CONF-951006--14

LA-UR-95- 1873

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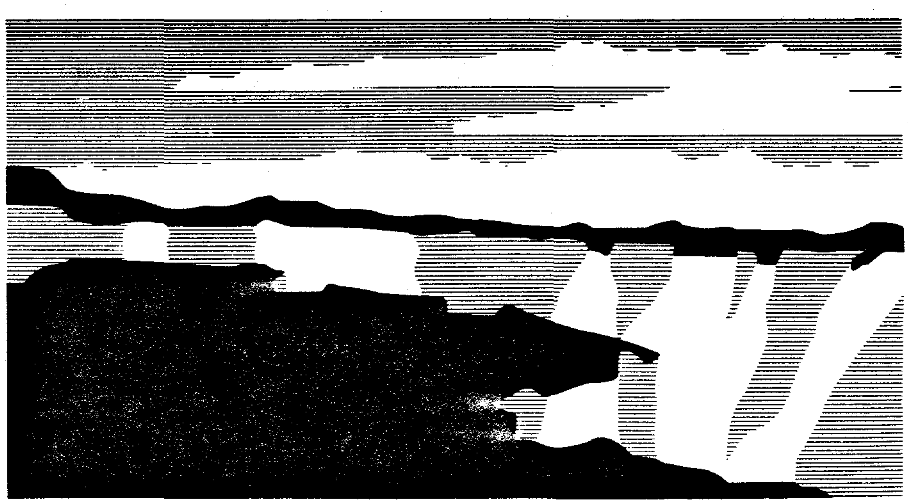
Submitted to: 1995 Winter Meeting Of The American Nuclear Society
San Francisco, California
October 29-November 2, 1995



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BENCHMARKING OF NESTLE AGAINST MEASURED PWR DATA AT BEGINNING OF LIFE

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To Be Submitted for Presentation at the
1995 Winter Meeting of the American Nuclear Society
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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. This paper presents the first comparisons of NESTLE predictions with measured data from pressurized water reactors (PWRs). Specifically, NESTLE predictions for critical soluble boron concentrations and isothermal temperature coefficients of reactivity (ITCs) are compared with beginning-of-life (BoL) measurements from four PWRs. All of those measurements were made at hot-zero-power (HZP) conditions prior to ascension to power.

DESCRIPTION OF PLANTS

Although it does not identify them by name, Ref. 2 provides reasonably detailed descriptions of the core design and loading pattern for the first cycle of four PWRs. A succinct summary of the first cycle of each of those plants is provided in Table I. All four have "out-in" loading patterns wherein the central portion of the core is a checkerboard of the two lower enrichments and the high enrichment is loaded on the periphery. In addition, all of them have discrete lumped burnable poison rods (LBPRs) in some of their assemblies.

The assemblies in plants C and D are an "optimized" design wherein the radius of the fuel rods has been decreased to provide a higher moderator-to-fuel ratio. This design, in combination with the wide range of enrichments and (in plant C) part-length LBPRs, produces a flux distribution that is very sensitive to changes in core operating conditions at BoL.

GENERATION OF CROSS SECTIONS

Cross-section data that had been generated previously[2] for the ARROTTA nodal code[3] were translated into NESTLE input format. Because of the similarity in the cross-section representation employed by the two codes, no approximations were required as part of the translation.

RESULTS

The NESTLE predictions for critical soluble boron concentrations are compared to the measured values in Table II. The agreement is excellent: the largest difference between the measured concentration and that predicted by NESTLE is 38 PPM, and the average difference is only 9 PPM, which is comparable to the uncertainty in most measurements of PPM at HZP. The consistent agreement in the critical soluble boron concentration with different control-rod banks inserted also demonstrates that NESTLE accurately predicts control-rod worth. Furthermore, the values predicted by NESTLE are very similar to those predicted by ARROTTA, which suggests that much of the difference in critical PPM may be due to the cross sections rather than the code itself.

The NESTLE predictions for ITCs are compared to the measured values in Table III. Once again, the values predicted by NESTLE are in excellent agreement with the measured ITCs and with those predicted by ARROTTA. The largest difference between the measurements and the corresponding NESTLE predictions is only 2.3 pcm/°F, and the average difference is only 0.4 pcm/°F. The agreement with the measurements from Plants C and D is particularly good, given the sensitivity of the flux distribution at these conditions. (Because of the large differences in enrichment and the out-in loading pattern, relatively small changes in the flux distribution can cause significant changes in the ITC.)

