VERIFICATION OF WIMS-ANL TO BE USED AS SUPPORTING CODE FOR WIMS-CANDU DEVELOPMENT

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Hereby this report is submitted as Technical Report for the subject "Development of Base Technology for Realistic Assessment of PHWR Safety", Year 2007

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Summary

The lattice code WIMS-ANL has been tested in order to assess it for the qualification to be used as a supporting code to aide the WIMS-CANDU development. A series of calculations have been performed to determine lattice physics parameters such as multiplication factors, isotopic number densities and coolant void reactivity. The WIMS-ANL results are compared with the predictions of WIMS-AECL/D4/D5 and PPV (POWDERPUFS-V), and the comparisons indicate that WIMS-ANL can be used not only as a supporting code to aide the WIMS-CANDU development, but also as a starting source for the study of developing detailed model that could delineate the realistic situations as it might occur during LOCA such as the asymmetric flux distribution across lattice cell.

TABLE OF CONTENTS

SECTIONS
PAGE

TABLE OF CONTENTS

TABLES
PAGE

TABLE OF CONTENTS

FIGURES
PAGE

TABLE OF CONTENTS

1. INTRODUCTION

As a part of Mid and Long Term Project to develop most realistic safety analysis methodology and tools to deal with the accidents such as LBLOCA of CANDU reactors, the development of detailed model that could delineate the realistic situations as it might occur during LOCA such as the asymmetric flux distribution across lattice cell has been incepted.

In order to secure the compatibility of the model and/or methodology to be migrated into WIMS-CANDU and also in consideration of the wide use of WIMS lattice codes in the international reactor physics community, it has been decided to use WIMS-D4, WIMS-D5 and WIMS-ANL as reference codes to carry out the developmental studies.

The preliminary studies using WIMS-D4/D5/ANL have shown that WIMS-ANL would be most preferable program among the three above-mentioned codes to be used as a reference source program for the further developmental studies. The reason for the WIMS-ANL preference is the coding practice and program structure emphasized on quality assurance. As an example for the supporting evidence of the code integrity, the WIMS-ANL perturbation run using DENSITY keyword to simulate coolant voiding easily yields consistent results in contrast to WIMS-D4/D5.

In the present report, a series of calculations have been performed using WIMS-ANL to determine lattice physics parameters such as multiplication factors, isotopic number densities and coolant void reactivity of 37-element CANDU 6 NU fuel lattice cell. The WIMS-ANL

results are compared with the predictions of WIMS-AECL/D4/D5 and PPV (POWDERPUFS-V), and the comparisons indicate that WIMS-ANL can be used not only as a supporting code to aide the WIMS-CANDU development, but also as a starting source program for the study

of developing model and/or methodology that could delineate the realistic situations as it might occur during LOCA such as the asymmetric flux distribution across lattice cell.

2. LATTICE CODE WIMS-ANL

As the code name suggests, WIMS-ANL has been developed at Argonne National Laboratory, Argonne, Illinois, U.S.A. It is a deterministic code system for lattice calculation. The program used in this report is Version 4.0 that was downloaded from IAEA/NEA Data Bank with the reference number CCC-0698/01 dated 04-JAN-2002 (Ref. 1).

WIMS-ANL is an extension of the Winfrith WIMS-D4 code. In contrast to WIMS-D4, WIMS-ANL is equipped with the SUPERCELL option that eliminates some of the limitations of the traditional SPECTROX solution and supports the solution of more complex geometries with a more detailed spatial mesh and multiple resonance materials. The code generates both macroscopic and microscopic cross sections with any selected number of energy groups.

The nuclear data library downloaded along with the source program is ENDF/B-VI which consists of two parts. The first part of the data library is in the format of the traditional WIMS data library structure. The library is structured with 162 isotopes, of which 72 are resonance isotopes.

The program has been compiled using Compaq Visual Fortran Professional Edition for Win32x86 System Version 6.6A compiler on Desktop PC x86 Family 6 Model 15 - Stepping 6 Genuine Intel ~2401Mhz Dual Core Execution system at PHWR Technology Lab.,

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2.1 Test Runs

In order to verify the integrity of the source program and also the nuclear data library, 18 sample test problems have been rerun and the outputs are compared with the sample outputs. The comparison revealed that both results are practically identical up to the occasional minor differences that can be observed at the trailing digits of the CPU dependent numerical significant digits which should be attributed to the different compilers as well as CPUs that are used for the sample outputs and the test runs, respectively.

2.2 Source Modifications

The source program has been modified as it might have been required during the course of the present study. The affected source listing lines are imbedded between two comment lines with appearance "c-----dhchung2007mmdd", with 2007mmdd indicating the modification date. Among many modifications, the most significant one was the debugging when a bug existed in the original source was found while the program was being tested on a CANDU cluster type input as shown below;

```
SUBROUTINE PRELUD (V, NUCID1, NUCID2, WS, IWS)
.
c-----dhchung20070419
c       IQ01THETAR = IQALLOC (NNN6*NNN5*NNN5, 1)
        IQ01THETAR = IQALLOC (NNN6*NNN5*NNN1, 1)
c-----dhchung20070419
.
```

The integer variable IQ01THETAR defines the relative address in the computer memory pointing the first element of the three-dimensional array variable THETAR. The reason for the modification is that in the

subroutines where the variable is used the array size is declared as THETAR(NNN6,NNN5,NNN1). Thus it was considered as a programming error, and the bug is removed accordingly.

The input and output file locations as well as their names are user-defined in the subroutine OPNFIL.

2.3 Inputs for 37-Element CANDU NU Fuel Lattice

The WIMS-ANL input for 37-element CANDU NU fuel lattice used to calculate k-infinity, k-effective and isotopic number densities as well as coolant void reactivity as a function of burnup is given in Appendix. The input parameters are based upon the CANDU 6 input data to the cell code PPV (Ref. 2). The WIMS-ANL code was run using only the first part of ENDF/B-VI 69 energy group nuclear data libraries. At the bottom of the input a partial input deck used for the coolant void reactivity calculation is also shown as an example.

The input files used for the present study are stored in the directory \ \ candulab \ projectmaterial \ dhchung \ TR 20070831 on common PC CANDULAB.

3. DISCUSSION OF RESULTS

In order to compare the predictions of WIMS-ANL with the PPV results, the input buckling of the WIMS-ANL is adjusted in such a way that both codes produce the same value of k-eff=1.09530 when the fuel is clean with no fission product at zero burnup.

Furthermore, the burnup points of PPV (Ref. 2) are less than those of the WIMS-ANL simulations. Thus the PPV values at WIMS-ANL burnup points are approximated by interpolating the PPV results so that

The predictions of WIMS-ANL and PPV can be directly compared at the same burnup points.

3.1 K-Infinity and K-Effective

The k-infinity and k-effective values of WIMS-ANL and PPV are given in Tables 1 and 2 along with the differences between two codes as a function of burnup, respectively. The same results are also shown graphically in Figures 1-4.

The results given at zero burnup correspond to the clean fuel condition with no fission product whereas at 1.01 MWh/kgU the saturating fission products are assumed to have built in. Neglecting the reactivity decrease due to depletion between 0-1.01 MWh/kgU burnup period the drop in the multiplication factors between this burnup interval would approximately correspond to the reactivity change due to saturating fission product build-up.

Defining the reactivity change as;

ρ = (1/K,No SFP-1/K,With SFP)*1000,

the values of saturating fission product reactivity worth are as follows;

Using K-Infinity		Using K-Effective	
WIMS-ANL	PPV	WIMS-ANL	PPV
-30.13 mk	-37.17 mk	-30.59 mk	-37.94 mk

As can be seen, the PPV results show approximately ~7 mk heavier

loading of saturating fission products compared to the WIMS-ANL calculations. The difference of the reactivity worth between using k-infinity and k-effective is 0.46 and 0.77 mk for WIMS-ANL and PPV, respectively.

At zero burnup the k-infinity value of WIMS-ANL is -0.00825 lower than the PPV value. The values between 0-~40 MWh/kgU can not be directly compared for two codes because the PPV values between this burnup interval are the interpolated ones out of the largely spaced original PPV burnup points.

Note that the k-infinity values of WIMS-ANL are underpredicted for the entire burnup range up to the exit burnup compared to the PPV predictions. For the range from plutonium peak (~50 MWh/kgU) up to about mid-burnup range (~100 MWh/kgU) the differences between the WIMS-ANL and PPV k-infinity values stay fairly unchanged, and the differences become smaller with burnup and at exit burnup the difference decreases nearly to about half of the difference at zero burnup.

