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Technical Services Division

Results of Benchmark Calculations

J L Hutton, A W Butement, C J Dean,
R J Perry and D J Powney

30 November 1994

Summary

This note presents results obtained with a new JEF library for the four benchmark experiments known as Dungeness, Kritz, Lemur and Esada. These results will be consolidated in a formal report at a later date.

Winfrith Technology Centre
Dorchester
Dorset DT2 8DH
United Kingdom
Telephone 01305 251888
Facsimile 01305 203030

	Name	Position	Signature	Date
Lead Author	J L Hutton	Project Manager	L. Hutton	6.12.94
Checked	C R Eaton	Validator	CR Eaton	6.12.94
Approved	C A Cooper	Department Manager	C A Cooper	6.12.94

RESULTS OF BENCHMARK CALCULATIONS

J L Hutton, A W Butement, C J Dean, R J Perry and D J Powney

1. INTRODUCTION

This paper presents the results of the benchmark calculations which were carried out during the HSE/IMC programme for 1994/95.The results are presented in this note for two reasons. First the calculations were scheduled for completion on November 1994 and this note is evidence that this milestone was achieved. Secondly the results presented in this note form useful evidence of the performance of the new 1994 WIMS library. These results will thus inform any discussion on the 1995/96 benchmarking programme. The calculations looked at the following experiments

(1) Dungeness B Commissioning Experiments
(2) Kritz -2 series of critical experiments
(3) Lemur exponential stack measurements
(4) ESADA series of lattice cell measurements

The calculations were carried out using the WIMS6 code package wherever possible. This meant using a pre-release version of the code. The calculations will therefore be repeated when the ANSWERS release of this code package is available to ensure repeatability. The Dungeness calculations used a stand alone version of the MONK5W code. This was done because the early version of WIMS6 would not work with such a large problem. This has now been corrected and it is anticipated that the WIMS6 code will be used for the final release of these results.

As noted above all the calculations used the new JEF based WIMS library referred to as the 1994 library. For back compatibility the calculations using the 1986 library are also presented or referred to in the text. The new library is used in two forms: these are the old 69 group format and the new 172 group format. For some calculations that used DSN, the code could not accommodate the extended library. In that case only the 69 group library was used. For the cases involved this was not a serious shortcoming and hence steps were not taken to correct this problem.

The results are presented in the sections following this introduction. They are in the same format as will be used for the final report on this work. The final report will be in the form of entries in the WIMS/MONK Validation Manual. Hence this note will show how the final report will look. Comments on the format are welcome.

Reactor Physics Shielding & Criticality Department
Reactor Physics Group
Technical Services Division
Winfrith

30 November 1994

SECTION :
SHEET : 1 (1 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TITLE : Dungeness 'B' Commissioning Experiments

DESCRIPTION

As part of the commissioning experiments carried out on the Dungeness 'B' AGR, the reactivity of various core loadings was measured. Two of these core configurations were modelled, using MONK5W, in a study carried out in 1983. These calculations have been repeated using the latest methods and a range of nuclear data libraries. The two core configurations modelled are summarised below.

a) A partially loaded small core with only 86 channels loaded and hence high radial leakage. All control rods were withdrawn. This was a cold, sub-critical core with an air pressure of 1 atmosphere.

b) A fully loaded core with 368 channels loaded with low leakage and partial control rod insertion. This was a cold core with the reactor being balanced to critical by an air pressure of 4 atmospheres.

CODE VERSION USED

These calculations were performed using a development version of MONK5W version 9A. The executable file was

/lynx/adrian/MONK/MIC_BURN/MONK5Wv8BDV1/LIBRARIES/monk5wv9adv3.out

compiled at 16.20 on 7/11/94.

RESULTS

For each of the two core configurations calculations were performed using the 1981 (1), 1986 (2) and 1994 (3) WIMS nuclear data libraries. The calculations conducted using the 1981 and 1986 libraries were carried out in 69 energy groups while those performed using the 1994 library were in both 69 and 172 groups. Each combination of core and library was calculated three times using different random number seeds. The three results for each case were then averaged to give a more reliable answer than a single run of the same accuracy. Tables 1 and 2 give the results obtained for the small and large core respectively.

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THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
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DATE : **November 1994**

Table 1: Results for the Small Core

RN seed	k-effective (k-coll)	k-score	mean (k-coll)
1981 WIMS Library (69 groups)			
832537877	1.0075 ±0.0010	1.0064 ±0.0011	1.0071 ±0.0006
98765	1.0069 ±0.0009	1.0079 ±0.0011	
54321	1.0070 ±0.0010	1.0066 ±0.0011	
1986 WIMS Library (69 groups)			
832537877	0.9990 ±0.0009	1.0001 ±0.0011	1.0018 ±0.0005
98765	1.0015 ±0.0010	1.0016 ±0.0011	
54321	1.0048 ±0.0009	1.0048 ±0.0011	
1994 WIMS Library (69 groups)			
832537877	1.0032 ±0.0010	1.0032 ±0.0011	1.0022 ±0.0006
98765	1.0018 ±0.0010	1.0020 ±0.0011	
54321	1.0015 ±0.0010	1.0020 ±0.0011	
1994 WIMS Library (172 groups)			
832537877	1.0001 ±0.0010	0.9999 ±0.0011	1.0014 ±0.0005
98765	1.0018 ±0.0009	1.0023 ±0.0011	
54321	1.0024 ±0.0009	1.0020 ±0.0011	
Experimental Result			
			0.99788 ±0.00024

