the horizontal distance between the points of saturation (V_{D1} and V_{D2}) and the wall potential condition ($V_D = V_c$). These points are designated as I'_{p1} and I'_{p2} in Fig. 2. For the case of Fig. 2 this short method yields $T_e = 1025°K$.

[1] I. Langmuir and H. M. Mott-Smith, Gen. Elec. Rev. **27**, 449 (1924).
[2] W. G. Dow, Phys. Rev. **76**, 453 (1949).

Tests of Self-Regenerating Fillings for Geiger Counters

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ONE of the serious difficulties which faces the users of Geiger counters of the self-quenching types, is that the operating conditions change with time. This effect is due to the progressive decomposition of the quenching vapor. In the end enough vapor is decomposed so that the counter becomes useless. Unfortunately, this decomposition is a necessary concomitant of the quenching mechanism.[1] It has therefore seemed worth while to examine possible vapors with a view to seeking any which might show a synthesis as well as a decomposition in the discharge. Since it is well known that ammonia can be made by the Haber process, and since this gas will also produce self-quenching action in counters, some counters were filled with this gas and tested.

Some of these counters have now been in continuous use for over two years, operating, except for occasional unavoidable interruptions, at as high counting rates as possible. They have recorded some 3×10^{10} counts. These results appear consistent with the original hypothesis that the ammonia molecule is not only decomposed in quenching but is resynthesized in the active part of the discharge.

Counters were tested which were one cm in radius, 8 cm long, with 4 mil tungsten central wires, and filled to a total pressure of about 15 cm Hg with 80 percent ammonia and 20 percent argon. Another set with only ammonia (no argon) was also run. Cathodes of evaporated silver, evaporated copper, solid copper, aquadag, and nickel were tried. Counters containing 10 cm ammonia only operated at around 1200 volts with plateaus of some 100 to 125 volts, i.e., operating characteristics were comparable to those usually found with the conventional argon-alcohol fillings, although the latter sometimes have longer plateaus. At pressures of 5 cm of ammonia, the operating voltages are 850 to 900 and the plateaus 50 to 75 volts in length. Adding argon gives shorter plateaus but lower starting potentials.

These counters exhibited two interesting characteristics. First, the counters seem to show an increase in background during a long run. This background may be due to a large number of spurious counts. In some cases the background increases very much. However, if the counter is allowed to "rest" for a while, the background returns to normal. This effect has been noted also by Simpson.[2] Of the counters tested, those with aquadag cathodes recovered the fastest.

The second characteristic of these counters was an increase in photo-sensitivity. The counter with the aquadag cathode became photo-sensitive after some 3×10^8 counts, the one with solid copper cathode after 1.5×10^8 and that with nickel after 10^9 counts. The photo-sensitivity remained after "rest" periods. In one case, to see whether this sensitivity would decrease with time, a counter was taken out of the run; it is still photo-sensitive after ten months "rest." This photo-sensitivity extends to yellow and in two cases to red light.

The experiments are being continued and will be reported in detail at a later date.

[1] S. A. Korff and R. D. Present, Phys. Rev. **65**, 274 (1944); W. Spatz, Phys. Rev. **64**, 236 (1943).
[2] J. A. Simpson (private communication).

Reproducibility of Photo-Neutron Standards

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THE construction of two nearly identical radium beryllium photo-neutron standards has given us an opportunity to ascertain the degree of reproducibility which can be expected in making standards of this type. These standards were constructed following the suggestion of Gammertsfelder and Goldhaber[1] by enclosing a capsule of compressed radium containing approximately 1 gram of radium in the center of a beryllium sphere 4.00 cm in diameter. Each of the two spheres was turned and the two halves threaded to have the same dimensions to within ±0.0001 inch. The radium was enclosed in a sealed capsule of platinum-iridium having walls 0.2 mm thick. The external dimensions of the capsules, which were right cylinders, are 0.84 cm in diameter and 0.86 cm in height. The capsules were mounted in the geometrical center of the sphere in cavities machined just large enough to accept them, as shown in Fig. 1. These standards are prepared for