A similar behavior of the k-effective differences between WIMS-ANL and PPV can be observed as in the case of k-infinity (see Figures 2 and 4). The k-effective differences decrease faster than the k-infinity differences and the WIMS-ANL k-effective becomes larger than the PPV k-effective at 185.99 MWh/kgU.

3.2 Isotopic Composition Ratios

The results of the WIMS-ANL and PPV isotopic composition calculations are given in Table 3 and also graphically in Figures 5 and 6, respectively. Note that WIMS-ANL does not deplete U238 so that there is about ~0.8% excessive U238 atoms in WIMS-ANL calculations at exit burnup compared to the PPV calculations.

The isotopic composition ratio which is defined as;

N-Ratio=N(U235)/N(U238)x1000

with N corresponding to atoms per unit mass of UO2.

The small difference (3.3e-04) of N-Ratio between WIMS-ANL and PPV at zero burnup is practically negligible. The value of the WIMS-ANL N-Ratio calculations underlies consistently the PPV values, and at exit burnup the WIMS-ANL value is about ~5.9% lower than the PPV value. Since this difference of about ~5.9% outweighs ~0.8% excessive U238 atoms in WIMS-ANL calculations, the comparisons being carried out here should be considered as legitimate.

The N-Ratio differences between WIMS-ANL and PPV increase and the maximum difference becomes -0.13807 at 130.70 MWh/kgU (see Figure 6) which is about ~4.4% of N-Ratio value. The differences then decrease with burnup although the relative differences (percentage) increase monotonically.

3.3 Pu239 Contents

Finally, the results of the WIMS-ANL and PPV Pu239 content calculations are given in Table 4 and also graphically in Figures 7 and 8, respectively. As can be seen, the PPV calculations overpredict Pu239 content initially up to the burnup point 25.13 MWh/kgU, and then the WIMS-ANL calculations overpredict with burnup. At exit burnup the WIMS-ANL prediction is about ~7.4% higher compared to the PPV value. It is to note that the excessive U238 atoms of about ~0.8% in WIMS-ANL calculations at exit burnup is small in percentage compared to ~7.4% of the Pu239 content difference so that the comparisons being carried out here should be again considered as legitimate.

3.4 Coolant Void Reactivity Coefficients

The coolant void reactivity coefficients calculated using WIMS-ANL and PPV are reported in a separate technical memorandum entitled “Progress Report on WIMS Model Development” and the memorandum is attached

to the present Technical Report as an Appendix.

4. CONCLUSIONS AND RECOMMENDATIONS

Based upon the investigations carried out in the present report the validity of the WIMS-ANL predictions applied to CANDU 6 NU fuel lattice can be observed in light of the PPV calculations which are currently in use for the design, safety and operational analysis of CANDU 6 reactors fuelled with natural uranium fuel.

The inclusion of U238 in the system of burnup chain equation is recommended.

5. ACKNOWLEDGEMENTS

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REFERENCE

1. J.R. Deen, W.L. Woodruff, C.I. Costescu and L.S. Leopando, “WIMS-ANL USER MANUAL, REV.4”, ANL/RERTR/TM-23, JANUARY 2001

2. “CANDU 6 Generating Station Physics Design Manual – Wolsong NPP 2/3/4”, 86-03310-DM-000, Revision 1, KAERI/AECL, 1995 August

Table 1

K-Infinity of WIMS-ANL and PPV along with Differences

(37 Element CANDU 6 NU Fuel Lattice)

MWh/kgU	K-Inf (WIMS-ANL)	K-Inf (PPV)	K-Inf Diff (ANL-PPV)	MWh/kgU	K-Inf (WIMS-ANL)	K-Inf (PPV)	K-Inf Diff (ANL-PPV)
0^{+}	1.12166	1.12991	-0.00825	80.43	1.05105	1.06485	-0.01380
1.01^{*}	1.08499	1.08437	0.00062	85.46	1.04758	1.06131	-0.01373
2.01	1.07874	1.08453	-0.00579	90.48	1.04405	1.05770	-0.01365
3.02	1.07602	1.08469	-0.00867	95.51	1.04048	1.05398	-0.01350
4.02	1.07436	1.08485	-0.01049	100.54	1.03687	1.05020	-0.01333
6.03	1.07281	1.08517	-0.01236	105.56	1.03323	1.04636	-0.01313
8.04	1.07260	1.08549	-0.01289	110.59	1.02956	1.04248	-0.01292
10.05	1.07317	1.08580	-0.01263	115.62	1.02587	1.03855	-0.01268
13.07	1.07426	1.08628	-0.01202	120.64	1.02220	1.03460	-0.01240
16.09	1.07529	1.08676	-0.01147	125.67	1.01853	1.03062	-0.01209
19.10	1.07607	1.08723	-0.01116	130.70	1.01485	1.02661	-0.01176
22.12	1.07652	1.08719	-0.01067	135.72	1.01122	1.02263	-0.01141
25.13	1.07665	1.08715	-0.01050	140.75	1.00756	1.01863	-0.01107
28.15	1.07647	1.08711	-0.01064	145.78	1.00397	1.01464	-0.01067
31.17	1.07610	1.08707	-0.01097	150.80	1.00041	1.01064	-0.01023
34.18	1.07541	1.08703	-0.01162	155.83	0.99683	1.00665	-0.00982
37.20	1.07462	1.08699	-0.01237	160.86	0.99337	1.00268	-0.00931
40.21	1.07362	1.08664	-0.01302	165.88	0.98992	0.99874	-0.00882
44.24	1.07204	1.08539	-0.01335	170.91	0.98647	0.99482	-0.00835
48.26	1.07025	1.08382	-0.01357	175.94	0.98313	0.99093	-0.00780
52.28	1.06828	1.08183	-0.01355	180.96	0.97974	0.98707	-0.00733
56.30	1.06614	1.07980	-0.01366	185.99	0.97646	0.98324	-0.00678
60.32	1.06388	1.07760	-0.01372	191.02	0.97328	0.97946	-0.00618
64.34	1.06148	1.07527	-0.01379	196.05	0.97017	0.97571	-0.00554
68.36	1.05897	1.07281	-0.01384	201.07	0.96718	0.97202	-0.00484

72.39	1.05640	1.07025	-0.01385	206.10	0.96394	0.96835	-0.00441
76.41	1.05376	1.06759	-0.01383	211.13	0.96078	0.96474	-0.00396

+ The fuel is clean with no fission product.

* The saturating fission products are assumed to have built in.

Table 2

K-Effective of WIMS-ANL and PPV along with Differences

(37 Element CANDU 6 NU Fuel Lattice)

MWh/kgU	K-Eff (WIMS-ANL)	K-Eff (PPV)	K-Eff Diff (ANL-PPV)	MWh/kgU	K-Eff (WIMS-ANL)	K-Eff (PPV)	K-Eff Diff (ANL-PPV)
0+	1.09530	1.09530	0	80.43	1.02798	1.03424	-0.00626
1.01*	1.05979	1.05160	0.00819	85.46	1.02463	1.03084	-0.00621
2.01	1.05372	1.05178	0.00194	90.48	1.02121	1.02737	-0.00616
3.02	1.05108	1.05197	-0.00089	95.51	1.01774	1.02380	-0.00606
4.02	1.04950	1.05215	-0.00265	100.54	1.01424	1.02015	-0.00591
6.03	1.04804	1.05252	-0.00448	105.56	1.01070	1.01645	-0.00575
8.04	1.04790	1.05288	-0.00498	110.59	1.00713	1.01270	-0.00557
10.05	1.04852	1.05325	-0.00473	115.62	1.00354	1.00891	-0.00537
13.07	1.04968	1.05380	-0.00412	120.64	0.99997	1.00510	-0.00513
16.09	1.05078	1.05435	-0.00357	125.67	0.99640	1.00125	-0.00485
19.10	1.05163	1.05489	-0.00326	130.70	0.99281	0.99737	-0.00456
22.12	1.05214	1.05493	-0.00279	135.72	0.98929	0.99352	-0.00423
25.13	1.05233	1.05497	-0.00264	140.75	0.98573	0.98966	-0.00393
28.15	1.05223	1.05501	-0.00278	145.78	0.98223	0.98580	-0.00357
31.17	1.05192	1.05505	-0.00313	150.80	0.97876	0.98192	-0.00316
34.18	1.05129	1.05509	-0.00380	155.83	0.97527	0.97807	-0.00280
37.20	1.05058	1.05513	-0.00455	160.86	0.97190	0.97422	-0.00232
40.21	1.04966	1.05486	-0.00520	165.88	0.96854	0.97041	-0.00187
44.24	1.04817	1.05373	-0.00556	170.91	0.96517	0.96661	-0.00144
48.26	1.04647	1.05227	-0.00580	175.94	0.96192	0.96283	-0.00091
52.28	1.04459	1.05040	-0.00581	180.96	0.95861	0.95910	-0.00049
56.30	1.04254	1.04848	-0.00594	185.99	0.95542	0.95538	0.00004
60.32	1.04037	1.04640	-0.00603	191.02	0.95231	0.95171	0.00060
64.34	1.03807	1.04418	-0.00611	196.05	0.94929	0.94807	0.00122
68.36	1.03565	1.04185	-0.00620	201.07	0.94637	0.94449	0.00188

