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Calculation of Effective Boron
Cross Sections in the Reflector
for One Dimensional Calculations.

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MASTER

When a two dimensional problem, which contains highly absorbing regions, is reduced to a one dimensional problem, it is customary to obtain effective thermal absorption cross section for the highly absorbing material by dividing the actual cross sections by a disadvantage factor.

The purpose of this note is to indicate a reasonable procedure for the calculation of the disadvantage factors for one or more thermal neutron groups. The procedure should be used in conjunction with the TNS and BSN codes.

For our purposes, the highly absorbing material is the boron vane in the beryllium reflector. As an approximation, the vane and reflector are represented as a cell consisting of an infinite slab of thickness $2a$ imbedded in a moderator of thickness $(b-a)$ on each side of the absorber.

The theory developed by Amouyal and Benoist ⁽¹⁾, as modified by Theys ⁽²⁾ and Ehsalla ⁽³⁾, results in the following expression for the disadvantage factor f ,

$$f = \frac{a \sum_1 a_1}{(b-a) \sum_2 a_2} \left[(b-a) \sum_2 a_2 \left(3 \lambda^{-2} + \frac{1}{\alpha} \right) + k_2 (b-a) \coth k_2 (b-a) - 1 \right] \quad (1)$$

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where

$\sum a_1$ = absorption cross section of absorber,

$\sum a_2$ = absorption cross section of moderator,

λ = .71

$K_2 = \sqrt{\sum a_2 / D_2}$,

D_2 = diffusion coefficient of moderator

α = the ratio of the current to the flux at the surface of the absorbing slab; to be computed from blackness theory.

Equation (1) is different from the equation given by Bhalla, and more accurate. It reduces to his result if one sets

$$K_2 (b-a) \coth K_2 (b-a) - 1 = K_2^2 (b-a)^2 / 3,$$

which results in an error smaller than 1.5% for $K_2 (b-a) < 0.5$. (2)

Equation (1) is applicable for a one velocity problem. In the multigroup approach, it is necessary to use group averaged constants in equation (1). A reasonable approach is to obtain these averages by averaging over a pure beryllium spectrum. Group averaged values of $\sum a_1$, $\sum a_2$, and K_2 can easily be obtained from the TMS code.

If the scattering cross section of the absorber is negligible compared to the absorption cross section, the parameter α , as a function of energy, can be evaluated as (4).

$$\alpha(E) = \frac{1}{2} \frac{1 - 2 E_3 \left[2a \sum a_2(E) \right]}{1 + 3 E_4 \left[2a \sum a_2(E) \right]} \quad (2)$$

where $E_n(Z)$, the exponential integral,

$$E_n(Z) = \int_0^1 \mu^{-n-2} e^{-Z/\mu} \frac{d\mu}{\mu} \quad (3)$$

is a tabulated function. (5)

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Again, to use Equation (1) for multigroup calculations, group averaged values of α can be obtained from the TNS code. This can be done by inserting values of α into TNS as if they were the absorption cross sections of some fictional material whose number density is zero.

Equation (1) can now be used for each of the thermal groups.

Finally effective boron cross sections, for input to DSN, can be computed from

$$\sum a_{\text{eff}} = \sum a_1 / \gamma \quad (4)$$

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