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COROPT HETEROGENEOUS
FLUX MODEL

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COROPT HETEROGENEOUS FLUX MODEL

Background and Summary

The PHYSICS module of COROPT calculates the power and flux distributions, power fractions, required fissile enrichment, and fuel mass balances. Sufficiently accurate data are clearly necessary for the results of the thermal hydraulic and fuel pin and assembly performance analysis to be acceptable. The smooth flux and power distribution model developed for the homogeneous core COROPT application has been shown to be accurate for homogeneous cores in the range of interest. However, this model and simple modifications of it have proven to not provide the accuracy desired for heterogeneous cores such as the LDP design. With the objective of providing a fast running approximate solution for the flux and power distributions and the other physics parameters, a new technique has been evaluated using the LDP core layout for test calculations.

The simplified method uses a response matrix calculation to determine the reactor eigenvalue, flux and power distribution for the COROPT starting point configuration. These physics parameters are then varied based on sensitivity coefficients as COROPT changes the core description to seek an optimum. The response matrix solution may then be used again to verify the final, optimized design point, or alternately to update the physics parameters if the design changes more than a specified amount from the initial point. Accurate simulation of the effects of changes in assembly size, composition, and burnup may be provided by parametric variation of the response coefficients.

The initial evaluation of this concept, which was completed in FY81, has focused on the calculation of response coefficients for typical large LMFBR fuel, internal blanket, radial blanket, and control assemblies, (LDP design data has been used for these tests); development of an accelerated eigenvalue and flux solution, and comparison of the resultant power distribution to that obtained using standard, verified design methods. The results of this initial evaluation indicate that the accuracy of the power distribution solution is quite good, within 5% of the standard multigroup diffusion solution, and that further work to implement an improved PHYSICS module in the heterogeneous COROPT is warranted.

Eigenvalue and Flux Solution Technique

The solution methodology used employs response coefficients to describe the response of an assembly (fuel, or inner blanket, etc.) to an incident partial neutron current of specified spatial and energy distribution (a "mode"). These coefficients are precalculated using neutron transport theory and may be written as simple analytic functions of the assembly enrichment, burnup, fuel volume fraction, etc. The coefficients are assembled to correspond with the reactor layout in hexagonal geometry to create a response matrix $[\beta]$ which represents the composite geometry and compositions. An iterative solution is found to the eigenvalue equation

$$\underline{J} = [\beta] \underline{J}$$

where $\underline{J}$ is a column vector representing all of the partial neutron currents at assembly interface.

Acceleration techniques based on standard successive overrelaxation methods are employed to provide near optimal convergence.

Heterogeneous Core Test Calculations

To evaluate the accuracy of this solution technique for large heterogeneous LMFBRs a series of test cases were run based on the LDP core design. Response coefficients in six energy groups were calculated for fuel, inner blanket, radial blanket, primary control withdrawn, and primary control inserted assemblies. The core layout shown in Figure 1 was used to evaluate the accuracy of the response matrix power distribution compared to that calculated using the SN2D diffusion theory code with six energy groups. Two cases were considered, all control withdrawn and the outermost 12 control rods inserted, to simulate typical rod withdrawal over a burnup cycle.

Figures 2 and 3 show the assembly powers from the response method and SN2D for all control out and 12 outer rods inserted respectively. From these results it is seen that the response matrix solution agrees with SN2D within $\pm 1.5\%$ for every fuel assembly. For the internal and radial blankets the response matrix systematically underpredicts the SN2D power by -5% . However, this is a nearly constant error which indicates that the distribution is correctly calculated and

a calibration factor could be used to match the SN2D blanket powers. This agreement is judged to be sufficient for the intended use of COROPT.* Table 1 presents the zone power parameters of interest in COROPT. The agreement is within 0.5% for each zone. From these data it is concluded that the response matrix solution will provide integral zonal powers with acceptable accuracy.

Conclusions and Further Work

Based on the heterogeneous test cases evaluated, the response matrix method appears to provide a reasonable basis for a modified COROPT PHYSICS module. While the test cases performed to date use six neutron groups, it is anticipated that a one or two group solution will also provide acceptable accuracy (assembly power $\pm 5\%$). Future work is planned to evaluate the one and two group solution and implement this into COROPT.

*Previous comparisons for homogeneous cores have shown the response matrix solution to be closer to the S_4 - P_0 transport solution than the diffusion solution.

Table I
PERCENT POWER BY REGION

	<u>CONTROL OUT</u>		<u>CONTROL IN</u>	
	REMAN	SN2D	REMAN	SN2D
FUEL 1	11.182	11.064	12.437	12.306
FUEL 2	27.618	27.262	28.746	28.524
FUEL 3	52.031	52.187	49.589	49.637
IB 1	0.511	0.532	0.578	0.600
IB 2	1.931	1.984	2.102	2.161
IB 3	3.535	3.648	3.508	3.593
RB	<u>3.193</u>	<u>3.323</u>	<u>3.040</u>	<u>3.178</u>
TOTAL	100.0	100.0	100.0	100.0

Figure 1
LDP CORE LAYOUT FOR TEST CASES