Letters to the Editor

Comments on "A Pulsed Neutron Experiment with Beryllium by the Use of a Gamma-Ray Flash from an Electron Linear Accelerator"

In a recent paper, Aizawa et al.[1] reported some interesting results on the decay of neutron pulses inside beryllium assemblies. They extended earlier studies to smaller assemblies and to longer times. From their measurements, they conclude that their results contradict the limit suggested by this author.[2] They also doubt the physical basis of the assumptions involved in deriving that limit. In this connection, we would like to make the following observations:

1. In an earlier paper, Zhezherun[3] also observed that his measured value of the decay constant in BeO exceeded the limit proposed by this author. However, from his previous measurements[4] of the energy variation of the total cross section of neutrons in BeO, he found that the values of the cross section at Bragg peaks were sample dependent and always less than (or equal to) the corresponding theoretical values. (A similar effect was noticed in graphite by Khubchandani.[5]) Therefore, for a given material one would expect the value of λ_{tr} at $E = E_0$ (for notation, see Ref. 1) to be, in general, larger than the corresponding calculated value, and hence the slope of the λ_K curve, which has to be determined by taking the observed value of λ_{tr} at $E = E_0$, would also be larger than the theoretical slope. It is, therefore, not surprising that some experimental points, particularly those for large B^2, should lie above the theoretical limiting curve for λ_K. This point was also brought out during discussions on Zhezherun's paper.[3] We feel it will be of considerable interest if the total cross section of neutrons near the first few Bragg peaks could be measured for samples of the material used by Aizawa et al.[1]

So far, nothing seems to indicate that the limit set by this author is in contradiction with experimental data. If anything, they can be used to comment, at least qualitatively, on the state of crystallinity of the material.

We completely agree with Aizawa et al.[1] that for $B^2 > B_c^2$, the decay constant must ultimately tend to λ_{lim}. However, in our paper,[2] we consider only the pseudomode and, provided it exists (it may not under certain conditions), we feel it will be bounded by λ_K.

2. We do not agree with Aizawa et al.,[1] or for that matter with Corngold,[6] that there is no physical justification for λ_K. In the first instance, the limit was deduced from purely physical arguments[2] but there is not much point in repeating them here. Later work, particularly by Corngold and his co-workers,[7,8] established the correctness of the limit (Corngold calls it λ_{el} and has derived a more general expression for it). More recently, Matsumoto[9] discussed the bounded Boltzmann equation in detail. Using his method of inelastic scattering expansion, he analyzed the pulsed neutron problem and found that "the pseudo mode presented by $\phi_{th}^{(0)}$ was found to approach the eigen spectrum of the thermal bounded equation. This circumstance supports Kothari's concept of the pseudo-mode."

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May 4, 1973

[1] O. AIZAWA, H. KADOTANI, K. KANDA, Y. FUJITA, and S. ITO, *Nucl. Sci. Eng.*, **50**, 38 (1973).

[2] L. S. KOTHARI, *Nucl. Sci. Eng.*, **23**, 402 (1965).

[3] I. F. ZHEZHERUN, *Proc. IAEA Symp. Neutron Thermalization and Reactor Spectra*, Ann Arbor, **2**, 379 (1967).

[4] I. F. ZHEZHERUN, I. P. SADIKOV, and A. A. CHERNISHOV, *Sov. At. Energy*, **13**, 250 (1960).

[5] P. G. KHUBCHANDANI, *Nucl. Sci. Eng.*, **8**, 172 (1960).

[6] N. CORNGOLD, *Nucl. Sci. Eng.*, **23**, 403 (1965).

[7] N. CORNGOLD and K. DURGUN, *Nucl. Sci. Eng.*, **29**, 354 (1967).

[8] R. CONN and N. CORNGOLD, *Nucl. Sci. Eng.*, **37**, 85 (1969).

[9] T. MATSUMOTO, *J. Nucl. Sci. Technol. (Japan)*, **9**, 453 (1972).

Reply to "Comments on 'A Pulsed Neutron Experiment with Beryllium by the Use of a Gamma-Ray Flash from an Electron Linear Accelerator' "

As to the total cross section of beryllium metal used in our experiment,[1] which was made from metal beryllium powder (-200 mesh) vacuum pressed at high temperatures, we have already finished the measurement of the cross section of the sample itself. We are now preparing to publish a paper entitled "Temperature-Effect of Thermal Neutron Scattering Cross Section of Beryllium." For reference we show here, as Fig. 1, a preliminary graph of the total cross section at room temperature, in which the measured cross section is in good agreement with the calculated one near the Bragg peaks; it is also in good agreement with the data shown in BNL-325 (Ref. 2). Then it is clear that there is no sample dependency on the cross section of beryllium metal; usually the grain size is so

[1] O. AIZAWA, H. KADOTANI, K. KANDA, Y. FUJITA, and S. ITO, *Nucl. Sci. Eng.*, **50**, 38 (1973).