72.39	1.03316	1.03940	-0.00624	206.10	0.94322	0.94093	0.00229
76.41	1.03061	1.03686	-0.00625	211.13	0.94013	0.93744	0.00269

+ The fuel is clean with no fission product.

* The saturating fission products are assumed to have built in.

Table 3

N(U235)/N(U238) Isotopic Composition Ratios of WIMS-ANL and PPV along with Differences

(37 Element CANDU 6 NU Fuel)

MWh/kgU	N-Ratio+ (WIMS-ANL)	N-Ratio+ (PPV)	Difference* (ANL-PPV)	MWh/kgU	N-Ratio+ (WIMS-ANL)	N-Ratio+ (PPV)	Difference* (ANL-PPV)
0	7.25663	7.25630	0.00033	80.43	4.20036	4.32080	-0.12044
1.01	7.20476	7.20565	-0.00089	85.46	4.06280	4.18690	-0.12410
2.01	7.15298	7.15597	-0.00299	90.48	3.92988	4.05726	-0.12738
3.02	7.10233	7.10634	-0.00401	95.51	3.80138	3.93123	-0.12985
4.02	7.05169	7.05767	-0.00598	100.54	3.67706	3.80890	-0.13184
6.03	6.95034	6.96129	-0.01095	105.56	3.55649	3.69040	-0.13391
8.04	6.84955	6.86678	-0.01723	110.59	3.43993	3.57510	-0.13517
10.05	6.75337	6.77407	-0.02070	115.62	3.32647	3.46316	-0.13669
13.07	6.61015	6.63806	-0.02791	120.64	3.21728	3.35467	-0.13739
16.09	6.47105	6.50578	-0.03473	125.67	3.11146	3.24909	-0.13763
19.10	6.33651	6.37745	-0.04094	130.70	3.00847	3.14654	-0.13807
22.12	6.20548	6.25207	-0.04659	135.72	2.90926	3.04712	-0.13786
25.13	6.07767	6.13031	-0.05264	140.75	2.81269	2.95031	-0.13762
28.15	5.95314	6.01120	-0.05806	145.78	2.71926	2.85625	-0.13699
31.17	5.83278	5.89501	-0.06223	150.80	2.62881	2.76502	-0.13621
34.18	5.71364	5.78197	-0.06833	155.83	2.54108	2.67620	-0.13512
37.20	5.59912	5.67122	-0.07210	160.86	2.45642	2.58988	-0.13346
40.21	5.48672	5.56336	-0.07664	165.88	2.37431	2.50619	-0.13188
44.24	5.34054	5.42272	-0.08218	170.91	2.29456	2.42471	-0.13015
48.26	5.19889	5.28650	-0.08761	175.94	2.21768	2.34556	-0.12788
52.28	5.06168	5.15414	-0.09246	180.96	2.14297	2.26885	-0.12588
56.30	4.92805	5.02545	-0.09740	185.99	2.07101	2.19422	-0.12321
60.32	4.79828	4.90024	-0.10196	191.02	2.00117	2.12179	-0.12062
64.34	4.67202	4.77834	-0.10632	196.05	1.93352	2.05152	-0.11800
68.36	4.54901	4.65961	-0.11060	201.07	1.86793	1.98351	-0.11558

72.39	4.42954	4.54362	-0.11408	206.10	1.80486	1.91745	-0.11259
76.41	4.31355	4.43081	-0.11726	211.13	1.74358	1.85347	-0.10989

+ N-Ratio=N(U235)/N(U238)x1000 : N corresponds to atoms per unit mass of UO2

* Difference=(N-Ratio WIMS-ANL) - (N-Ratio PPV)

Table 4

$Pu239^{+}$ Contents of WIMS-ANL and PPV along with Differences

(37 Element CANDU 6 NU Fuel*)

MWh/kgU	Pu239 (WIMS-ANL)	Pu239 (PPV)	Pu239 Diff (ANL-PPV)	MWh/kgU	Pu239 (WIMS-ANL)	Pu239 (PPV)	Pu239 Diff (ANL-PPV)
0	0	0	0	80.43	34.88592	33.88130	1.00462
1.01	0.10471	0.51770	-0.41299	85.46	36.07773	34.97230	1.10543
2.01	0.38123	1.04940	-0.66817	90.48	37.18895	35.98370	1.20525
3.02	0.78378	1.60259	-0.81881	95.51	38.22934	36.92550	1.30384
4.02	1.27734	2.16438	-0.88704	100.54	39.20545	37.80070	1.40475
6.03	2.43890	3.32479	-0.88589	105.56	40.11825	38.61200	1.50625
8.04	3.72557	4.51410	-0.78853	110.59	40.97253	39.36750	1.60503
10.05	5.05979	5.71835	-0.65856	115.62	41.77296	40.06870	1.70426
13.07	7.06197	7.53249	-0.47052	120.64	42.52082	40.71880	1.80202
16.09	9.00962	9.32446	-0.31484	125.67	43.22291	41.32290	1.90001
19.10	10.87719	11.06960	-0.19241	130.70	43.88425	41.88360	2.00065
22.12	12.65865	12.76400	-0.10535	135.72	44.50713	42.40270	2.10443
25.13	14.35439	14.38830	-0.03391	140.75	45.08341	42.88520	2.19821
28.15	15.96870	15.94830	0.02040	145.78	45.63239	43.33270	2.29969
31.17	17.50643	17.43750	0.06893	150.80	46.14455	43.74680	2.39775
34.18	18.97188	18.85100	0.12088	155.83	46.62038	44.13110	2.48928
37.20	20.36984	20.20080	0.16904	160.86	47.07609	44.48670	2.58939
40.21	21.70423	21.48080	0.22343	165.88	47.49968	44.81500	2.68468
44.24	23.39028	23.09790	0.29238	170.91	47.89656	45.11890	2.77766
48.26	24.97792	24.60910	0.36882	175.94	48.27660	45.39920	2.87740
52.28	26.47566	26.02730	0.44836	180.96	48.61744	45.65770	2.95974
56.30	27.88902	27.35980	0.52922	185.99	48.94315	45.89620	3.04695
60.32	29.22428	28.61400	0.61028	191.02	49.26291	46.11570	3.14721
64.34	30.48523	29.79610	0.68913	196.05	49.56559	46.31840	3.24719
68.36	31.67767	30.90750	0.77017	201.07	49.86402	46.50530	3.35872

72.39	32.80647	31.96130	0.84517	206.10	50.09694	46.68030	3.41664
76.41	33.87485	32.94970	0.92515	211.13	50.31087	46.84490	3.46597

+ Grams/Bundle .

* Initial UO2 weight per bundle=21.782 kg.