CONCLUSIONS

The NESTLE code has been shown to predict critical soluble boron concentrations, ITCs, and control-rod worth that are in excellent agreement with measured data from a variety of PWRs. Furthermore, the agreement with the corresponding values from

ARROTTA demonstrates that, given the same input, the two codes produce very similar results.

ACKNOWLEDGMENT

The cross-section data for these calculations were obtained from the Electric Power Research Institute (EPRI). Special thanks are due to J. Chao and L. Agee of EPRI, who approved the use of them, and to L. D. Eisenhart of S. Levy, Inc., who supplied the actual data.

References

1. P. J. Turinsky, R. M. K. Al-Chalabi, P. Engrand, H. N. Sarsour, F. X. Faure, and W. Guo, "NESTLE: A Few-Group Neutron Diffusion Equation Solver Utilizing the Nodal Expansion Method for Eigenvalue, Adjoint, Fixed-Source Steady-State and Transient Problems," Idaho National Engineering Laboratory report EGG-NRE-11406 (June 1994).

2. R. D. Mosteller, M. J. Anderson, and L. D. Eisenhart, "Validating ARROTTA for a PWR at Beginning of Core Life," Electric Power Research Institute report NSAC-135 (January 1989).

3. L. D. Eisenhart, "ARROTTA Computer Code System Documentation," to be published by the Electric Power Research Institute.

Table I
Plant Characteristics

Plant	Rated Power (MWt)	Number of Assemblies	Type of Assemblies	Type of LBPR	Fuel Enrichment (w/o)
B	3250	193	15 x 15	Full Length	2.248, 2.789, 3.292
C	2775	157	17 x 17	Part Length	1.6, 2.4, 3.1
D	3411	193	17 x 17	Full Length	1.6, 2.4, 3.1
F	2560	217	14 x 14	Part Length	1.9, 2.3, 2.8

Table II
Measured and Predicted Critical Soluble Boron Concentrations

Plant	Temperature (°F)	Control-Rod Banks Inserted	Critical Soluble Boron Concentration (PPM)		
			Measured	ARROTTA[a]	NESTLE
B	547	None	1350	1314	1312
		D[b]	1348	—	1310
		C[c], D	1203	—	1170
		B[b], C, D	1085	—	1063
		A[c], B, C, D	940	—	914
C	557	None	1189	1190	1187
D	557	None	975	997	996
		D	902	933	932
		C, D	816	841	837
F	532	None	952	951	953
		5, 6, 7	844	813	823
		2, 3, 4, 5, 6, 7	606	580	605

[a]Values taken from Ref. 2
[b]200 Steps Withdrawn (Fully Withdrawn at 220 Steps)
[c]180 Steps Withdrawn (Fully Withdrawn at 220 Steps)

Table III

Measured and Predicted ITCs at BoL

Plant	Temperature (°F)	Control-Rod Banks Inserted	Critical Boron Concentration (PPM)	ITC (pcm/°F)		
				Measured	ARROTTA[a]	NESTLE
B	547	D[b]	1348	-1.3 ± 0.3	-1.6	-1.6
		C[c], D	1203	-5.2 ± 0.3	-5.6	-5.3
		B[b], C, D	1085	-9.0 ± 0.9	-9.1	-8.5
		A[c], B, C, D	940	-10.3 ± 1.7	-10.7	-9.9
C	557	None	1189	3.5	1.3	2.1
D	557	None	975	-1.7	-3.2	-2.7
		D	902	-2.8	-4.3	-3.9
		C, D	816	-8.0	-8.9	-8.0
F	532	None	952	0.8	-0.8	-0.9
		5, 6, 7	844	-4.1	-5.4	-4.9
		2, 3, 4, 5, 6, 7	606	-10.4	-10.3	-8.1

[a]Values taken from Ref. 2
[b]200 Steps Withdrawn (Fully Withdrawn at 220 Steps)
[c]180 Steps Withdrawn (Fully Withdrawn at 220 Steps)