Proceeding as before, but removing the integrals in x which contain $f(x)$, we obtain

$$\phi_{\max}(\text{par.}) = 1.39\, \phi_{\max}(\text{slab}),$$

which is consistent with Eqs. (3) and (4) which apply only in the special case of uniform composition. The relations containing $\bar{\phi}_1$ and the average values cannot be obtained without specifying $f(x)$.

Similar results can be obtained in cylindrical geometry. The threshold values of $\bar{\phi}_1$ are given below for two modes of a bare uniform cylinder in which the steady state flux is

$$\phi = \phi_{\max}\,(\text{cyl}) J_0 \left(\frac{2.4048r}{R}\right) \sin\left(\frac{\pi z}{Z}\right).$$

For the first axial mode

$$g_1 = \frac{2.724}{R} J_0 \left(\frac{2.4048r}{R}\right) \cdot \sqrt{2/Z}\, \sin\left(\frac{2\pi z}{Z}\right).$$

Substituting in Eq. (2) as before, the result is

$$\bar{\phi}_1 = 0.491\, \phi_{\max}\,.$$

For the first azimuthal mode

$$g_1 = \frac{3.511}{R} J_1 \left(\frac{3.832r}{R}\right) \cdot \sqrt{1/\pi}\, \sin\theta \cdot \sqrt{2/Z}\, \sin\left(\frac{\pi z}{Z}\right).$$

where θ is the azimuthal angle. Substituting in Eq. (2) the result is

$$\bar{\phi}_1 = 0.588\, \phi_{\max}\,.$$

REFERENCES

1. A. G. Ward, CRRP-657 (1956).
2. D. Randall and D. S. St. John, *Nucleonics* **16** (3), 82–86, 129 (1958).

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A Sulfur–Phosphorus Absolute Fast Neutron Flux Detector

Sulfur threshold detectors incorporating phosphorus for counting efficiency determination have been used at our laboratory. Detectors made from a mixture of a known ratio of phosphorus and sulfur were exposed to a known thermal flux producing radioactive P^{32} from the P^{31} $(n,\gamma)P^{32}$ reaction. The detectors were then counted in a standard beta counter and the counting efficiencies determined.

Cadmium covers were used to prevent further P^{32} production by thermal neutron capture during activation as $S^{32}(n, p)P^{32}$ threshold detectors. Since the counting efficiency for each detector was known, the P^{32} activity and therefore the absolute fast neutron flux could be determined.

The detectors were allowed to decay for at least three days before counting to eliminate the Si^{31} 2.6 hr activity resulting from the P(n, p)Si reaction and the Na^{24} 15 hr activity resulting from the Al(n, α)Na reaction in the aluminum capsules used.

Results reproducible within about 20% were obtained with a mixture of one part red phosphorus to ten parts sulfur flour, and also with phosphorus pentasulfide (P_2S_5). The corrections required due to epicadmium production of P^{32} by neutron capture were approximately 3% in the first case and 10% in the second. These corrections were estimated by activating similarly shaped cadmium covered phosphorus detectors in the fast flux to be measured and assuming the same counting efficiency as in the case of the sulfur–phosphorus detector.

It would be desirable to use a lower ratio of phosphorus to sulfur to minimize thermal activation during the fast flux measurement. This must be balanced against the statistical counting error introduced due to the low activity of the thermal flux calibration run.

The 2200 meters/sec cross section of phosphorus was taken to be 0.20 ± 0.01 barn. This is slightly higher than the value given by Hughes and Schwartz (*1*) since better values are available for the comparison standards on which their value is based (*2*). The energy dependence of the $S^{32}(n, p)P^{32}$ cross section spectrum was taken from Hughes and Schwartz (*1*) but normalized to give 65 mb for the mean cross section for a fission spectrum (*3*).

The principle of using thermal activation to produce an internal calibration might be applied to other elements. Two possibilities are the $Cl^{35}(n, \alpha)P^{32}$ reaction with an effective threshold at approximately 4 Mev and the $Al^{27}(n, \alpha)Na^{24}$ reaction with an effective threshold at approximately 8 Mev.

REFERENCES

1. D. J. Hughes and R. B. Schwartz, "Neutron Cross Sections," BNL 325, 2nd ed., Brookhaven National Laboratory (1958).
2. John R. Stehn, Brookhaven National Laboratory, private communication.
3. B. H. Parker, "The Measurement of Fast Neutron Flux Using the $S^{32}(n, p)P^{32}$ Reaction," AERE-R3443 (1960).

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Resonance Absorption in Materials with Grain Structure (Addendum)

We have been asked how the results of a previous paper on the resonance absorption in materials with grain structure (*1*) (quoted as I) have to be modified, when the absorber grains occupy a sizeable fraction of the total volume. While it should be recognized that the assumption of random distribution is less good in this case, a formal answer is easily obtained.

We use the same notation as in I. Let V_c be the volume fraction of the moderator matrix surrounding the absorber grains, and V_a the volume fraction of the grains, so that

$$V_c + V_a = 1. \tag{A.1}$$

Formerly it was assumed that $V_a \ll 1$, so that $V_c \approx 1$. Now with $V_c < 1$, the moderator cross section per absorber nucleus σ_m, becomes

$$\sigma_m = V_c N_c \sigma_c / V_a N_0 \tag{A.2}$$

and one obtains in place of (I, 2.8)

$$\frac{L}{\lambda} = \frac{\ell_0 N_c \sigma_c}{V_a} = \frac{\ell_0 N_c \sigma_c N_0 V_c}{V_a N_0 V_c} = \frac{\ell_0 N_0 \sigma_m}{V_c} \tag{A.3}$$

and thus in place of (I, 2.9) and (I, 2.10)

$$C = \frac{1}{1 + \ell_0 N_0 \sigma_m / V_c} \tag{A.4}$$

$$P_0{}^* = P_0 \frac{\sigma_m / V_c}{(\sigma_m / V_c) + P_0 \sigma_{t0}}. \tag{A.5}$$

With the use of (A.2) this can be transcribed into the form

$$P_0{}^* = P_0 \frac{N_c \sigma_c}{N_c \sigma_c + V_a N_0 P_0 \sigma_{t0}} = P_0 \frac{\Sigma_c}{\Sigma_c + V_a P_0 \Sigma_0}, \tag{A.6}$$

that is, the competition for neutrons escaping from one grain is determined by the macroscopic cross section of the matrix material and the shielded macroscopic cross section of the absorber grains weighted by their volume fraction. One loses in this case the smooth transition to complete homogenization since the macroscopic cross section for the moderator is different in the matrix from the completely smeared out case. Equation (A.6) gives in the limit of infinitely small grains, i.e., $P_0 \rightarrow 1$,

$$P_0{}^* = \frac{\Sigma_c}{\Sigma_c + V_a \Sigma_0}, \tag{A.7a}$$

that is neutrons still see the original moderator number density N_c between grains. In case of complete homogenization (without change in total volume) one has instead

$$P_0{}^* = \frac{V_c \Sigma_c}{V_c \Sigma_c + V_a \Sigma_0}, \tag{A.7b}$$

that is, the number density of moderator nuclei is reduced to $V_c N_c$. Equations (A.7a) and (A.7b) become identical only when $V_c = 1$.

REFERENCES

1. R. K. Lane, L. W. Nordheim, and J. B. Sampson, *Nucl. Sci. Eng.* **14**, 390 (1962).

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