INFORMATION CATEGORY

From: Reactor Physics & Mathematics

Date: April 16, 1964

Subject: Calculation of Differential and Integral Absorption in Control Vane from CMC Flux Values on and in Vane

unclassified
DW/LO sawbuck 4/16/64
 Authorized Classifier/Date

To: J. M. Ravets

cc J. G. Gallagher
 H. Woodsum
 F. D. Retallick
 W. H. Arnold

Suppose we are given the values of the flux for a given energy group at the five points shown in Figure 1. Let d be the distance from point 1 to point 3. Then we can fit the following group 4 data

$$\phi_1 = 2.059$$

$$\phi_2 = .063$$

$$\phi_3 = 1.055$$

$$\phi_4 = 7.494$$

$$\phi_5 = 1.634$$

for points on a line between points 1 and 3 by

$$\phi(x) = \phi_1 E_2(\Sigma_{tr}x) + \phi_3 E_2([d - x] \Sigma_{tr}). \quad (1)$$

For $x = .0635$ and $\Sigma_{tr} = 42.355$, Equation 1 gives $\phi(.0635) = 0.048$. This is to be compared with the value 0.063 for the CMC value at point 2. Since

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$E_2(.127 \times 42) \approx 6 \times 10^{-4}$ Equation 1 gives the CMC values at points 1 and 3.

It is no approximation to take $\phi_7 = \phi_5$ and $\phi_6 = \phi_4$. We can interpolate linearly* along the arcs between the points 1 and 5, 3 and 7, 1 and 4, 3 and 6. Then the integrated reaction rate is given by

Between 1 and 4

$$\phi_{1L}(\alpha) = \frac{\phi_1 - \phi_4}{90 - 30} (\alpha^\circ - 90) + \phi_1$$

Between 1 and 5

$$\phi_{1u}(\alpha) = \frac{\phi_1 - \phi_5}{90 - 150} (\alpha^\circ - 90) + \phi_1$$

Between 6 and 3

$$\phi_{jL}(\alpha) = \frac{\phi_3 - \phi_4}{90 - 30} (\alpha^\circ - 90) + \phi_3$$

Between 3 and 7

$$\phi_{ju}(\alpha) = \frac{\phi_3 - \phi_5}{90 - 150} (\alpha^\circ - 90) + \phi_3$$

Referring to Equation 1

$$\phi = \phi_i E_2(\sigma_{tr} x) + \phi_j E_2(\sigma_{tr} [d - x])$$

$$\int_0^d \sigma_a \phi dx = \frac{\sigma_a}{\sigma_{tr}} \int_0^{\sigma_{tr} d} \left[\phi_i E_2(y) + \phi_j E_2([\sigma_{tr} d - y]) \right] dy$$

*Obviously we could, by using more information from CMC or some other source, do better than a linear interpolation along the arc length.

and since

$$E_n(x) = \int_x^{\infty} E_{n-1}(x') dx'$$

$$\int_0^{y_0} E_2(x') dx' = E_3(0) - E_3(y_0)$$

and

$$E_3(0) = 0.5$$

So,

$$\int_0^{y_0} E_2(x') dx' = 0.5 - E_3(y_0)$$

so

$$\sigma_a \int_0^d \phi dx = \frac{\sigma_a}{\sigma_{tr}} \left[\phi_i (0.5 - E_3(d \sigma_{tr})) + \phi_j \{-E_3(d \sigma_{tr}) + 0.5\} \right]$$

$$\sigma_a \int_0^d \phi dx = \frac{\sigma_a}{\sigma_{tr}} \left[0.5 - E_3(d \sigma_{tr}) \right] (\phi_i + \phi_j)$$

To integrate along the arc length of the vane $ds = R_0 d\alpha$

$$\text{total absorption} = \sigma_a \int_0^d dx \int_{30^\circ}^{150^\circ} R_0 \phi d\alpha$$

So total absorption =

$$2\pi \frac{\sigma_a}{\sigma_{tr}} R_0 \frac{120}{360} \left[0.5 - E_3(d\sigma_{tr}) \right] \times \\ \times \left[\frac{1}{4} (\phi_1 + \phi_5) + \frac{1}{4} (\phi_1 + \phi_4) + \frac{1}{4} (\phi_3 + \phi_4) + \frac{1}{4} (\phi_3 + \phi_5) \right]$$

Where R_0 is the radius of the boron vane. Also

$$E_3(d\sigma_{tr}) \approx 5 \times 10^{-4}.$$

$$\text{So total absorption} = 2\pi \frac{\sigma_a}{\sigma_{tr}} R_0 \frac{1}{3} \cdot \frac{1}{4} (\phi_1 + \phi_3 + \phi_4 + \phi_5)$$

So, since $\sigma_a \approx \sigma_{tr}$, the total absorption

$$\approx \frac{2\pi}{12} R_0 (\phi_1 + \phi_3 + \phi_4 + \phi_5)$$

Note: σ here means macroscopic cross-section.

D. W. Drawbaugh

Figure 1

Addendum, WANL-TMI-1038

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The attenuation in groups 1, 2, and 3 through the vane is much less than the group 4 attenuation, so for these groups we cannot use "blackness theory" to fit the CMC fluxes. It seems most reasonable to do a linear interpolation between points 1 and 2 and between points 2 and 3 to get the slopes. Then the average flux in the outer half of the vane per unit flux on the outer surface = $\frac{\phi_1 + \phi_2}{2\phi_1}$

the average flux in the inner half of the vane per unit flux on the inner surface = $\frac{\phi_2 + \phi_3}{2\phi_3}$

From this the total absorption in the vane may be computed as

Total absorption

$$\frac{2\pi R_0 d \sigma_a}{2} \left(\frac{120}{360} \right) \left[\frac{\phi_1 + \phi_2}{2} + \left(\frac{\phi_1 + \phi_2}{2\phi_1} \right) \phi_5 + \left(\frac{\phi_2 + \phi_3}{2\phi_3} \right) \phi_7 + \frac{\phi_2 + \phi_3}{2} + \frac{\phi_1 + \phi_2}{2} + \left(\frac{\phi_1 + \phi_2}{2\phi_1} \right) \phi_4 + \left(\frac{\phi_2 + \phi_3}{2\phi_3} \right) \phi_6 + \frac{\phi_2 + \phi_3}{2} \right] \frac{1}{4}$$

Or, since $\phi_7 = \phi_5$ and $\phi_6 = \phi_4$, total absorption =

$$\frac{\pi R_0 d \nabla_a}{12} \left[\phi_1 + \phi_3 + \phi_4 + \phi_5 + 2\phi_2 + \frac{1}{2} \left(\frac{\phi_2}{\phi_1} + \frac{\phi_2}{\phi_3} \right) (\phi_4 + \phi_5) \right].$$

d is the thickness of the vane in centimeters.

D. W. Drawbaugh