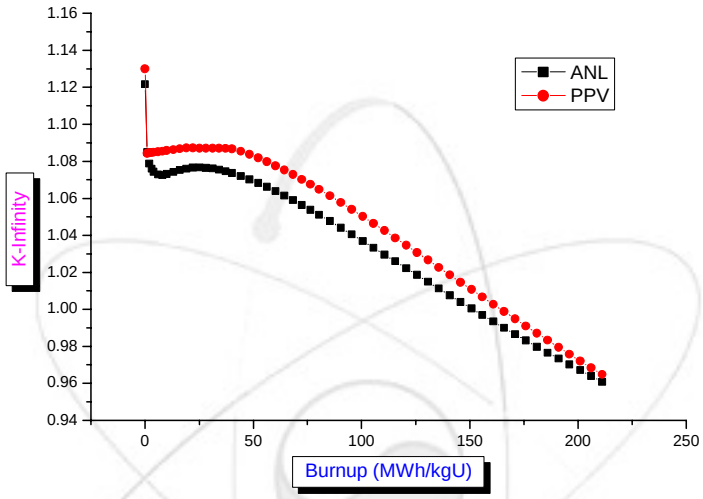

Figure 1 Lattice K-Infinity of 37 Element CANDU 6 NU Fuel

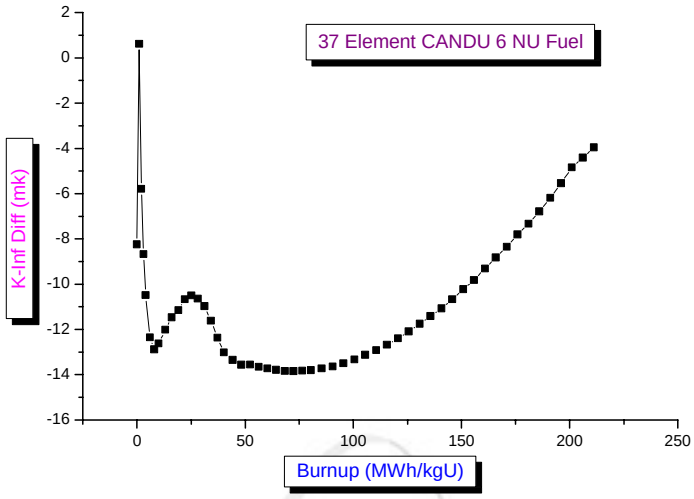

Figure 2 Lattice K-Infinity Differences between WIMS-ANL and PPV

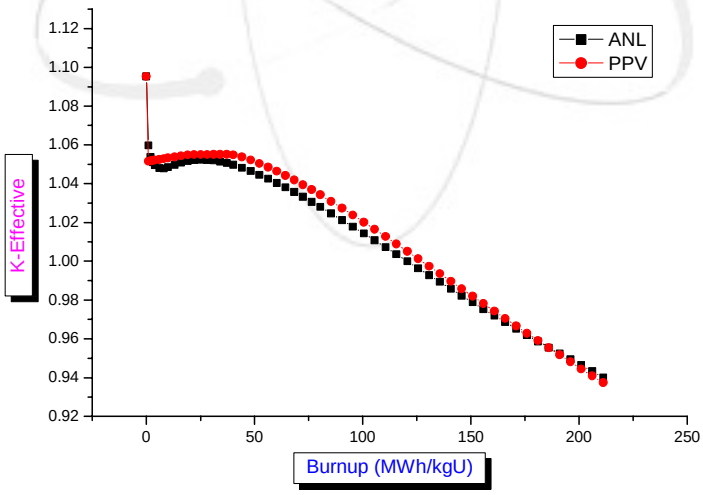

Figure 3 Lattice K-Effective of 37 Element CANDU 6 NU Fuel

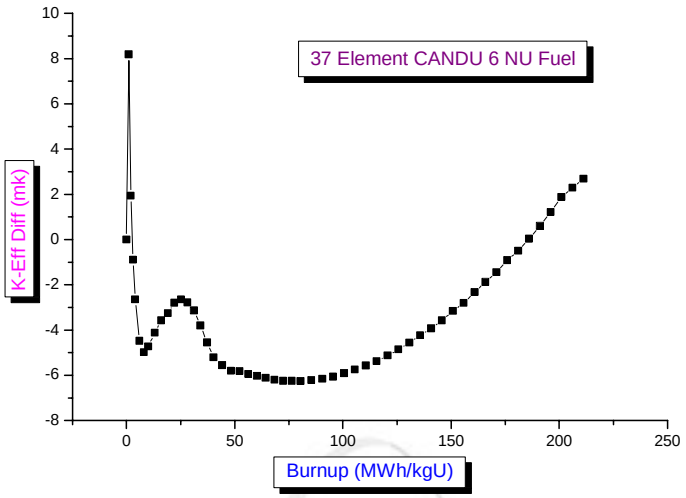

Figure 4 Lattice K-Effective Differences between WIMS-ANL and PPV

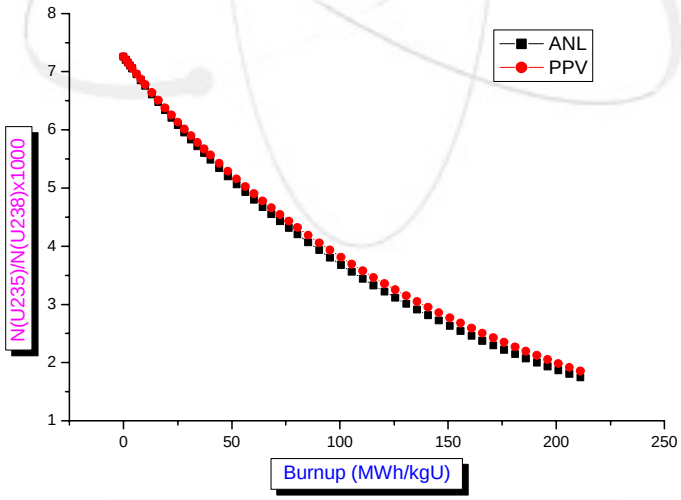

Figure 5 N(U235)/N(U238) Isotopic Composition Ratios for 37 Element CANDU 6 NU Fuel

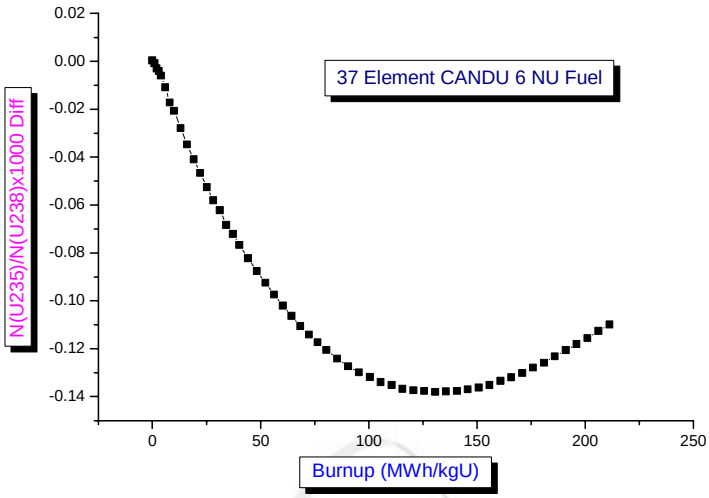

Figure 6 N(U235)/N(U238) Isotopic Composition Ratio Differences between WIMS-ANL and PPV

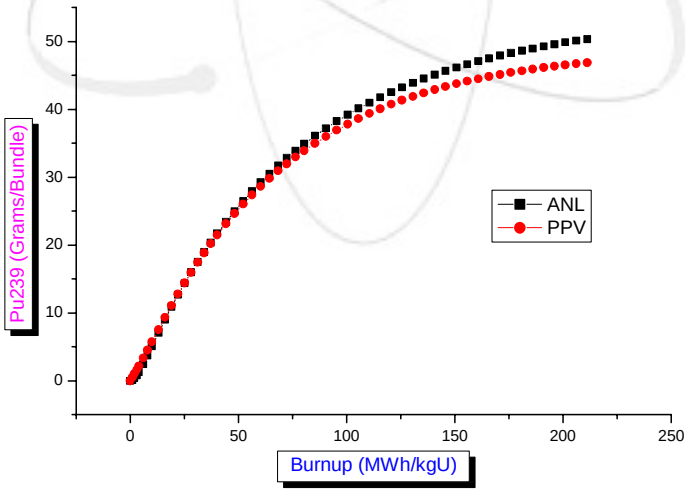

Figure 7 Pu239 Content of 37 Element CANDU 6 NU Fuel Bundle

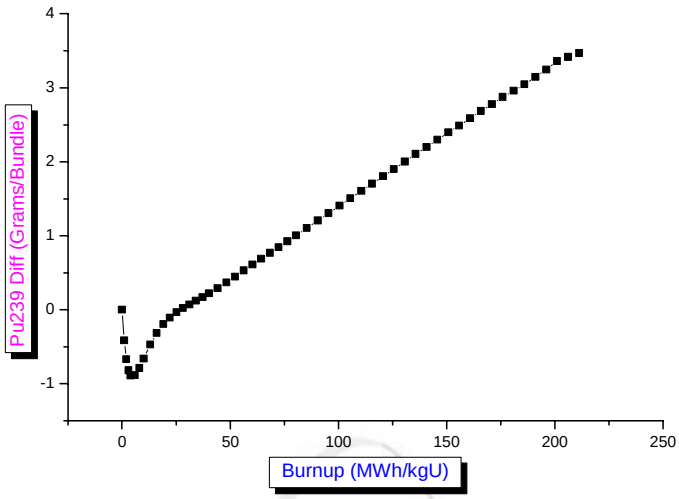

Figure 8 Pu239 Content Differences between WIMS-ANL and PPV for 37 Element CANDU 6 NU Fuel Bundle

