for neutrons reaching the detector turns out to be ~6.5. The additional scattering events have the effect of compensating for the variation in the lead cross section.

In summary, the effect of lead shields up to 5 cm thick has been shown to be small in typical neutron spectrum measurements performed with proton recoil proportional counters. Note that the possible bias of thicker shields, such as the 8.9-cm-thick shield used by Batchelor and Hyder,[6] remains to be determined and that there are possible geometric effects yet to be resolved. It should also be kept in mind that an elastic scattering event in lead degrades the neutron energy by ~1%. A hardening correction, i.e., a shift in the energy axis, is therefore necessary even for relatively thin shields. This correction may or may not be significant depending on the nature of the experiment.

G. Fieg
M. Lalovic

Karlsruhe Nuclear Research Center
Institute for Neutron Physics and Reactor Technology
Karlsruhe, West Germany

G. Woodruff

University of Washington
Department of Nuclear Engineering
Seattle, Washington 98195

May 5, 1975

[6]R. BATCHELOR and H. R. McK. HYDER, *J. Nucl. Energy*, **3**, 7 (1956).

Comment on "Influence of Deep Minima on Multigroup Cross-Section Generation"

Although the author of a recent technical note[1] addressed the problem of defining a weighting spectrum for the cross section and successfully demonstrated the sensitivity of the results to the buckling (B^2) used, he did not address the basic problem that the actual group-averaged cross section is a spatially dependent quantity.

The spatial variation in group-averaged cross sections has been experimentally shown to be significant.[2,3] It has been demonstrated that the cross-section probability-table method can be used to calculationally reproduce the experimentally observed spatial variations.[4] It was further demonstrated[5] that the cross-section probability-table method can be used in conjunction with Case's method[6] to define an asymptotic spectrum that is identical to that obtained by Becker:

$$N_0(E) = \frac{V}{2} \ln\left(\frac{V\Sigma_T + 1}{V\Sigma_T - 1}\right) = \frac{1}{2iB} \ln\left(\frac{\Sigma_T + iB}{\Sigma_T - iB}\right) ; \quad V = \frac{1}{iB} .$$

[1]M. BECKER, *Nucl. Sci. Eng.*, **57**, 75 (1975).
[2]J. B. CZIRR and R. L. BRAMBLETT, *Nucl. Sci. Eng.*, **28**, 62 (1967).
[3]R. L. BRAMBLETT and J. B. CZIRR, *Nucl. Sci. Eng.*, **35**, 350 (1969).
[4]D. E. CULLEN,and E. F. PLECHATY, *Trans. Am. Nucl. Soc.*, **17**, 490 (1973).
[5]D. E. CULLEN and C. R. WEISBIN, *Trans. Am. Nucl. Soc.*, **17**, 488 (1973).
[6]E. M. CASE, *Linear Transport Theory*, Addison-Wesley Publishing Company, Reading, Massachusetts (1967).

More important, it has been demonstrated[7] that the probability-table method reproduces not only the asymptotic spectrum for deep penetration but also the transient spectrum for shallow penetration. The combination of asymptotic and transient spectra leads to spatially dependent cross sections that can result in large differences in reaction rate or flux[8] when compared to the normal multigroup calculations.

In terms of neutron transport, the above spectrum can be considered a generalization of Bondarenko[9] self-shielding, while in terms of photon transport it is equally applicable as a generalization of the method normally used to define the Rosseland[10] mean.

Dermott E. Cullen

Lawrence Livermore Laboratory
University of California
P. O. Box 808
Livermore, California 94550

June 9, 1975

[7]D. E. CULLEN, *Nucl. Sci. Eng.*, **55**, 387 (1974).
[8]D. E. CULLEN, "A Method for Multi-Group Neutron Calculations in the Unresolved Resonance Region," UCRL-75164, Lawrence Livermore Laboratory (1973).
[9]I. I. BONDARENKO, "Group Constants for Nuclear Reactor Calculations," Consultants Bureau, New York (1964).
[10]G. C. POMRANING, *The Equations of Radiation Hydrodynamics*, Pergamon Press, New York (1973).

Response to "Comment on 'Influence of Deep Minima on Multigroup Cross-Section Generation' "

Cullen[1] has commented that in discussing the influence of deep minima on multigroup cross sections,[2] we did not address the basic problem that the group-averaged cross section is a spatially dependent quantity. He also suggested that a recently published method[3] could be utilized to treat the spatial variations.

It is, of course, true that group-averaged cross sections are space dependent in principle. However, an underlying assumption behind use of multigroup methods is that at some level of detail, this space dependence can be neglected. In our own work, we have tried to assess what this level is through use of approximate space-dependent calculations.[4]

Our purpose in Ref. 2 was to demonstrate the kind of difficulty that could arise in using standard weighting procedures with data files of high resolution. Whether spatial dependence also is a potential difficulty is likely to depend on the nature of the problem. For example, if one is dealing with a slowing-down problem (i.e., one where scattering is predominant and where the sources at energies of interest are determined by inscattering) and one encounters a narrow deep minimum, it may be reasonable to assume that the spatial shape (buckling) characterizing energies above the minimum would govern. Under such circumstances, the weighting function is likely to be the principal concern and the spatial dependence is likely to be

[1]D. E. CULLEN, *Nucl. Sci. Eng.*, **58**, 261 (1975).
[2]M. BECKER, *Nucl. Sci. Eng.*, **57**, 75 (1975).
[3]D. E. CULLEN, *Nucl. Sci. Eng.*, **55**, 387 (1974).
[4]E. T. BURNS, PhD Thesis, Rensselaer Polytechnic Institute (1971).