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No: WANL-TMI-1157

Date June 30, 1964

From M. D. Nelligan, Reactor Analysis

Subject Comparison of the S_2 and S_4
Approximations in the DTK⁴
Transport Code

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INFORMATION CATEGORY

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PROBLEM:

Compare results of the S_2 approximation with those of the S_4 approximation in the DTK code.

CONCLUSIONS:

The S_2 approximation seems nearly as adequate as S_4 for eigenvalue calculations and gives close agreement for power shape; it should be quite useful for reactivity coefficient calculations of a survey nature. The agreement is particularly good for the absorber ring* representation of the control rods. Computer running time could be nearly cut in half by use of the S_2 approximation, particularly if a convergence criterion of .0001 were used. For accurate final calculations, however, S_4 is recommended.

In comparing S_2 and S_4 results with the AIM-5 diffusion code, for 4 group calculations, it was found that the S_2 results were considerably more consistent with the S_4 results than with the diffusion theory results for all cases examined.

DISCUSSION:

For radial problems with an absorber ring, S_2 gives an eigenvalue that is approximately 0.0005 lower than S_4 , 2.0% lower edge power, and 0.25% lower maximum power. In clean radial problems (no absorber ring), it gives an eigenvalue approximately 0.001 higher than S_4 , and 1% lower edge power. For axial problems, the S_2

* WANL-TMI-990, "Multi-Group Radial Control Rod Representation for the NRX-A,"
P. J. Sipush, February 26, 1964.

eigenvalue is 0.0025 lower, the edge power 3% lower, and the maximum power 0.2% higher. These values are given as average correction factors for S_2 results.

Hydrogen reactivity coefficients from axial problems for 2" hydrogen slabs in Zepo* were 1.6% and 6.9% higher using S_2 for the mid-region and top-region respectively.

Better reactivity coefficient agreement would be expected in a radial absorber ring problem due to the better eigenvalue agreement obtained from these problems. The use of a flat flux guess does not appreciably effect the eigenvalue, and has very little effect on power shape for $\epsilon = 10^{-5}$ convergence.

The agreement between S_2 and S_4 for both eigenvalue and power was the same with a convergence criterion of 0.0001 as with a 0.00001 criterion (a 4 group absorber ring problem). Indications are that S_2 with $\epsilon = 0.0001$ is sufficient whenever very accurate results are not needed. See Table 1. Running time of S_2 is about 70% of S_4 for a flat flux input, and approaches 50% for a flux guess.

Three sets of 4 group calculations were made to determine whether the S_2 formulation approximates the diffusion theory approach. Two sets were DTK compared with AIM-5, and one set DSN compared with AIM-5. In all three sets, the S_2 results were much closer to the S_4 than to the AIM results for both eigenvalue and edge power. These three calculations (See Table 2) indicate that S_2 gives pronounced differences from diffusion theory. These 4 group problems were based on TNS values for the thermal group constants with the thermal self scatter cross section taken as

$$\sum_{gg} = \sum_{tr} - \sum_a .$$

* WANL-TMI-526, "Analysis of WANL NRX-A Experiments Performed in Los Alamos Zepo Facility," L. I. Kopp, September 25, 1963.

The fast group constants were generated by GAM II. Much of the differences noted may arise from the different treatments of leakage in diffusion and transport theory. The S_2 and S_4 flux and power plots for the NRX-A radial cold absorber ring problems are given in the classified addendum to this report.

SIGNED

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TABLE I - COMPARISON OF RESULTS OF S_2 AND S_4 APPROXIMATIONS IN DTK CODE

Problem Description	Geom.	Groups	$\Delta K (S_4 - S_2)$	% Difference* Edge Power
a) ZEPO H_2 Base case	Axial	18	.00248	+ 2.95%
b) ZEPO H_2 added to top	"	18	.002429	+ 4.32%
c) ZEPO H_2 Added to middle	"	18	.002459	2.73%
d) ZEPO Base case	"	8	.00301	2.36%
e) NRX-A - 0% power	"	8	.001278	- .65%
f) " - 70% power	"	8	.001475	- .41%
g) " - 100% power	"	8	.001441	- .005%
h) " ZEPO Base case	Radial	18	-.001127	1.13%
i) PAX-cold-clean	Radial	8	-.000587	.91%
j) NRX hot-clean	Radial	8	-.001185	- .53%
k) NRX cold absorber ring	Radial	8	.000343	2.56%
l) NRX hot absorber ring	Radial	8	.000143	1.55%
m) PAX clean	Radial	4	.000637	.67%
n) PAX absorber ring	Radial	4	.00625	1.74%

$$* \% \text{ Diff} = \frac{S_4 - S_2}{S_4} \times 100$$

TABLE 2 - COMPARISON FOR DIFFERENT CONVERGENCE CRITERIA

Problem Description	Geom.	Groups	S_n	ϵ	K	% Difference P_{edge}
absorber NRX cold ring	Radial	4	4	10^{-5}	.9992995	.24%
absorber NRX cold ring	Radial	4	2	10^{-5}	.9983643	.24%
$\Delta K = .000935$						
absorber NRX cold ring	Radial	4	4	10^{-4}	.999156	.24%
absorber NRX cold ring	Radial	4	2	10^{-4}	.998223	.24%
$\Delta K = .000933$						

TABLE 3 - COMPARISON OF S_2 - S_4 APPROXIMATION WITH DIFFUSION CODE CALCULATIONS

Problem Description	Geom.	Groups	Comparison	ΔK^*	% Difference ^{**} Edge Power
PAX Cold clean	Radial	4	S_4 vs S_2	-.000637	-.67%
PAX cold clean absorber	Radial	4	AIM vs S_2	-.014038	-6.5%
PAX cold ring absorber	Radial	4	S_4 vs S_2	.000625	1.74%
PAX cold ring	Radial	4	AIM vs S_2	-.0041688	-2.66%
NRX-B DSN clean	Radial	4	S_4 vs S_2	-.001636	1.05%
NRX-B DSN clean	Radial	4	AIM vs S_2	-.008236	1.62%

$$* \Delta K = C - S_2$$

$$** \% \text{ Diff} = \frac{C - S_2}{S_2} \quad \text{where } C = S_4 \text{ or AIM-5}$$