APPENDIX - A

Input deck for simulations of normal operation.

```
**********************************************************
************************ WIMS-ANL **********************
*                                                        *
*          Wolsong Unit 2/3/4 - Normal Operation         *
*            Input parameters are derived from           *
*    CANDU 6 Generating Station Physics Design Manual    *
*                  86-03310-DM-000, Revision 1           *
*                                                        *
**********************************************************
**********************************************************
CELL            7
SEQUENCE        4
```

```
NRODS          37   -12   100   11   4   3   1
NGROUP          33     2     2
NMESH           80   100
NREGION         12     4   100
NMATERIAL       11     4
NREACT          -1
PREOUT
*
INITIATE
ANNULUS      1       1.4310      10          *COOLANT
ANNULUS      2       2.1790      10          *COOLANT
ANNULUS      3       2.9260      10          *COOLANT
ANNULUS      4       3.6740      10          *COOLANT
ANNULUS      5       4.4210      10          *COOLANT
ANNULUS      6       5.1689      10          *COOLANT
ANNULUS      7       5.6032       6          *PT
ANNULUS      8       6.4478       7          *GAP
```



```
ANNULUS      9       6.5875       8          *CT
ANNULUS     10       7.1002       9          *MODER
ANNULUS     11       7.6002       9          *MODER
POLYGON     12       4      9     14.2875
NPIJAN      12
*
*** 1st Ring   ****
ARRAY   1   1   1    0.000    0              *Reference
*** 2nd Ring   ****
ARRAY   2   1   6    1.490    0              *Reference
*** 3rd Ring ****
ARRAY   3   1 12    2.875    0.261799     *Reference
*** 4th Ring ****
ARRAY   4   1 18    4.333    0              *Reference
*
RODSUB       1      1        0.430      1    *FUEL1
RODSUB       1      2        0.6122     1    *FUEL1
```

```
RODSUB      1     3       0.654     5    *CLAD
*
RODSUB      2     1       0.430     2    *FUEL2
RODSUB      2     2       0.6122    2    *FUEL2
RODSUB      2     3       0.654     5    *CLAD
*
RODSUB      3     1       0.430     3    *FUEL3
RODSUB      3     2       0.6122    3    *FUEL3
RODSUB      3     3       0.654     5    *CLAD
*
RODSUB      4     1       0.430     4    *FUEL4
RODSUB      4     2       0.6122    4    *FUEL4
RODSUB      4     3       0.654     5    *CLAD
*
*
MATERIAL   1   10.31716   960.16   1      16   13.44251     $
    2235   0.7113986   2238   99.2886014                    *FUEL1
```



```
MATERIAL   2    1
MATERIAL   3    1
MATERIAL   4    1
*
MATERIAL   5    6.3918    561.16   2   91   98.1813          $
      56   0.210329    52 0.10001   58   0.007              $
    1010   0.5962E-04                                       *CLAD
*
MATERIAL   6    6.5041    561.16    4     91   97.3127       $
      93    2.58       56 0.046756 52 0.008091             $
      58 0.0035015 1010 0.00002431                          *PT
*
MATERIAL   7    0.0014    451.66    4   1212   27.11         $
      16   72.89                                           *Gas Gap
*
MATERIAL   8 6.4003    342.16     4    91    98.2082        $
      56    0.135122   52   0.1 58 0.055093                $
```

```
    1010 0.5962E-4                                    *CT
*
MATERIAL   9 1.085089 342.16   4   4002   20.09          $
      16   79.9   2001   0.0151                         *Moderator
*                                                     (99.85wt%)
MATERIAL 10    0.807859    561.16   3   4002   19.96      $
      16   79.955   2001   9.0677E-02                    *Coolant
*                                                     (99.10wt%)
MATERIAL 11   2.686145   561.00   4   91 82.85827        $
      56   0.177503 52 0.084402 58 0.005911            $
    1010 5.03E-05   4002 3.367829     16 13.49072      $
    2001   0.0153                                      *ENDREGION
*
*
FEWGROUP   2   4   6   7 10 12 14 16 18 20 22 24 25 26 27 $
          30 33 38 39 42 45 47 49 51 53 55 57 59 61 63 $
          65 67 69
PROTECTED – Proprietary                KAERI/TR-3454/2007 Page A-4

*
MESH   4 2 2 2 2   2 1 1 1 1   1 5
SUPPRESS   0 0 0 0 0   0 0 0 0 0   0 0 0 0 0   0
PRTOPT     1
POWERC      1 41.89 0.00001 1
*ODDS      -21
BUCKLINGS 0.4343E-04    0.2817E-04
TOLERANCE 1E-05
BEGINC
****************************** EDIT ************************
ISOXS        0       0      55      1      0      0      0      0
ENDCAP    11 2.68524E-02 -1 1.0 6
OPTION       0
THERMAL     12
*ALPHA       18
BEEONE       0
DNB          1   0 0 0 0 0 0 0
```

```
DNB            2   0 0 0 0 0 0 0
DNB            3   0 0 0 0 0 0 0
DNB            4   0 0 0 0 0 0 0
DNB            5   0 0 0 0 0 0 0
DNB            6   0 0 0 0 0 0 0
DNB            7   0 0 0 0 0 0 0
DNB            8   0 0 0 0 0 0 0
DNB            9   0 0 0 0 0 0 0
DNB           10   0 0 0 0 0 0 0
DNB           11   0 0 0 0 0 0 0
DIFFUSION      2   1 6.5875
VECTOR        21 33
BUCKLINGS 0.4343E-04    0.2817E-04
PARTITION     45 69
LEAKAGE        5
BEGINC
************************end of edit************************
```


```
*
POWERC 1 41.89 1 1 *   day       1
BEGINC
BEGINC
*
POWERC 1 41.89 1 1 *   day       2
BEGINC
BEGINC
*
.
.
*
POWERC 1 41.89 5 1 *   day     210
BEGINC
BEGINC
*
POWERC 1 41.89 0.00001 1 *   day     210
```

```
BEGINC
BEGINC
*
* End of input
*
```

Partial input deck for simulations of coolant voiding.

```
Input down to here is same as for normal operation case
************************end of edit************************
*
******************** beginning of voiding ********************
POWERC 1 41.89 0.0001 1 *   day       1
DENSITY   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   0.9000
BEGINC
BEGINC
*
```



```
POWERC 1 41.89 0.0001 1 *   day       1
DENSITY   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   01.1111111
BEGINC
BEGINC
******************** end          of voiding ********************
*
POWERC 1 41.89 1 1 *   day       1
BEGINC
BEGINC
*
******************** beginning of voiding ********************
POWERC 1 41.89 0.0001 1 *   day       1
DENSITY   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   0.9000
BEGINC
BEGINC
*
POWERC 1 41.89 0.0001 1 *   day       1
```

```
DENSITY  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  01.1111111
BEGINC
BEGINC
****************** end          of voiding ******************
*
```


APPENDIX - B

Memo

PHWR Technology Lab.

File: *File Number*
Date: *07-08-31*

From: DaiHai Chung
To: WonYoung Kim
Cc: JooHwan Park, BoWook Rhee

Subject: Progress Report on WIMS Model Development

Summary

As a preliminary step to develop the detailed model of WIMS to be implemented into WIMS-CANDU, the lattice code WIMS-ANL has been further tested in order to confirm the validity of using it as a starting source program for the WIMS model development. The coolant void reactivity of 37-element CANDU 6 natural uranium fuel lattice has been calculated using WIMS-ANL and compared the results with the predictions of WIMS-AECL/D5 and PPV. The comparison indicates the usefulness of WIMS-ANL so that it can be further used to support the development of WIMS model.

