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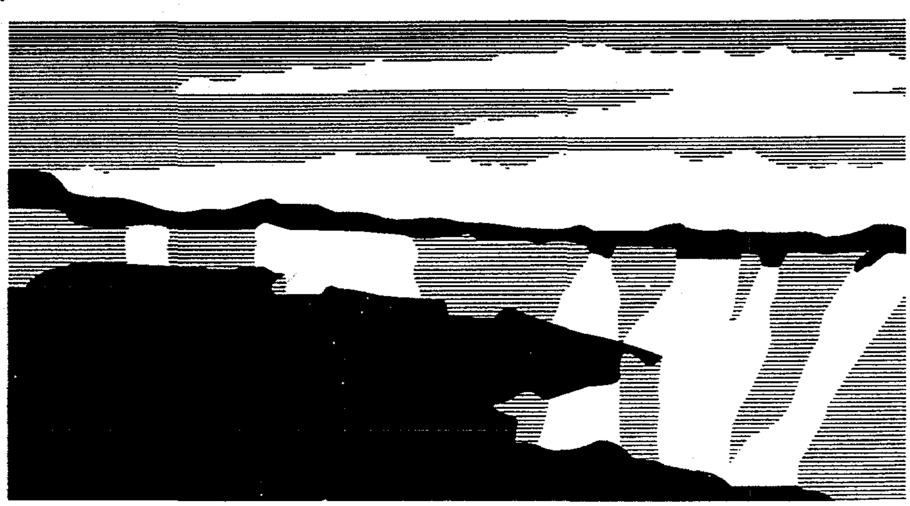

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VALIDATION OF NESTLE AGAINST STATIC REACTOR BENCHMARK PROBLEMS

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The NESTLE advanced nodal code[1] was developed at North Carolina State University with support from Los Alamos National Laboratory and Idaho National Engineering Laboratory. It recently has been benchmarked successfully against measured data from pressurized water reactors (PWRs).[2] However, NESTLE's geometric capabilities are very flexible, and it can be applied to a variety of other types of reactors. This study presents comparisons of NESTLE results with those from other codes for static benchmark problems for PWRs, boiling water reactors (BWRs), high-temperature gas-cooled reactors (HTGRs) and CANDU heavy-water reactors (HWRs).

For steady-state cases, NESTLE solves the multigroup neutron diffusion equations using the nodal expansion method (NEM) in conjunction with a nonlinear iterative method.[3] The formulation is such, however, that the solution degenerates to the finite-difference method (FDM) if the nonlinear iterations are omitted. This feature allows the validation of NESTLE to proceed in two steps: (1) comparison of its FDM solution with other FDM solutions, and (2) comparison of its NEM solution with the reference solution.

DESCRIPTION OF CASES

The IAEA benchmark problem is a PWR with 177 assemblies and octant symmetry. The two-dimensional case[4] has nine controlled assemblies, while the three-dimensional case[5] has nine assemblies with control rods fully inserted and four assemblies with control rods partially inserted.

The static LRA problem is an axially uniform BWR with 712 bundles and octant symmetry. The only difference between the two-dimensional[6] and three-dimensional[7] cases is that the latter is axially finite.

The static CANDU problem contains an inner core, an outer core, and a reflector. The only difference between the two-dimensional[8] and three-dimensional[9] cases is that the latter is axially finite.

The two-dimensional HTGR problem[10] is a sextant-symmetric HTGR with 247 fuel channels and 180 reflector channels. The specifications for this problem differ from the others described herein in two important respects: the geometry is hexagonal rather than Cartesian, and there are four energy groups rather than two.

The three-dimensional static LMW problem[11] contains 81 fuel assemblies and is octant symmetric. Four of the assemblies have control rods that are partially inserted. The problem is non-physical in the sense that controlled fuel assemblies extend beyond the top of the core, but it is a severe test for a code because of the sharp flux gradients that occur.

OVERVIEW OF OTHER CODES

The descriptions of these benchmarks each report results from several codes. For the sake of brevity, the NESTLE results will be compared only to a subset of the reported results. Those results were obtained with the VENTURE,[12] QUANDRY,[13] CERKIN,[14] and/or CERBERUS codes.[15] VENTURE, CERKIN, and CERBERUS all use the FDM to solve multigroup neutron diffusion equations, while QUANDRY[13] employs the analytic nodal method (ANM) for the same purpose.

RESULTS

The values that NESTLE calculates for k_{eff} for the two-dimensional cases are compared with those from other codes in Table I. Similarly, results for the three-dimensional cases are presented in Table II. Excellent and consistent agreement is achieved for all cases.

In addition, although not shown herein because of space constraints, NESTLE produces excellent agreement with the power distributions from the FDM and reference solutions.

CONCLUSIONS

These results demonstrate that NESTLE FDM calculations replicate the FDM calculations from other FDM codes almost identically and that the NESTLE NEM calculations produce excellent agreement with reference solutions. As expected, NEM produces accurate results with mesh spacings that are much larger than those required for accurate FDM calculations. Furthermore, NESTLE produces accurate results not only for PWR geometries but also for BWR, HTGR, and CANDU geometries. This behavior provides assurance that, after steady-state thermal-hydraulics modules for BWRs, HTGRs, and CANDUs are installed in NESTLE, it can be used with confidence for calculations for those types of reactors.

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TABLE I

Results for Two-Dimensional Static Benchmark Problems

Problem	Code	Method	Mesh Spacing (cm)	k_{eff}
IAEA PWR	VENTURE	FDM	20	1.03208
			Extrap.	1.02959
	NESTLE	FDM	20	1.03201
		NEM	20	1.02951
			5	1.02959
LRA BWR	QUANDRY	ANM	15	0.99641
	NESTLE	NEM	15	0.99628
CANDU HWR	CERKIN	FDM	NR	0.98119
	NESTLE	FDM	15	0.98113
		NEM	15	0.98141
HTGR	VENTURE	FDM	36.2	1.12725
			Extrap.	1.11835
	NESTLE	FDM	36.2	1.12722
		NEM	36.2	1.11852

NR = Not Reported

TABLE II

Results for 3-Dimensional Static Benchmark Problems

Problem	Code	Method	Mesh Spacing (cm) Planar	Axial	k_{eff}
IAEA PWR	VENTURE	FDM	5	10	1.02864
			Extrap.	Extrap.	1.02903
	NESTLE	FDM	5	10	1.02864
		NEM	5	10	1.02907
			20	20	1.02899
LMW LWR	QUANDRY	ANM	20	20	0.99974
	NESTLE	NEM	20	20	0.99960
			5	5	0.99968
LRA BWR	QUANDRY	ANM	15	25*	0.99644
	NESTLE	NEM	15	15	0.99627
			7.5	7.5	0.99638
CANDU HWR	CERKIN	FDM	NR	NR	1.00355
	CERBERUS	FDM	30/60**	60	1.00356
	NESTLE	FDM	30	60	1.00315
		NEM	30	60	1.00357
			15	60	1.00351

NR = Not Reported
*15 cm in Axial Reflector
**30 cm near Fuel/Reflector Interface, 60 cm Elsewhere