[2] D. J. HUGHES and R. B. SCHWARTZ, "Neutron Cross Sections," BNL-325, Brookhaven National Laboratory (1958).

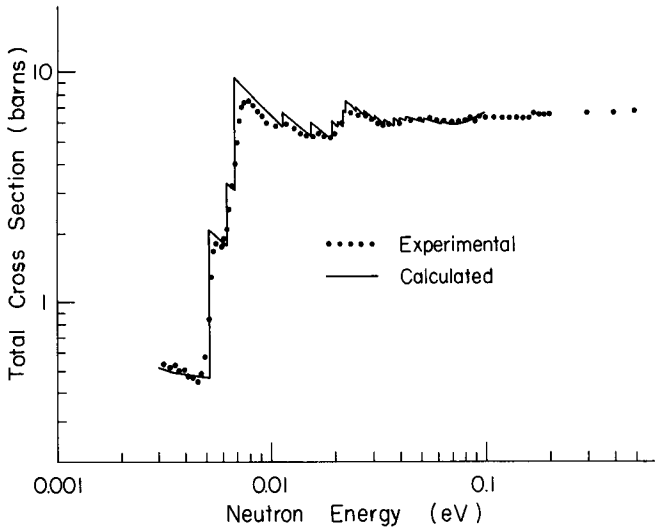

Fig. 1. Total neutron cross section for beryllium metal measured at room temperature.

small that the block may be in a perfect polycrystalline state. Therefore, the experimental value of λ_{II} will be nearly equal to the calculated one, and the present slope of the λ_K curve seems to be correct.

The second comment concerns the conception of the pseudomode. We recognize the existence of the pseudomode in which the pulsed neutron flux apparently decays exponentially. For instance, there is some region where the instantaneous decay constant becomes constant, as shown in Fig. 7 of Ref. 1, except for the case of the 15- × 15- × 15-cm assembly. In such a small assembly, however, the region where the instantaneous decay constant becomes constant vanishes. In this case, the conception of a pseudomode becomes uncertain. Therefore, we feel the concept of a pseudomode is a convenience for explaining some experimental results. It has physical meaning only when certain experimental conditions are satisfied.

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June 4, 1973

Comments on the Electron-Photon Transport by the Discrete Ordinates Method

In a recent article by Bartine et al.,[1] the promising idea of treating electron transport by the discrete ordinates method was developed. As we have been using a similar approach in attacking the problem, perhaps the following suggestions concerning several items in their procedure, based on our direct experience, can help improve the agreement between S_N calculation and experiment:

1. In many practical problems of electron transport, especially dosimetric ones, overall energy conservation (and energy deposition) would be of primary concern. In the standard treatment of energy group structure and cross-section averaging followed by Bartine et al. (Ref. 2, pp. 15-16), conservation of particle number and "activation rates" is emphasized, with damage for energy conservation. We see this to be a real handicap in the present electron transport method.

2. The cutoff concept at the low-frequency limit of bremsstrahlung is best understood by including both elastic and radiative electron-nucleus processes in the so-called "electron scattering without atomic or nuclear excitation," reviewed by Motz et al.[3] According to this interpretation, the lower the cutoff value chosen, the larger the reduction ("soft-photon correction factor") needed in the "quasi-elastic" scattering cross section (Mott-Moliere or Rutherford formulas). Specifically, the cutoff value of 10^{-4} MeV used in the work of Bartine et al. (Ref. 1, Sec. III.C.) would need the approximate reductions in the "elastic" scattering formula, shown in Table I. This effect is especially important with increasing Z and energy; perhaps it could be responsible, in part, for the tendency to lateral shifting noticed when comparing calculation with experiment in the (aluminum, 2.5 MeV) and (gold, 1 MeV) cases of Bartine et al.

TABLE I

Approximate Reduction in the "Elastic" Scattering Formula

Initial Electron Energy (MeV)	Scattering Angle (deg)		
	45	90	135
2.5	8.5%	13%	15%
10	18%	23%	25%

TABLE II

Sequence of Legendre Coefficients for a Typical Case

L	A_L (Legendre Coefficients)		
	Normal	P-7 Correction	P-10 Correction
0	1	1.54 E-4	2.84 E-4
1	0.999 993	1.47 E-4	2.77 E-4
4	0.999 940	0.94 E-4	2.24 E-4
7	0.999 846	0	1.30 E-4
10	0.999 716	0	0
20	0.999 055	0	0

[1] D. E. BARTINE et al., *Nucl. Sci. Eng.*, **48**, 159 (1972).

[2] D. E. BARTINE et al., "Low-Energy Electron Transport by the Method of Discrete Ordinates," ORNL-TM-3438, Oak Ridge National Laboratory (1971).

[3] J. W. MOTZ et al., *Rev. Mod. Phys.*, **36**, 881 (1964).