1. Introduction

As a part of Mid and Long Term Project to develop the most realistic safety analysis methodology and tools to deal with the accidents such as LBLOCA of CANDU reactors, the development of detailed model eventually to be implemented into the lattice code WIMS-CANDU has been incepted. The detailed model will be developed in such a way to delineate the realistic situations as they might occur during LOCA such as the asymmetric flux distribution across lattice cell and the spatially distributed void fractions within the coolant region.

In order to secure the compatibility of the model to be migrated into WIMS-CANDU and also in consideration of the wide use of WIMS lattice codes in the international reactor physics community, it has been decided to use WIMS-D4, WIMS-D5 and WIMS-ANL as reference codes to assist the development of the detailed model.

The preliminary studies using WIMS-D4/D5/ANL have shown that WIMS-ANL would be most preferable program among the three above-mentioned codes to be used as a reference source program for the further development of the WIMS detailed model. The reason for the WIMS-ANL preference is the coding practice and program structure emphasized on quality assurance. As an example for the supporting evidence of the code integrity, the WIMS-ANL perturbation run using DENSITY keyword easily yields the consistent results compared to WIMS-D4/D5.

In the present report, the 37-element CANDU 6 NU fuel lattice void reactivity calculated by using WIMS-ANL are compared with the predictions of WIMS-AECL/D5 and PPV codes. The WIMS-AECL/D5 and PPV results are obtained from Reference 1.

2. WIMS-ANL Input

The WIMS-ANL input for 37-element CANDU NU fuel used to calculate coolant void reactivity is given in Appendix. The input parameters are based upon the CANDU 6 input data to the cell code PPV (Ref. 2). The WIMS-ANL code was run using ENDF/B-VI 69 energy group nuclear data libraries downloaded with source program – IAEA/NEA Data Bank CCC-0698-1. At the bottom of the input a partial input deck used for the coolant void reactivity calculation is also shown as an example.

3. Discussion of Results

The coolant void reactivity calculated using WIMS-ANL (see Appendix for input) is shown in Fig. 1 (see also Table 1). The values plotted represent the case at mid-burnup (~100 MWh/kgU) and the void

reactivity is calculated using the k-effective values for the voided and unvoided cases, respectively. The void reactivity is defined as;

Void Reactivity (mk) = (1/k-eff,unvoided – 1/k-eff,voided)*1000

The coolant density ratio (voided/unvoided) is given in logarithmic abscissa, and the smallest ratio is CDR=0.0001. In this case – complete voiding - the void reactivity is practically equal to the value of the case for CDR=0.001, and does not show any anomalies of numerical behavior for a very small number CDR=0.0001, which can be observed as the vindication of the integrity and soundness of the code structure. For the range CDR=0.01-0.90 the VR curve runs smoothly without showing any unusual pattern.

The coolant void reactivity calculated using WIMS-ANL k-infinity values is given in Fig. 2 and Table 2 at zero/mid/exit burnup. Note that the void reactivity given for at zero burnup corresponds to the case with free of

fission products. For the complete voiding the reactivity has the largest value of VR=14.99 mk for the fresh fuel. For the fuel at mid and exit burnup the largest value of void reactivity is VR=12.90 mk and VR=12.93 mk, respectively, and the both values are practically same and approximately ~2 mk lower compared to the fresh fuel case. The void reactivity of the fuel at zero/mid/exit burnup decreases linearly with CDR and the differences of void reactivity of the fuel between at zero and mid/exit burnup narrow down also with CDR and for CDR=0.9 the differences are approximately 0.2 mk, which are about 1/10 of the differences for the case of complete voiding.

A similar case to the above-discussed case is shown in Fig. 3 and Table 3 where the void reactivity is calculated using k-effective. As can be seen the void reactivity in this case is slightly smaller compared to the above-discussed case. The difference of void reactivity between zero and mid/exit burnup cases corresponding the complete voiding is approximately ~2.3 mk, which is slightly larger

than ¯2 mk as discussed in the case of k-infinity. However the difference is again narrowed down to approximately ¯0.2 mk for CDR=0.9 as in the previous case. The void reactivity curves shown in Fig. 3 behave in similar pattern as given in Fig. 2.

In Fig. 4 and Table 4 the WIMS-ANL calculated void reactivity using k-infinity and k-effective for CDR=0.001 is shown as function of burnup. The void reactivity increases initially with burnup until ¯3 MWh/kgU and then decreases sharply until about ¯50 MWh/kgU which is in the burnup range of plutonium peak. From there on the void reactivity curves almost flatten out toward exit burnup. The differences between the void reactivity obtained using k-infinity and k-effective increase slowly with burnup until level off at about ¯160 MWh/kgU to approximately ¯0.6 mk. The leveled-off values of void reactivity as obtained using k-infinity and k-effective are approximately ¯13 mk and ¯12.4 mk, respectively.

The predictions of void reactivity as determined by using WIMS-ANL/AECL/D5 and PPV are graphically shown in Fig. 5 as well as the values in Table 5 as function of burnup again. Note that the burnup points of WIMS-ANL are different from those of WIMS-AECL/D5 and PPV as the results of these codes are quoted from Ref. 1. It is pronounced that the void reactivity predicted by WIMS-AECL is above the values of WIMS-ANL whereas the prediction of PPV is well underneath the WIMS-ANL values. The values of void reactivity predicted by WIMS-ANL and WIMS-D5 are very close and the curves of both cases behave also very similarly. Note that the void reactivity predicted by WIMS-AECL and PPV decreases with burnup between the plutonium peak and exit burnup range, and these phenomena is much more pronounced for the PPV case.

Finally the differences of the void reactivity based upon k-effective between WIMS-ANL and WIMS-AECL are given in Fig. 6 and Table 6. The maximum value of the differences between the WIMS-ANL and WIMS-AECL predictions is 1.895 mk at zero burnup and the difference decreases

initially and then increases until the range of plutonium peak and the difference decreases monotonically from there on toward exit burnup. The average value of the differences is about ~1.130314 mk.

4. Conclusions

Based upon the investigations carried out in the present report the validity of the WIMS-ANL void reactivity predictions can be observed in light of the WIMS-AECL calculations which are currently in use for the LOCA analysis of CANDU reactors fuelled with natural uranium fuel. The average value ~1.130314 mk of the differences between the WIMS-ANL and WIMS-AECL void reactivity is in acceptable range in consideration of the uncertainty sources coming from the physics modeling as well as numerical operations.

5. Acknowledgements

This work was supported by Korea Research Foundation and The Korean Federation of Science and Technology Societies Grant funded by Korea Government (MOEHRD, Basic Research Promotion Fund).

References

[1] WonYoung Kim, “Private Communication”, July 2007
[2] “CANDU 6 Generating Station Physics Design Manual – Wolsong NPP 2/3/4”, 86-03310- DM-000, Revision 1

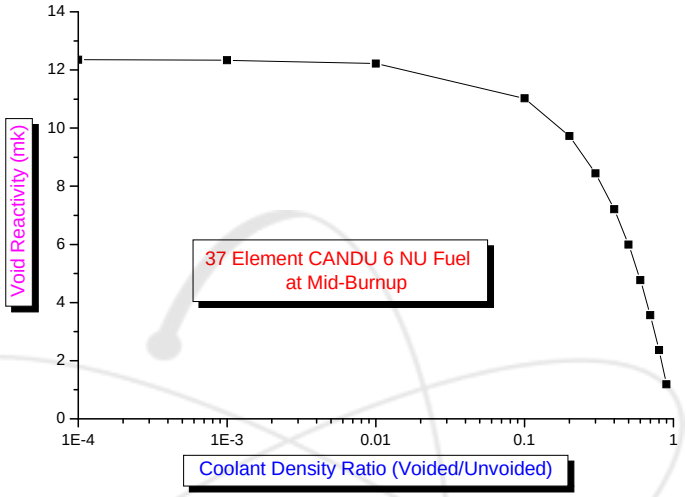

Figure 1 WIMS-ANL Lattice Coolant Void Reactivity Predictions using K-Effective

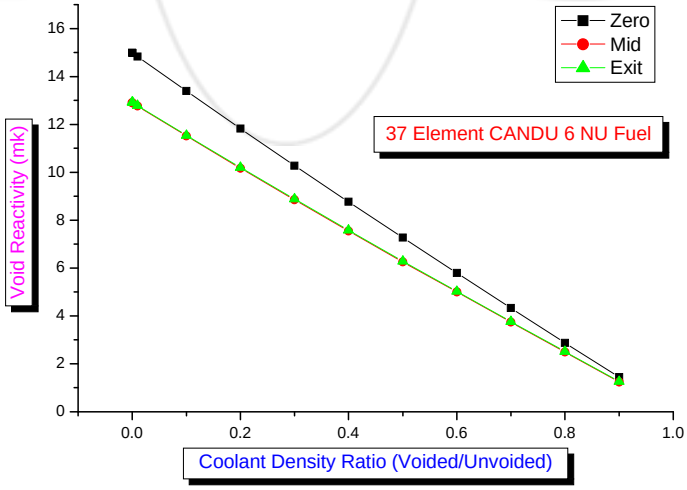

Figure 2 WIMS-ANL Lattice Coolant Void Reactivity Predictions at Zero/Mid/Exit Burnup using K-Infinity

