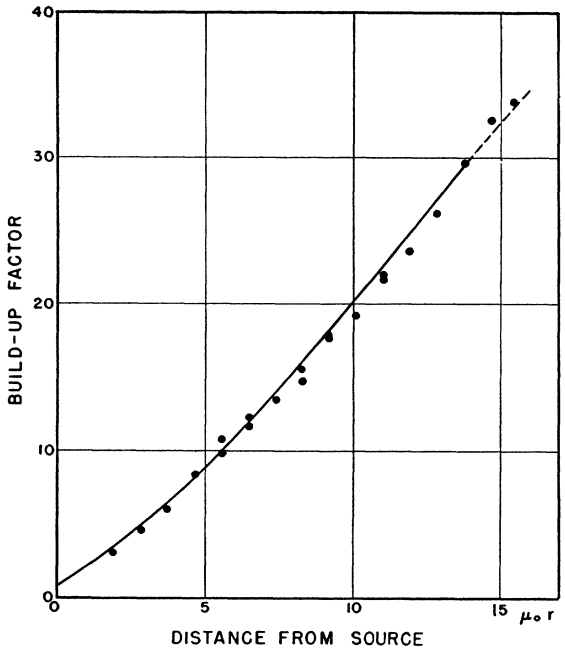

FIG. 4. Comparison of the calculated curve for the "build-up factor" with the experimental results of reference 6. The spectral distributions illustrated in Fig. 3 were weighted with the theoretical response in roentgens of a standard free air ionization chamber and then again with the specific correction factor of the chamber used in reference 6. The integral response over the whole spectrum divided by the calculated response to the primary radiation alone gives the theoretical build-up factor.

These results seem to give some confidence in the following conclusions.

(1) A method is available for calculating the distribution of x-rays in uniform media with a moderate amount of labor up to fairly large depths of penetration.

(2) This technique can presumably be applied with success to the broad class of transport phenomena governed by Boltzmann-type equations. It takes advantage even of rather crude theoretical predictions on the behavior of a distribution function to formulate an initial approximation which can thereafter be rapidly improved by straightforward numerical work.

The present approach is complementary to the earlier papers[7] which dealt primarily with the asymptotic behavior of the photon distribution and which made extensive use of the method of Laplace transforms. The work reported in those papers has now been developed into a more comprehensive treatment which will be the object of a separate report.

We wish to thank Mrs. F. A. Stinson for carrying out most of the numerical work.

* Work supported by the ONR, Applied Mathematics Branch.

[1] R. E. Marshak, Revs. Modern Phys. **19**, 201 (1947), Eq. (63); the kernel of the equation depends on the pertinent physical mechanism of scattering.
[2] H. W. Lewis, Phys. Rev. **78**, 526 (1950).
[3] P. R. Karr and J. C. Lamkin, Phys. Rev. **76**, 1843 (1949).
[4] L. V. Spencer and Fannie Jenkins, Phys. Rev. **76**, 1885 (1949).
[5] D. Jackson, *Fourier Series and Orthogonal Polynomials*, (Mathematical Ass. of Amer. Monograph, 1941), p. 149.
[6] G. R. White, Phys. Rev. **80**, 154 (1950).
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Spontaneous Fission in Cm^{242}

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SPONTANEOUS fission has been observed in Cm^{242}. It was detected initially in samples of Am^{241} irradiated with slow neutrons in the Chalk River pile. Chemical separation in ion-exchange resin columns showed that curium was responsible. Irradiations of widely differing intensity yielded curium samples with the same ratio of spontaneous fission rate to Cm^{242} α-activity. This, and the fact that the spontaneous fission rate decayed with the same half-life as Cm^{242}, identified the isotope.

The fission counter was similar to one previously used by Tunnicliffe[1] in this laboratory. The samples, on 1-in. diameter smooth platinum disks, were mounted on the electron collecting electrode, which was located at the center of curvature of the negative H.T. electrode, a hemisphere of radius 2 in. The counter was filled to a pressure of 8 cm Hg with argon containing 5 percent of carbon dioxide, and thus only the first $\frac{1}{2}$ cm (air equivalent) of the fission fragment and α-tracks was effective. This method of improving the discrimination between the two particles was first used in this laboratory by Pontecorvo and West.[2]

The counter was operated with the H.T. electrode at a potential of -400 v, sufficient to ensure minimum collection time.[3] Using a linear amplifier (T.R.E. type 1008A) with rise and fall time constants set to 0.15 μsec the "build-up" of α-pulses was unimportant for source strengths up to about 3×10^8 α-disintegrations/min.

