Proceedings of the Korean Nuclear Society Autumn Meeting
Seoul, Korea, October 1999

ASSESSMENT OF WIMS-AECL USING PHYSICS MEASUREMENT OF WOLSONG-2 REACTOR

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ABSTRACT

For the validation of WIMS/RFSP code system, benchmark calculations have been performed against physics measurement of Wolsong-2 reactor. The lattice parameters and incremental cross sections were generated by WIMS-AECL and SHETAN, respectively. The benchmark calculations have been done for the criticality, boron worth, reactivity devices, and heat transport system temperature coefficient. The results have shown that the criticality is estimated within 3mk, and the boron worth is underestimated by 0.55mk/ppm. The zone controller and adjuster rod worths are in general consistent with the measurement results. However, the simulations have shown that the prediction errors are relatively large for the shutoff rods, mechanical control absorber, and moderator temperature coefficient.

I. INTRODUCTION

For the CANDU core design and analysis, a lattice code POWDERPUFS-V(PPV)[1] has long been used in conjunction with a supercell code MULTICELL.[2] However the application of PPV is limited to natural uranium fuel because of empirical correlations implemented. Therefore a multigroup transport code WIMS-AECL[3] has been widely used for the advanced CANDU fuel development programs owing to the capability of modelling two-dimensional geometry and device isotopic diverse compositions. This study performs the benchmark calculation of the CANDU core analysis code system coupled of WIMS-AECL, SHETAN[4] and RFSP[5] using physics measurement data of Wolsong-2 reactor.[6]

II. CORE SIMULATION AND RESULTS

II.1 Critical Core

The critical operating conditions of the Phase-B measurement are as follows:

- The average zone level of zone controller is 16.94%.
- The purities of coolant and moderator are 99.63 and 99.84wt%, respectively.
- The temperature of coolant and moderator is 308.12 and 302.16K, respectively.
- The mechanical control absorber is inserted by 55% .
- The critical boron concentration is 9.0ppm, and the error bound is ±0.5ppm.

The WIMS/RFSP simulation has shown that the eigenvalue of the initial core is 0.997 which is 3mk off the criticality.

II.2 Calibration of Control Device

The reactivity worth of liquid zone controller unit (ZCU) was calculated at the initial condition. Since the ZCU are calibrated by the boron concentration change in the moderator, the boron reactivity coefficient was calculated. In Table 1, the boron reactivity coefficient is 7.75mk per ppm boron.

The calibration of the ZCU was performed by adding the boron batch whose worth is about 0.45mk. After a batch was added, the average ZCU water level was fitted in order to maintain criticality. The results are summarized in Table 2 as a function of the boron batch. The average ZCU worth is compared with the measurement result in Table 3 for the typical operating ranges. The variation of average ZCU level is also plotted in Figure 1 and compared with the measurement result. It can be seen that the maximum error is 4%.

The reactivity worth of individual adjuster rod was calculated by RFSP code for the calibration of ADJs. The calculation was independently done by the eigenvalue calculations for individual ADJs. As shown in Table 4, the difference of the reactivity worth between the calculation and measurement is less than 20%. The reactivity worths of ADJ banks were also calculated the results are shown in Table 5.

The individual worth of the shutoff rod (SOR) was calculated as given in Table 6 where the maximum error is -20%. The individual and bank worths of the mechanical control absorber (MCA) were also calculated as given in Table 7 and 8, respectively. Unlike the core of ADJ, the reactivity worths of SOR and MCA are overpredicted by WIMS/RFSP, which seems to be due to the poor estimation of thermal flux in the absorber region. This error should be a combined effect of the homogenization and the relatively large node size, which requires further investigations.

II.3 Heat Transport System Temperature Coefficient

For the heat transport system temperature coefficient, the moderator temperature was fixed at ~35℃ and the boron concentration in the moderator was 8.5ppm. The coolant and fuel temperature were the same, and varied from 35 to 260℃. The corresponding coolant density was calculated for D_2O at saturated and non-boiling condition with 99.64wt% purity. The variation of heat transport system temperature coefficient is shown in Table 9. The heat transport system temperature coefficient was generally consistent with the measured data.

III. CONCLUSION

In general, the estimation of the reactivity device worth by WIMS/RFSP provides a consistent trend compared with the physics measurement results. However, the magnitude of error is relatively large compared with the worths estimated by the current CANDU design codes PPV/RFSP. It should be noted that the simulation by WIMS/RFSP in this study does not include any adjustment on the incremental cross section and RFSP mesh structure. Therefore it is recommended that the homogenization effect and the optimum mesh size should be studied in the near future.

Acknowledgement

This project has been carried out under the Nuclear Research and Development program by Korea Ministry of Science and Technology. The authors are grateful to the core management staffs of Wolsong nuclear plant for providing the physics measurement data.