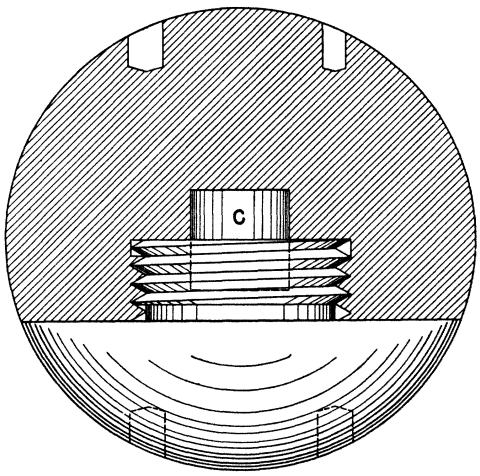

FIG. 1. Primary photo-neutron standard consisting of a 4-cm diameter beryllium sphere with 1-gram capsule of radium (*C*) at the center.

the purpose of serving as a national primary standard for measurement of sources of neutrons. They were made in duplicate so that one may be retained at the National Bureau of Standards as a reference source and the other loaned for comparison measurements when this seems desirable.

Although the radium capsules were made as nearly identical as possible it was found that from measurement of the external gamma-radiation the amount of radium contained in each after completion was not quite the same. In each case the radium salt had been compressed to maximum density. The ratio of the radium contents for standard I to standard II was found to be

$$I_\gamma/II_\gamma = 0.9897 \text{ with std. dev.} = 0.052 \text{ percent.}$$

After assembly in the beryllium spheres the ratio of the neutron intensity emitted by these sources was determined. These measurements were made by means of a long counter made in accordance with the procedure described by Hanson and McKibben.[2] The counter tube was filled with B^{10} enriched BF_3. For each measurement the standard was mounted on a base provided with pins which fitted into small holes in the beryllium sphere. This base was mounted at a fixed position on the axis of the neutron counter at a distance of approximately 21 cm. Therefore, it was comparatively easy to interchange the two standards for observations and have them at the same distance from the detector. The support was arranged so that the sources could be rotated about their vertical axes and measurements were repeated for each 90° of rotation to correct for any lack of symmetry. The

statistics of the counting yielded a standard deviation of 0.073 percent. The ratio of the neutron intensities determined in this way came out

$$I_N/II_N=0.9871.$$

The variation with rotation amounted to 0.17 percent.

The number of neutrons emitted from these spheres should also be proportional to the mass of beryllium present. Although these spheres were machined to be as nearly identical as possible a small difference in weight was found. The ratio of masses is given by

$$I_M/II_M=0.9968.$$

We may now correct the observed ratio of neutron intensities for the differences in the radium and beryllium in the two sources. We obtain

$$\left(\frac{I_N}{II_N}\right)_{corr}=0.9871\times\frac{1}{0.9897}\times\frac{1}{0.9968}=1.0006.$$

This indicates that this type of source is reproducible with an accuracy depending on the precision with which the radium and beryllium in it can be measured.

Recently, Bretscher, Cook, Morton, and Wilkinson[3] have prepared radium beryllium fluoride ($RaBeF_4$) as a reproducible source of neutrons suitable as standards. They show that the rate of neutron emission from this compound is proportional to the radium present within ± 0.5 percent. The chemical preparation of this compound must be carefully controlled to secure uniform results. Also, since this compound is an α, n source, there will be a growth of neutron activity corresponding to the growth of polonium in the source, which at equilibrium amounts to approximately 9 percent. These authors state that this compound yields 3.15×10^6 neutrons per sec. per gram of radium in the compound. Preliminary measurements show that our standards yield approximately 1.1×10^6 neutrons per second per gram of radium. Therefore, the photo-neutron standards described above have about 1/3 the efficiency and roughly 3 times the diameter of a comparable $RaBeF_4$ standard. These disadvantages are comsated for, to a large extent, by the simplicity of the preparation, the accuracy with which they can be reproduced, and the elimination of the effect of the growth of polonium. Furthermore, the radium can be removed from the photo-neutron sources in its original condition if at any time the source is to be discarded. A chemical separation is required to remove the radium from the $RaBeF_4$ sources.

[1] G. R. Gammertsfelder and M. Goldhaber, Phys. Rev. 69, 369 (1946).
[2] A. O. Hanson and J. L. McKibben, Phys. Rev. 72, 673 (1947).
[3] Bretscher, Cook, Morton, and Wilkinson, Proc. Roy. Soc. 196A, 436 (1949).