The spontaneous fission rate was measured as 6.2/min per 10^8 Cm^{242} α-disintegrations/min. The over-all limits of error in this figure should not exceed 2 percent. Using a value of 162.5 days for the α half-life[4] the spontaneous fission half-life becomes $(7.2\pm0.2)\times10^6$ years.

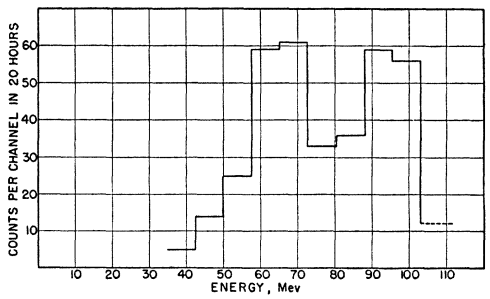

FIG. 1. Energy distribution of the fission pulses.

A rough measurement was made of the energy distribution of the spontaneous fission fragments in an ionization chamber rather similar to that described by Bunemann, Cranshaw, and Harvey.[5] The ion chamber contained two plane parallel electrodes 10 cm square 4.3 cm apart, and a shielding grid placed 1.5 cm in front of the electron-collecting electrode. The source was mounted in in the center of the negative H.T. electrode (cathode) and covered with a simple collimator, a sheet of 0.37-mm brass drilled with 3-mm holes. The chamber was filled to a pressure of one atmosphere with argon containing 5 percent carbon dioxide. A collecting field (between cathode and grid) of 470 volts/cm was used, amply adequate for saturation, and the grid was run at -1.5 kv to prevent its collecting any of the electrons traveling to the collector.

Preliminary experiments on α-particles (using a larger electrode spacing and somewhat lower field strengths) showed that the pulse distribution was well preserved even with rise and fall time constants in the amplifier as low as 0.5 μsec. With this fast response the "build-up" pulses of fission energy size from a source of the strength used (5×10^6 α-disintegrations/min) would be negligible compared with the observed spontaneous fission rate of 18 per hour.

TABLE I. Energies of the fragments in the fission of several nuclei.

Nucleus	Most probable energy (Mev) Light fragment	Heavy fragment	Ratio
Spontaneous fission in Cm^{242}	95 97, 94 91	65 68, 66 65	1.43
$Pu^{239}+n$	94.6	65.2	1.45
$U^{235}+n$	94.5	60.2	1.57
$U^{233}+n$	93.0	56.6	1.64

The fission pulses were sorted by a simple ten-channel pulse analyzer and recorded on a ten-pen Esterline Angus operation recorder. The distribution obtained in one of the runs is shown in Fig. 1. The energy scale was obtained by comparison with the α-pulses in terms of a pulse signal-generator.[6]

The results of three runs are given in Table I together with data on slow neutron fission.[7] Before any detailed comparison could be made, much longer runs with finer pulse analyzer resolution would be required. Moreover, a thinner source would also be desirable. However, the investigation aimed at seeing if there were any major difference between spontaneous and slow neutron induced fission. Apparently there is not.

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[1] P. R. Tunnicliffe, Chalk River report CRG-449, unpublished.
[2] B. Pontecorvo and D. West, Chalk River report MP-210 (1945), unpublished.
[3] B. Rossi and H. Staub, *Ionization Chambers and Counters* (McGraw-Hill Book Company, Inc., New York, 1949), p. 14.
[4] Hanna, Harvey, and Moss, Phys. Rev. **78**, 617 (1950).
[5] Bunemann, Cranshaw, and Harvey, Can. J. Research **A27**, 191 (1948).
[6] Because of the very high α-counting rate the α-pulses were compared with the signal generator on a triggered oscilloscope. In spite of the short distance between the source and the grid, enough α-particles left the source sufficiently obliquely to give a well-resolved trace corresponding to the total α-energy.
[7] D. C. Brunton and W. B. Thompson, Can. J. Research **A28**, 498 1950).

Low Temperature Resistance Minimum in Magnesium Measured by a Mutual Inductance Method*

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SOME experiments performed recently by the authors to investigate the low temperature resistance of magnesium have utilized a method which may prove to be useful for many types of low temperature resistance measurements. Owing to the strong influence of impurities and crystal structure on low temperature resistivities, a method was developed which makes it possible to use a bulk sample of material rather than a drawn wire. The principle utilized in this method is that the complex mutual inductance of two coaxial coils surrounding a sample depends on the conductivity of the sample. The mutual inductance is measured with a bridge. The calculations can be easily carried out for cylindrical