References

1. E.S.Y. Tin, "POWDERPUFS-V Physics Manual, Part 1", TDAI-31, AECL, Canada,1979.

2. A.R. Dastur et al., "MULTICELL User's Manual", TDAI-208, AECL, Canada, 1979.

3. Donnelly. J. V., "WIMS-CRNL: A User's Manual for the Chalk River Version of WIMS,"

AECL-8955, Atomic Energy of Canada Limited, 1986.

4. H. C. Chow and M. H. M Roshd, " SHETAN-A Three Dimensional Integral Transport Code for Reactor Analysis", AECL-6878, Canada 1980.

5. B. Rouben, "Reactor Fuelling Simulation Program - RFSP" : Programming Description for Version", TTR-370, December 1992.

6. S. M. Kim, "Physics Post Simulation of Wolsong unit 2", Wolsong NPP, 1997.

Table 1. Reactivity Change with Boron Concentration in Moderator

Boron Concentration (ppm)	Excessive Reactivity (mk)	Boron Coefficient (mk/ppm)
6	19.432	
7	11.635	7.797
8	3.869	7.766
9	-3.867	7.736
10	-11.566	7.699
Avg.		7.7495*

* 8.310 by PPV/RFSP

Table 2. Calibration of Zone Controller

Batch	Boron(ppm)	Reactivity (mk)	WIMS/RFSP ZCU Level Change(%)	Measured ZCU Level Change(%)	ZCU Worth (mk/%AVZL)
1	0.058	0.449	9.560	10.1	0.0470
2	0.057	0.442	8.090	8.59	0.0547
3	0.058	0.451	7.430	7.18	0.0607
4	0.058	0.449	6.980	6.54	0.0644
5	0.058	0.449	6.450	6.64	0.0697
6	0.058	0.445	6.050	6.15	0.0736
7	0.058	0.447	5.900	6.14	0.0757
8	0.058	0.449	5.860	5.98	0.0767
9	0.058	0.453	6.000	5.96	0.0755
10	0.058	0.445	6.000	6.37	0.0742
11	0.057	0.444	5.630	6.12	0.0799
Total	0.635	4.924	73.950	77.87	

Table 3. Comparison of Average Zone Level Worth

AVZL(%)	WIMS/RFSP	Measured	Difference(%)
20 ~ 60	0.07368 mk/%AVZL	0.07166 mk/%AVZL	2.818
20 ~ 80	0.06938 mk/%AVZL	0.06769 mk/%AVZL	2.496

Table 4. Reactivity Worth of Individual Adjuster Rod

Adjuster Withdrawn	WIMS/RFSP	Measurement	Difference(%)	PPV/RFSP	Difference(%)
1	0.199	0.215	-7.41	0.232	7.95
2	0.519	0.551	-5.84	0.584	5.96
3	0.642	0.696	-7.79	0.726	4.27
4	0.353	0.381	-7.32	0.374	-1.81
5	0.644	0.703	-8.45	0.727	3.35
6	0.513	0.553	-7.29	0.577	4.28
7	0.189	0.215	-12.06	0.235	9.34
8	0.229	0.247	-7.41	0.265	7.15
9	0.66	0.674	-2.07	0.726	7.73
10	0.85	0.910	-5.93	0.94	4.03
11	0.49	0.518	-5.35	0.501	-3.22
12	0.847	0.911	-7.04	0.943	3.50
13	0.657	0.723	-9.07	0.717	-0.76
14	0.225	0.284	-20.87	0.267	-6.12
15	0.194	0.216	-10.19	0.232	7.41
16	0.514	0.520	-1.06	0.577	11.07
17	0.644	0.700	-7.93	0.731	4.51
18	0.350	0.370	-5.43	0.374	1.06
19	0.644	0.709	-9.19	0.727	2.51
20	0.510	0.572	-10.85	0.577	0.87
21	0.187	0.219	-14.57	0.232	5.99
Total	10.06	10.881	-7.54	11.264	3.52

Table 5. Reactivity Worth of Adjuster Bank

Adjuster Bank Withdrawn	ADJ rod Number	WIMS/RFSP	Measurement	Difference (%)	PPV/RFSP	Difference (%)
1	1,7,11,15,21	1.236	1.36	-9.12	1.38	1.47
2	2,6,18	1.399	1.53	-8.56	1.53	0
3	4,16,20	1.387	1.51	-8.15	1.52	0.66
4	8,9,13,14	2.021	2.33	-13.26	2.27	-2.58
5	3,14	1.5	1.77	-15.25	1.69	-4.52
6	5,17	1.524	1.79	-14.86	1.71	-4.47
7	10,12	2.703	3.37	-19.79	3.02	-10.39
Total		11.77	13.66	-13.84	13.12	-3.95