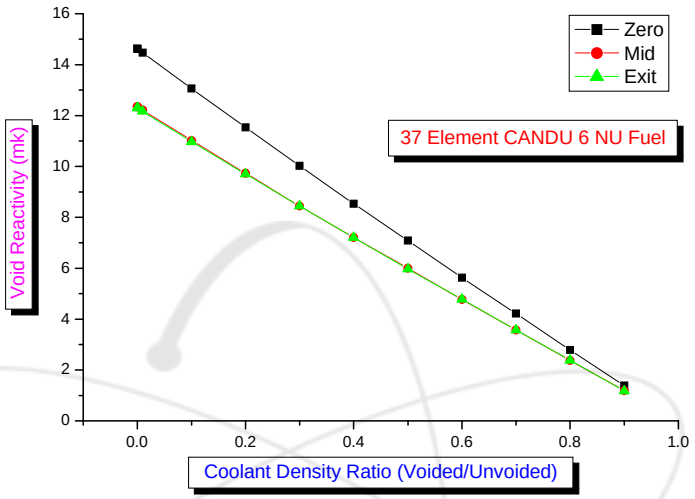

Figure 3 WIMS-ANL Lattice Coolant Void Reactivity Predictions at Zero/Mid/Exit Burnup using K-Effective

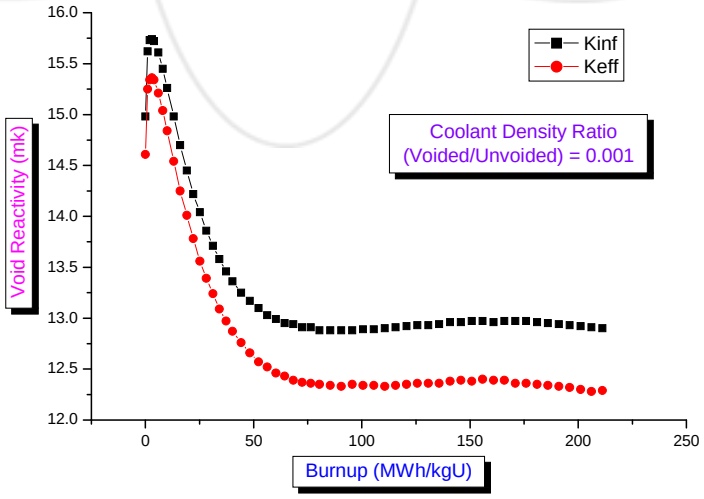

Figure 4 WIMS-ANL Lattice Coolant Void Reactivity Predictions for 37 Element CANDU 6 NU Fuel

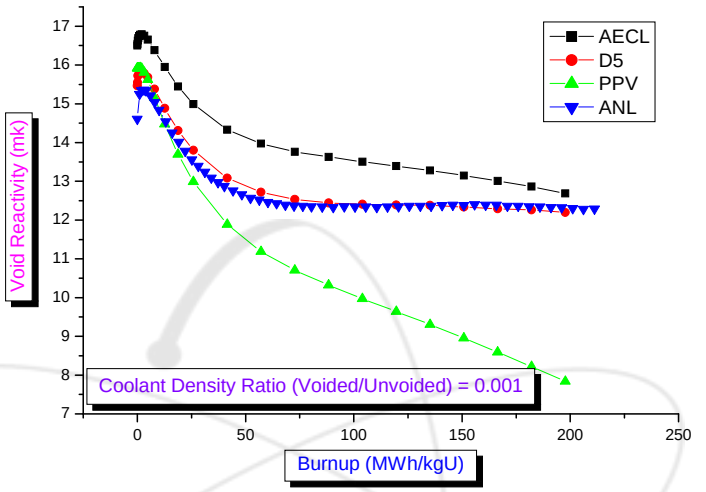

Figure 5 WIMS-ANL/AECL/D5 and PPV Lattice Coolant Void Reactivity Predictions for 37 Element CANDU 6 NU Fuel using K-Effective

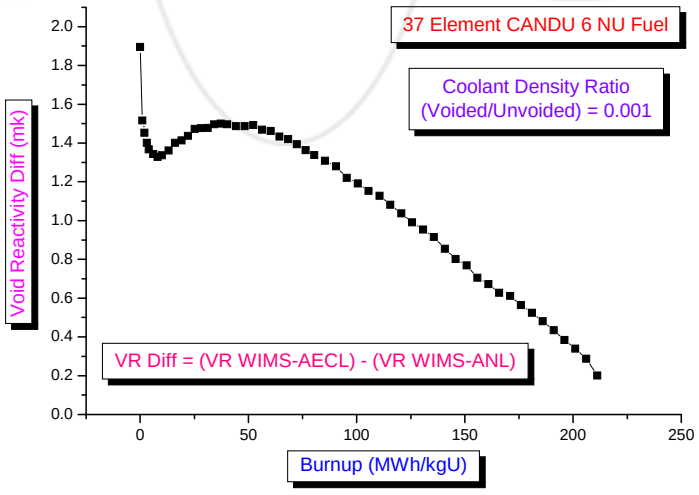

Figure 6 Lattice Coolant Void Reactivity Differences between WIMS-AECL and WIMS-ANL using K-Effective

Table 1
WIMS-ANL Lattice Coolant Void Reactivity Predictions using K-Effective
(37 Element CANDU 6 NU Fuel at Mid-Burnup ~100 MWh/kgU)

CDR	VR
1E-4	12.35
1E-3	12.34
0.01	12.22
0.10	11.02
0.20	9.73
0.30	8.44
0.40	7.21
0.50	6.00
0.60	4.77
0.70	3.57
0.80	2.37
0.90	1.19

CDR = Coolant Density Ratio (Voided/Unvoided)
VR = Void Reactivity (mk)

Table 2
WIMS-ANL Lattice Coolant Void Reactivity Predictions
at Zero/Mid/Exit Burnup using K-Infinity
(37 Element CANDU 6 NU Fuel)

CDR	VR-Zero	VR-Mid	VR-Exit
1E-4	14.99	12.90	12.93
1E-3	14.98	12.89	12.92
0.01	14.83	12.77	12.79
0.10	13.40	11.52	11.54
0.20	11.83	10.17	10.20
0.30	10.28	8.85	8.88
0.40	8.77	7.55	7.58
0.50	7.27	6.26	6.29
0.60	5.80	5.00	5.02
0.70	4.33	3.74	3.76
0.80	2.88	2.49	2.51
0.90	1.44	1.24	1.26

Zero = 0 MWh/kgU
Mid = ~100 MWh/kgU
Exit = ~200 MWh/kgU

Table 3
WIMS-ANL Lattice Coolant Void Reactivity Predictions
at Zero/Mid/Exit Burnup using K-Effective
(37 Element CANDU 6 NU Fuel)

CDR	VR-Zero	VR-Mid	VR-Exit
1E-4	14.63	12.35	12.31
1E-3	14.61	12.34	12.30
0.01	14.47	12.22	12.17
0.10	13.06	11.02	10.97
0.20	11.53	9.73	9.70
0.30	10.02	8.44	8.44
0.40	8.53	7.21	7.21
0.50	7.08	6.00	5.97
0.60	5.63	4.77	4.78
0.70	4.22	3.57	3.57
0.80	2.79	2.37	2.38
0.90	1.39	1.19	1.18

Table 4
WIMS-ANL Lattice Coolant Void Reactivity Predictions
for 37 Element CANDU 6 NU Fuel
(Coolant Density Ratio <Voided/Unvoided>=0.001)