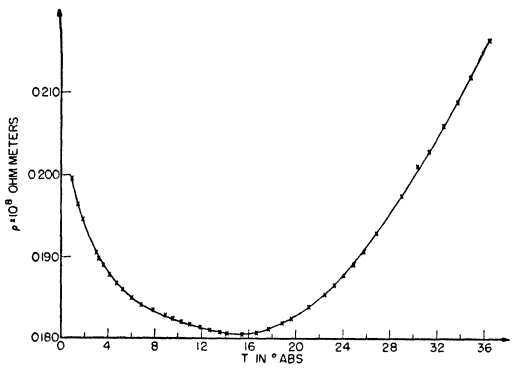

FIG. 1. A plot of resistivity *vs* temperature for a cylindrical sample of magnesium.

symmetry[1] (two coaxial coils containing a cylindrical core of conductivity σ), yielding a relation between the mutual inductance and the core conductivity. Refinements to the calculation can be introduced to correct for the finite length of the coil and the core.

This method has several advantages over the customary measurements made with wires and resistance bridges. No connections to the sample are necessary, thus eliminating contact effects and the possibility of a heat leak down the connecting wires. Single crystal samples can be easily made in a shape suitable for use in conductivity measurements. Further, the bulk resistivity comes fully into play, making small imperfections, which might greatly influence wire measurements, of little importance.

The resistivity of magnesium has been measured by this method in order to study the resistance minimum reported by Garfunkel, Dunnington, and Serin.[2] An illustration of the results is shown in Fig. 1.

At the present time, measurements are under way at this Laboratory to investigate the effect of impurity content and crystal structure on the resistance minimum.

* This work was supported in part by the Signal Corps, the Air Materiel Command, and ONR.
[1] N. W. McLachlan, *Bessel Functions for Engineers* (Oxford University Press, London, 1941), Chapter IX.
[2] Garfunkel, Dunnington, and Serin, Phys. Rev. **79**, 1 (1950).

Detection of Gamma-Ray Polarization by Pair Production*

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IT has been pointed out by Yang,[1] that pair production may provide a method for detecting the polarization of γ-rays in the high energy range: $h\nu \gg mc^2$ (m being the electron mass) where the usual Compton recoil method becomes insensitive. The idea is to utilize the azimuthal dependence of the pair production cross section $d\sigma$, the azimuth ϕ being measured around the direction $\mathbf{k}$ of the incident quantum and from the plane containing $\mathbf{k}$ and the electric polarization vector $\boldsymbol{\varepsilon}$ of the quantum. Actually, of course, one must consider two azimuths ϕ_+ and ϕ_- for the positive and negative electron respectively. Berlin and Madansky,[2] from whose paper our notation is borrowed, have made a careful study of the dependence of $d\sigma$ on ϕ_- when $\phi_+=\phi_-+\pi$. In this case the plane of the pair contains *exactly* the direction $\mathbf{k}$ of the incident quantum, and one can speak simply of the azimuth $\phi=\phi_-$ of the plane of the pair with respect to the plane of polarization. From the experimental standpoint it will be practically impossible to select the pairs which satisfy the Berlin-Madansky condition. Both electrons will be emitted within a narrow cone around $\mathbf{k}$, and the plane of the pair will always make a very small angle with $\mathbf{k}$. No matter whether pairs are observed in a photographic emulsion or produced in a thin target and detected with counters, scattering within the emulsion or target will unavoidably distort the initial directions to a considerable extent. It seems more reasonable, therefore, to set as our goal the measurement of the angle between the plane of the pair and the plane of polarization without any selection. The question then arises whether the case considered by Berlin and Madansky is sufficiently representative to permit a rough prediction of what is to be expected in the general case. The result of the following calculation may indicate that it is not.

The Bethe-Heitler formula for $d\sigma$ has a quite complicated dependence on the various parameters involved, so that the sign and magnitude of the effect to be expected can be seen only at the end of a laborious integration. In order to find a simpler picture we have used the Weizsäcker-Williams approximation.[3] In order to deal with pair production, Williams makes a Lorentz-transformation parallel to $\mathbf{k}$ with velocity $v=c(\xi-1)/(\xi+1)$, with $\xi=h\nu/mc^2$. In the new system the quantum has an energy $h\nu_1=mc^2$. The method can be applied if $\xi\gg1$ so that v is very close to c; the field of the nucleus can then be approximately substituted by a spectrum $\sim(C/\nu)d\nu$ of virtual quanta, C being a slowly variable function of ν, which we shall treat as a constant. These quanta move in the direction $-\mathbf{k}$, and if one of them, having an energy $h\nu_2>mc^2$, collides with the real quantum, a pair may be produced. It is characteristic of the Weizsäcker-Williams