets are longer than the negative field magnets to bend the electrons around the machine; this, with the positive k, makes the focusing of the radial betatron oscillations stronger than that of the vertical oscillations. With the small number of sectors of this machine, eight, some vertical focusing and radial defocusing is provided by the magnet edges.

Electrons are betatron-accelerated at 40 volts per turn from 25 kev to 400 kev, the average orbit radius going from 36 cm to 52 cm during the acceleration. Accelerated beam is obtained both with a pulsed current injector and a continuous current injector. In the first case the accelerated beam, detected at the outside edge of the machine both by collected charge on a probe and by x-rays, appears as a pulse delayed 160 μsec from injection. Halving the betatron accelerating voltage doubles the delay time, corresponding then to about 20 000 revolutions of the electrons. A pulsed expander is used to pull the electrons away from the injector, although appreciable beam is obtained without the expander. Using continuous current injection, accelerated beam is observed to come out over 600 μsec of the 2000-μsec period of one betatron cycle. It is rather surprising that any beam is obtained with continuous injection, without any expander, since the electrons must make 25 revolutions before they gain enough energy from the betatron flux to pull the orbit away from the injector, a longer survival time than calculated for this machine.

The frequencies of the radial and vertical betatron oscillations have been measured both statically, using pin holes and a ZnS screen,[3] and dynamically with the accelerated beam, using rf excitation of the betatron oscillations.[4] The results are essentially