Reflection and Polarization of Neutrons by Magnetized Mirrors

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WE have recently been studying the refraction of neutrons in magnetic materials by means of critical reflection from ferromagnetic mirrors. The original purpose of the experiments was to demonstrate the existence of two indices of refraction in iron[1-3] and to investigate the feasibility of production of polarized neutrons by reflection from magnetized iron. Since the work was begun, two valuable applications of the method have been suggested. Halpern[4] has pointed out that the critical angle observed with the mirror magnetized in the direction of neutron propagation is quite sensitive to the assumed form of the neutron-electron magnetic interaction and can be used to decide the correct form. Hamermesh[5] has suggested that completely polarized neutrons might be obtained by reflection from magnetized cobalt without the necessity of monochromatization because only one spin state will reflect regardless of neutron wave-length. Both suggestions have been followed successfully with results which are here reported briefly.

Neutrons from the thermal column of the Argonne heavy water pile were filtered through BeO and collimated by means of 0.1-in. slits 10 feet apart. The BeO filter transmits only those neutrons of the Maxwell distribution with $\lambda>4.4$A hence there is a sharp drop in the intensity reflected from a mirror when the critical angle θ_c for 4.4A is exceeded. As the mirror angle, θ, increases up to θ_c all incident wave-lengths are reflected and the intensity increases linearly with θ (because of the increasing number of neutrons intercepted by the mirror). Above θ_c the intensity drops off as $1/\theta^3$ because of the shape of the Maxwell distribution. Thus a single index is expected to give an intensity shown by the line marked "Bloch" in Fig. 1 while two indices (each operative for half the incident neutrons) would give the lower curve. As Halpern[4] has suggested, the dipole-dipole interaction used by Bloch[6] leads to the one index curve (with $\theta_c=23.8'$), while the Dirac interaction used by Schwinger[7] and by Halpern and Johnson[8] leads to the two index curve ($\theta_c=14.2'$ and $30.7'$). The curves of Fig. 1 are those calculated for the two interactions including slight corrections for the resolution of the apparatus and the finite reflectivity for angles just above critical. The experimental intensity points agree well with the two index curve and verify the correctness of the Dirac interaction. There is of course the possibility of short range forces which would give rise to angular distributions other than that of the Dirac interaction; it can only be said that their effect in the present experiment is much less than the normal magnetic scattering.[9]

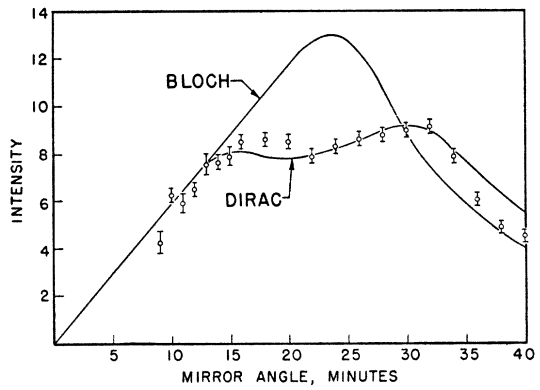

FIG. 1. Intensity of neutrons reflected from a ferromagnetic mirror.

The polarization of neutrons reflected from a mirror is measured by reflection from a second mirror. Ideally, a polarized beam will show complete reflection at a second mirror magnetized in the same direction as the first mirror, but zero reflection at a mirror magnetized in the reverse direction. This "double reflection" effect is completely analogous to the "double transmission" effect used to measure the polarization of neutrons produced by transmission. Actually, as for double transmission, it is extremely difficult to prevent depolarization and reorientation of the neutron spins in the stray fields between polarizer and analyzer. It is much simpler to keep both mirrors magnetized parallel and to measure the change in intensity resulting from depolarization of the beam between the mirrors. The depolarization is easily produced by insertion of a thin piece of unmagnetized iron in the beam, and the changes in intensity are just half those expected in the double reflection method, complete polarization being identified by a drop of one-half in intensity. This depolarization method of analysis was used in the production of polarized neutrons with cobalt mirrors. The cobalt mirrors (5 in.$\times$10 in.) were