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COMPARISON OF THE CENTRM RESONANCE PROCESSOR TO THE NITAWL RESONANCE PROCESSOR IN SCALE

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I. INTRODUCTION

This report compares the NITAWL and CENTRM resonance processors in the SCALE code system.[1] The cases examined consist of the International OECD/NEA Criticality Working Group Benchmark 20 problem.[2] These cases represent fuel pellets partially dissolved in a borated solution. The assumptions inherent to the Nordheim Integral Treatment, used in NITAWL, are not valid for these problems. CENTRM resolves this limitation by explicitly calculating a problem dependent point flux from point cross-sections, which is then used to create group cross-sections.[3]

II. PROBLEM DESCRIPTION

The cases are modeled as infinite arrays of 2.5 w% enriched UO_2 spheres in a borated solution where the spheres represent the UO_2 pellets. The boron concentration, UO_2 volume fraction, and percent of UO_2 in the pellet are varied. The 30 analyzed cases can be divided into five problem sets. Set 1 cases have a 1.0297 cm triangular pitched assembly with a 0.6 UO_2 volume fraction. Set 2 cases have a 1.0943 cm triangular pitched assembly with a 0.5 UO_2

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volume fraction. Set 3 cases have a 1.1788 cm triangular pitched assembly with a 0.4 UO_2 volume fraction. Set 4 cases have a 0.9749 cm rectangular pitched assembly with a 0.5 UO_2 volume fraction. Set 5 cases have a 1.0501 cm rectangular pitched assembly with a 0.4 UO_2 volume fraction.

Each set contains six cases where the percent UO_2 in the pellet and Boron concentration are varied. Cases a and b contain 100% of the UO_2 in the pellet, cases c and d contain 75%, and cases e and f contain 50%, with the remaining UO_2 in the surrounding solution. Cases a, c, and e contain 3500 ppm Boron and cases b, d, and f contain 1500 ppm Boron in the solution.

III. CALCULATIONS AND RESULTS

All cases are analyzed using BONAMI to process the unresolved resonance data, NITAWL to process the resolved resonances, and XSDRN to calculate λ_∞. The same sets of problems are also analyzed using the code sequence BONAMI, CENTRM/PMC, and XSDRN. These results are compared to an earlier set of calculations done by Bernnat and Keinert.[2] In the Bernnat results, special care was taken to properly treat the resonances in the solution by calculating a very fine mesh neutron spectrum over the resolved resonance range. The results and comparisons are shown in Table 1.

The NITAWL, CENTRM, and Bernnat results for cases 1a - 5a and 1b - 5b agree to within a few tenths of a percent with the exception of case 5a. The NITAWL and CENTRM results for case 5a and 3a agree to within 0.2%. This is due to all the uranium being in the pellet and the two cases having the same volume fraction and Boron concentration. The remaining Bernnat results show significantly better agreement with the CENTRM results than with the

TABLE 1
Comparison of Results using the NITAWL, CENTRM Resolved Resonance Processor to Bernnat Results for the Criticality Working Group Benchmark 20 Problem

Case	wt% UO_2 in Pellet	Boron Conc. (ppm)	NITAWL (λ_∞)	CENTRM (λ_∞)	Bernnat[2] (λ_∞)	NITAWL/ CENTRM % ($\Delta\lambda_\infty$)	NITAWL/ Bernnat % ($\Delta\lambda_\infty$)	CENTRM/ Bernnat % ($\Delta\lambda_\infty$)
1a	100	3500	1.0132	1.0086	1.0099	-0.465	-0.336	0.129
1b	100	1500	1.1008	1.0957	1.0983	-0.465	-0.228	0.237
1c	75	3500	0.9323	0.9891	0.9924	5.743	6.056	0.333
1d	75	1500	1.0086	1.0722	1.0795	5.932	6.568	0.676
1e	50	3500	0.9284	0.9843	0.9881	5.679	6.042	0.385
1f	50	1500	1.0027	1.0653	1.0732	5.876	6.569	0.736
2a	100	3500	1.0022	1.0002	0.9955	-0.2	-0.673	-0.472
2b	100	1500	1.1338	1.1315	1.1327	-0.203	-0.097	0.106
2c	75	3500	0.9330	0.9770	0.9744	4.504	4.249	-0.267
2d	75	1500	1.0506	1.1020	1.1054	4.664	4.957	0.308
2e	50	3500	0.9299	0.9726	0.9704	4.39	4.174	-0.227
2f	50	1500	1.0447	1.0946	1.0981	4.559	4.863	0.319
3a	100	3500	0.9474	0.9463	0.9443	-0.116	-0.328	-0.212
3b	100	1500	1.1285	1.1272	1.1276	-0.115	-0.08	0.035
3c	75	3500	0.8917	0.9221	0.9166	3.297	2.717	-0.6
3d	75	1500	1.0564	1.0938	1.0937	3.419	3.41	-0.009
3e	50	3500	0.8900	0.9194	0.9142	3.198	2.647	-0.569
3f	50	1500	1.0510	1.0873	1.0877	3.339	3.374	0.037
4a	100	3500	1.0039	1.0002	0.9930	-0.37	-1.098	-0.725
4b	100	1500	1.1358	1.1315	1.1328	-0.38	-0.265	0.115
4c	75	3500	0.9331	0.9770	0.9732	4.493	4.12	-0.39
4d	75	1500	1.0507	1.1020	1.1050	4.655	4.914	0.271
4e	50	3500	0.9295	0.9726	0.9699	4.431	4.165	-0.278
4f	50	1500	1.0443	1.0946	1.0978	4.595	4.873	0.291
5a	100	3500	0.9481	0.9464	0.9337	-0.18	-1.542	-1.36
5b	100	1500	1.1293	1.1272	1.1221	-0.186	-0.642	-0.455
5c	75	3500	0.8919	0.9221	0.9127	3.275	2.279	-1.03
5d	75	1500	1.0565	1.0938	1.0914	3.41	3.198	-0.22
5e	50	3500	0.8898	0.9195	0.9113	3.23	2.359	-0.9
5f	50	1500	1.0508	1.0873	1.0859	3.357	3.232	-0.129

NITAWL results. The CENTRM/Bernnat differences vary from 0.009% to 1.03%. The NITAWL/Bernnat differences vary from 2.279% to 6.569%.

The largest NITAWL/Bernnat differences, >6.0%, occur in cases 1c - 1f, which have the UO_2 volume fraction of 0.6. With UO_2 in the pellet and solution, the NITAWL/Bernnat differences vary with UO_2 volume fraction. For a UO_2 volume fraction of 0.5, cases 2 and 4, the differences vary between 4.1% and 4.9%. For a UO_2 volume fraction of 0.4, cases 3 and 5, the differences vary between 2.2% and 3.4%.

For a given pitch and volume fraction, there is a smaller difference change caused by increasing the Boron concentration. Increasing the Boron concentration increases the NITAWL/Bernnat and CENTRM/Bernnat differences by up to 0.8%, as seen when comparing cases 5e and 5f.

IV. CONCLUSIONS

The CENTRM/PMC code provides a significant improvement over NITAWL for processing the resolved resonances in problems involving double heterogeneity. The presence of uranium in the UO_2 pellets and surrounding solution cause the assumptions in NITAWL to be invalid. CENTRM removes this and other limitations by explicitly calculating a zone-wise continuous energy flux spectrum which is used to produce the problem dependent group cross-sections.

V. REFERENCES

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