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SHIELD CALCULATIONS FOR LEAD AND WATER MIXTURES

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Abstract

In this memorandum the penetration of neutrons through mixtures of Pb and H_2O is calculated by the methods outlined in ORNL-748, formula p. 11. The general formulas given for 20% Pb, 30% Pb, 40% Pb include the contribution of the continuous spectrum; the calculations show the necessity of using this contribution for distances up to about half a meter from the source plane, so that a better fit with empirical data can be expected at small distances. When certain corrections for the high energy theoretical curves, and other corrections to empirical curves are estimated, a fair agreement with the experimental results for 33% Pb is indicated.

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Numerical results from computations for mixtures of lead and water.

a. Discontinuous spectrum

Values of $S = \lambda \Sigma (2n+1) h_n K_n^2$

E	20% Pb	30% Pb	40% Pb
5	12.6	8.0	6.0
7	10.3	7.1	5.4
9	10.4	7.2	5.5

b. Continuous spectrum

Values of $A^2 + B^2$

	20% Pb		30% Pb	40% Pb
λ	E = 5	E = 7	E = 7	E = 7
.98	.61	.83	1.05	1.06
.96	.64	.74	.85	.84
.94	.63	.69	.74	.72
.92	.65	.68	.71	.69
Ave.	.6325	.74	.84	.83

For E = 5, the average of $A^2 + B^2$, multiplied by π, equals 1.987, nearly 2 which is the factor in the denominator for the problem with the assumption of absorption at each collision. If the average of $A^2 + B^2$ is taken as constant, and if the total cross section of the mixture is assumed to be of the form:

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$$\sigma^{tot} = c' + b'/E$$

the continuous spectrum, integrated over the energy, gives

$$\frac{1}{\alpha\pi\,(A^2+B^2)_{av.}} \quad \frac{1}{\sigma_{av.}z} \left\{ W'\,K_1\,(W')\,e^{-c'z} \right\}, \quad W' = 2\sqrt{\alpha\, b' z}$$

The fission energy spectrum is here assumed to be of the form $\exp(-\alpha E)\,dE$.

The discontinuous spectrum, for $\sigma^{tot}/\lambda = c + b/E$, gives the term

$$\frac{1}{\alpha S}\, W\,K_1\,(W)\,e^{-cz}, \quad W = 2\sqrt{\alpha\, b\, z} \qquad b = .3735, \quad c = .071$$

Here S is considered a slowly varying quantity in the integration, and assigned a constant value, for instance the numerical value for $E = 7$. Except for a constant factor, the high energy flux is represented by

$$f(z) = \frac{1}{\pi(A^2+B^2)_7\,\sigma_7 z}\, W'\,K_1(W')\,e^{-c'z} + \frac{1}{S}\, W\,K_1(W)\,e^{-cz}$$

Here $\alpha = .72$, and for different mixtures, c', b', and $1/\sigma$ are taken from the following table:

	20% Pb	30% Pb	40% Pb
c'	.0825	.0921	.1016
b'	.336	.3045	.273
$1/\sigma$	7.66	7.37	7.11

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Discussion

The attached curves show the mixtures 30% Pb, 40% Pb normalized to coincide with the curve for 20% Pb at 10 cm. Experimental data for 33% Pb (Experiment 8) for thermal energies and center line measurements is shown for a number of points. The effect of the Hurwitz correction for H_2O would increase the original values at 110 cm. by a factor of nearly 2; assuming the same correction for this data, the last point would be increased by a $\log_{10} 2 = .30103$, giving the point marked with a square on the graph.

If the theoretical curves were employed with suitable displacements to indicate thermal energies of aged neutrons, the corresponding curves would be slightly steeper; a quite fair matching of theory and experiment is indicated.

For better theoretical results the analysis of the aging effect in these mixtures would be required; this seems to be somewhat unsatisfactory at present.

The cross section for O has been taken equal to 1 barn.

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