Table 6. Reactivity Worth of Individual Shutoff Rod

SOR inserted	WIMS/RFSP	Measurement	Difference(%)	PPV/RFSP	Difference(%)
1	1.32	1.292	2.14	1.288	-0.34
2	1.652	1.601	3.21	1.635	2.15
3	1.656	1.598	3.60	1.634	2.23
4	1.319	1.310	0.66	1.284	-2.02
5	1.032	0.913	13.04	0.964	5.59
6	2.284	1.891	20.76	2.173	14.89
7	2.281	1.957	16.58	2.157	10.24
8	1.033	0.980	5.49	0.954	-2.57
9	1.577	1.313	20.11	1.495	13.87
10	2.607	2.266	15.06	2.497	10.20
11	2.703	2.398	12.72	2.567	7.049
12	2.602	2.321	12.09	2.483	6.97
13	1.569	1.396	12.44	1.479	5.99
14	1.528	1.314	16.25	1.476	12.30
15	1.524	1.421	7.23	1.463	2.94
16	1.573	1.572	0.01	1.497	-4.82
17	2.602	2.210	17.74	2.493	12.80
18	2.701	2.363	14.29	2.567	8.62
19	2.602	2.334	11.51	2.484	6.45
20	1.567	1.382	13.35	1.481	7.13
21	1.034	0.906	14.16	0.957	5.66
22	2.281	1.846	23.54	2.161	17.04
23	2.275	1.946	16.92	2.161	11.06
24	1.029	1.008	2.05	0.952	-5.59
25	1.316	1.264	4.12	1.29	2.06
26	1.647	1.593	3.41	1.635	2.66
27	1.648	1.631	1.06	1.632	0.074
28	1.309	1.351	-3.14	1.283	-5.06
Total	50.271	45.378	10.78	48.142	6.09

Table 7. Reactivity Worth of Individual Mechanical Control Absorber

MCA rod Inserted	WIMS/RFSP	Measurement	Difference(%)	PPV/RFSP	Difference(%)
1	2.148	1.885	13.98	2.08	10.37
2	2.151	1.944	10.65	2.065	6.22
3	2.154	1.876	14.84	2.075	10.63
4	2.142	2.009	6.61	2.065	2.78
Total	8.595	7.713	11.43	8.285	7.41

Table 8. Reactivity Worth of Mechanical Control Absorber Bank

MCA Bank Inserted	WIMS/RFSP	Measurement	Difference(%)	PPV/RFSP	Difference(%)
1 (MCA#1, #4)	5.813	4.85	19.86	5.437	12.10
2 (MCA#2, #3)	5.82	4.73	23.04	5.436	14.93
Total	11.633	9.58	21.43	10.873	13.50

Table 9. Variation of Reactivity due to Heat Transport System Temperature

Coolant Temp. (℃)	WIMS/RFSP(mk)	Measured	Difference (%)
35.25	0	-	-
50.06	-0.809	-0.890	-9.09
64.87	-0.761	-0.738	3.12
79.92	-0.739	-0.733	0.82
96.85	-0.818	-0.738	10.84
110.84	-0.624	-0.674	-7.41
125.53	-0.627	-0.725	-13.52
140.82	-0.623	-0.597	4.38
155.26	-0.537	-0.537	-0.02
174.14	-0.636	-0.576	10.42
187.21	-0.448	-0.487	-8.09
199.78	-0.393	-0.339	15.89
215.04	-0.433	-0.408	6.25
230.07	-0.358	-0.307	16.45
245.09	-0.289	-0.254	13.71
259.84	-0.219	-0.200	9.41

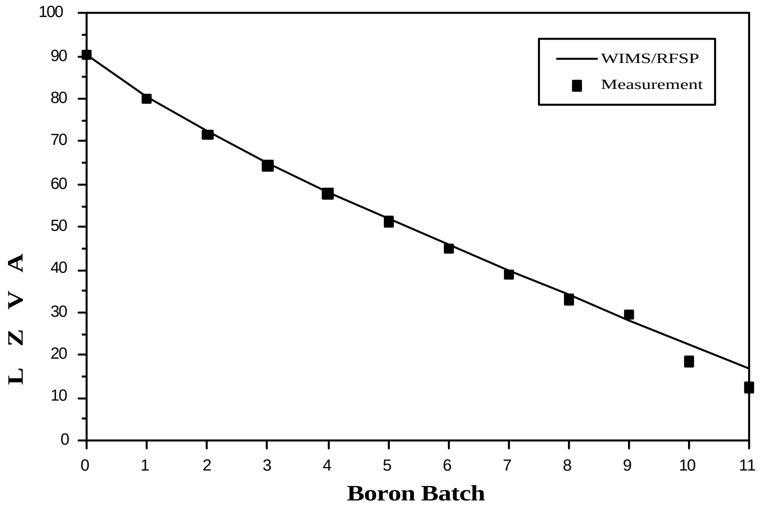

Figure 1. Calibration of Zone Controller