MWh/kgU	VR (K-inf)	VR (K-eff)	MWh/kgU	VR (K-inf)	VR (K-eff)
0	14.98	14.61	80.43	12.88	12.35
1.01	15.62	15.25	85.46	12.88	12.34
2.01	15.73	15.34	90.49	12.88	12.33
3.02	15.74	15.36	95.52	12.88	12.35
4.02	15.72	15.34	100.54	12.89	12.34
6.03	15.61	15.21	105.57	12.89	12.34
8.04	15.45	15.04	110.60	12.90	12.33
10.06	15.26	14.84	115.62	12.91	12.34
13.07	14.98	14.54	120.65	12.92	12.35
16.09	14.70	14.25	125.68	12.93	12.36
19.10	14.45	14.01	130.70	12.93	12.36
22.12	14.22	13.78	135.73	12.94	12.36
25.14	14.04	13.56	140.76	12.96	12.38
28.15	13.86	13.39	145.79	12.96	12.39
31.17	13.71	13.24	150.81	12.97	12.38
34.19	13.58	13.09	155.84	12.97	12.40
37.20	13.46	12.97	160.87	12.96	12.39
40.22	13.36	12.87	165.89	12.97	12.39
44.24	13.25	12.76	170.92	12.97	12.36
48.26	13.17	12.66	175.95	12.97	12.36
52.28	13.10	12.57	180.97	12.96	12.35
56.30	13.03	12.52	186.00	12.95	12.34
60.33	12.99	12.46	191.03	12.94	12.33
64.35	12.95	12.43	196.06	12.93	12.32
68.37	12.94	12.39	201.08	12.92	12.30
72.39	12.91	12.37	206.11	12.91	12.28
76.41	12.91	12.36	211.14	12.90	12.29

Table 5
WIMS-ANL/AECL/D5 and PPV Lattice Coolant Void Reactivity Predictions for 37 Element CANDU 6 NU Fuel using K-Effective (Coolant Density Ratio <Voided/Unvoided>=0.001)

MWh/kgU	VR (ANL)	MWh/kgU	VR (ANL)	MWh/kgU	VR (AECL)	VR (D5)	VR (PPV)
0	14.61	80.43	12.35	0	16.51	15.46	15.92
1.01	15.25	85.46	12.34	0.08	16.54	15.55	15.92
2.01	15.34	90.49	12.33	0.23	16.63	15.72	15.92
3.02	15.36	95.52	12.35	0.43	16.70	15.74	15.92
4.02	15.34	100.54	12.34	0.74	16.75	15.76	15.93
6.03	15.21	105.57	12.34	1.21	16.78	15.78	15.93
8.04	15.04	110.60	12.33	2.03	16.79	15.81	15.92
10.06	14.84	115.62	12.34	3.20	16.75	15.78	15.81
13.07	14.54	120.65	12.35	4.77	16.66	15.68	15.62
16.09	14.25	125.68	12.36	7.89	16.38	15.38	15.16
19.10	14.01	130.70	12.36	12.58	15.95	14.88	14.48
22.12	13.78	135.73	12.36	18.83	15.44	14.31	13.70
25.14	13.56	140.76	12.38	25.86	14.99	13.80	12.99
28.15	13.39	145.79	12.39	41.48	14.33	13.08	11.89
31.17	13.24	150.81	12.38	57.11	13.98	12.72	11.19
34.19	13.09	155.84	12.40	72.73	13.76	12.54	10.70
37.20	12.97	160.87	12.39	88.35	13.63	12.44	10.32
40.22	12.87	165.89	12.39	103.98	13.51	12.41	9.98
44.24	12.76	170.92	12.36	119.60	13.39	12.39	9.64
48.26	12.66	175.95	12.36	135.23	13.28	12.39	9.30
52.28	12.57	180.97	12.35	150.85	13.15	12.34	8.96
56.30	12.52	186.00	12.34	166.47	13.01	12.29	8.59
60.33	12.46	191.03	12.33	182.10	12.86	12.26	8.22
64.35	12.43	196.06	12.32	197.72	12.68	12.20	7.84
68.37	12.39	201.08	12.30				
72.39	12.37	206.11	12.28				
76.41	12.36	211.14	12.29				

Table 6
Lattice Coolant Void Reactivity Differences between
WIMS-AECL and WIMS-ANL using K-Effective
(Coolant Density Ratio <Voided/Unvoided>=0.001)
(37 Element CANDU 6 NU Fuel)

MWh/kgU	VR Diff (AECL-ANL)	MWh/kgU	VR Diff (AECL-ANL)
0	1.89500	80.43	1.33824
1.01	1.51672	85.46	1.30952
2.01	1.45318	90.48	1.27975
3.02	1.40147	95.51	1.21975
4.02	1.36723	100.54	1.19090
6.03	1.34365	105.56	1.15339
8.04	1.32875	110.59	1.12741
10.05	1.33680	115.62	1.08212
13.07	1.36202	120.64	1.03648
16.09	1.40128	125.67	0.99054
19.10	1.41332	130.70	0.95382
22.12	1.43700	135.72	0.91504
25.13	1.47257	140.75	0.85427
28.15	1.47660	145.78	0.80182
31.17	1.47828	150.80	0.76842
34.18	1.49677	155.83	0.70535
37.20	1.49981	160.86	0.67188
40.21	1.49680	165.88	0.62737
44.24	1.48769	170.91	0.61137
48.26	1.48728	175.94	0.56362
52.28	1.49194	180.96	0.52369
56.30	1.46853	185.99	0.48084
60.32	1.46265	191.02	0.43454
64.34	1.43345	196.05	0.38412
68.36	1.41921	201.07	0.33896
72.39	1.39357	206.10	0.28800
76.41	1.36366	211.13	0.20049

Appendix

The input deck given here is the same as given in APPENDIX – A of the main body of this Technical Report.

<table>
<tr><td colspan="8">서 지 정 보 양 식</td></tr>
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<tr><td>페 이 지</td><td>48 p.</td><td>도 표</td><td colspan="2">있음(√), 없음( )</td><td>크 기</td><td colspan="2">27 Cm.</td></tr>
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-__ 급비밀</td><td colspan="2">보고서종류</td><td colspan="2">기술보고서</td></tr>
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<tr><td colspan="8">초록 (15-20 줄내외)</td></tr>
<tr><td colspan="8">격자 코드 WIMS-ANL 이 WIMS-CANDU 개발을 위하여 검증되었다. 비교된 노물리 파라미터들은 증배계수, 동위원소의 수 밀도, 냉각재 기포반응도 등이다. WIMS-ANL 에 의해 계산된 계수들은 WIMS-AECL, WIMS-D4, WIMS-D5 와 POWDERPUFS-V 등 다른 격자 코드들과 비교되었다. 중수형원자로의 안전해석을 위한 격자코드를 개발하기 위하여 검토된 WIMS-ANL 을 토대로하여 WIMS-CANDU 의 상세 모델 개발과 더불어 LOCA 시 사고해석을 위한 코드개발이 기대된다</td></tr>
<tr><td colspan="2">주제명키워드
(10 단어내외)</td><td colspan="6">CANDU-6 원자로, 노물리, 격자코드, 37 봉 천연우라늄핵연료, 연소도, 증배계수, 동위원소, 반응도, 반응도계수, 냉각재기포화, 냉각재기포반응도계수</td></tr>
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Project Manager and Department	Joo Hwan Park (PHWR Technology Lab.)
Researcher and Department	DaiHai Chung (PHWR Technology Lab.)

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Abstract (15-20 Lines)

The lattice code WIMS-ANL has been tested in order to assess it for the qualification to be used as a supporting code to aide the WIMS-CANDU development. A series of calculations have been performed to determine lattice physics parameters such as multiplication factors, isotopic number densities and coolant void reactivity. The WIMS-ANL results are compared with the predictions of WIMS-AECL/D4/D5 and PPV (POWDERPUFS-V), and the comparisons indicate that WIMS-ANL can be used not only as a supporting code to aide the WIMS-CANDU development, but also as a starting source for the study of developing detailed model that could delineate the realistic situations as it might occur during LOCA such as the asymmetric flux distribution across lattice cell.

Subject Keywords (About 10 words)	CANDU-6 Reactor, Reactor Physics, Lattice Physics, Lattice Code, 37-Element Natural Uranium Fuel, Multiplication Factors, Isotopic Compositions, Reactivity, Reactivity Coefficients, Coolant Voiding, Coolant Void Reactivity Coefficients