Currently Used

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SECTION :
SHEET : 1 (3 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
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Table 2: Results for the Full Core

RN seed	k-effective (k-coll)	k-score	mean (k-coll)
1981 WIMS Library (69 groups)			
832537877	1.0157 ±0.0010	1.0161 ±0.0011	1.0157 ±0.0006
98765	1.0157 ±0.0010	1.0169 ±0.0012	
54321	1.0157 ±0.0010	1.0158 ±0.0011	
1986 WIMS Library (69 groups)			
832537877	1.0081 ±0.0010	1.0079 ±0.0012	1.0090 ±0.0006
98765	1.0085 ±0.0010	1.0080 ±0.0011	
54321	1.0104 ±0.0010	1.0117 ±0.0011	
1994 WIMS Library (69 groups)			
832537877	1.0095 ±0.0010	1.0099 ±0.0011	1.0092 ±0.0005
98765	1.0098 ±0.0009	1.0101 ±0.0012	
54321	1.0084 ±0.0009	1.0086 ±0.0011	
1994 WIMS Library (172 groups)			
832537877	1.0124 ±0.0010	1.0128 ±0.0012	1.0095 ±0.0005
98765	1.0090 ±0.0009	1.0101 ±0.0011	
54321	1.0072 ±0.0009	1.0077 ±0.0011	
Experimental Result			
			critical

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SHEET : 1 (4 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

ANALYSIS

Some of the cases produce a significant spread of results from the three random number seeds. Without a more detailed statistical analysis it is difficult to attribute this spread to any mechanism. It could be that these cases have not fully converged. Taking the mean of the three k values gives a result which can be quoted with reasonable confidence.

The averaged results from the 1986 and 1994 libraries are fairly consistent. For these libraries reactivity was over-predicted by 0.35 - 0.43% in the small core and by 0.9 - 0.95% in the large core.

The results from the 1981 library are somewhat higher, over-predicting reactivity in the small and full cores by 0.92% and 1.57% respectively.

QUALIFICATIONS

The over-prediction in the full core cases is greater than that for the small core. The reasons for this are unclear at present. The significant changes which occur when moving from the small to full core are:

a) air pressure is increased from 1 to 4 atmospheres,
b) control rods are inserted,
c) higher enrichment fuel is loaded into the outer channels.

Incorrect calculation of the effects of any of the above changes could give rise to the observed discrepancy.

The results for the 1981 WIMS library are significantly higher than those obtained in the 1983 study. It should be noted, however, that the 1983 results were based on calculations which tracked only 20000 neutrons and were thus far short of the convergence reported for the new calculations. These results must therefore be treated with caution.

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SECTION :
SHEET : 1 (5 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TEST CASE DETAILS:

DESCRIPTION

As far as was practicable the geometries in the two cores were modelled explicitly using the MONK geometry package. Some approximations were made to simplify the modelling of minor details which have a negligible effect on reactivity. Cross-sections for each material were generated using the NOVICE sub-group option. For each combination of core configuration and library, three calculations were performed using different random number seeds. In each case the calculation was run over 1000 stages with 250 neutrons per stage, giving a total of 250000 neutrons tracked.

QUALIFICATIONS

Most of the steel in these cases was represented by a combination of iron and a 1/V absorber, according to the ARGOSY prescription for steel. As steel accounts for ~10% of absorptions in these cores this approximation could have had a significant effect on reactivity. This representation was based on measurements in GLEEP. Scoping calculations using true steel compositions indicate the ARGOSY/GLEEP representation to be reasonable. This is not thought to be the cause of the high reactivity calculated. Further test cases should consider the modelling of rod insertion which was over-predicted by WIMS/SNAP in 1983, although not as much as indicated by the current k values.

REFERENCES

There are eight test cases, one for each combination of core configuration and library.

The small core cases are held in the directory

/roo1/erafcd/QA/1994/benchmarks.IMC/dungeness/smallcore/monk5w.standalone

and the full core cases in the directory

/roo1/erafcd/QA/1994/benchmarks.IMC/dungeness/fullcore/monk5w.standalone.

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SECTION :
SHEET : 1 (6 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

In both cases the names of the files containing the test cases are as follows.

Library	Energy Groups	Filename
1981	69	input.1981.rn1
1986	69	input.1986.rn1
1994	69	input.1994.rn1
1994	172	input.1994.172.rn1

These test cases will be included in the validation database in due course.

SECTION :
SHEET : 1 (7 of 7)

THEME : **MONK5W EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **GRAPHITE MODERATED**

AUTHOR : **R J Perry**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

REFERENCES

1 M J Halsall, C J Taubman
The 1981 WIMS Nuclear Data Library
AEEW-R 1442
September 1983

2 M J Halsall, C J Taubman
The 1986 WIMS Nuclear Data Library
AEEW-R 2133
September 1986

3 C J Dean, R J Perry
The 1994 WIMS Nuclear Data Library
ANSWERS/WIMS6/1994LIBRARY1
October 1994

SECTION :
SHEET : 1 (1 of 5)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **D J Powney**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TITLE : KRITZ-2

DESCRIPTION

The KRITZ-2 series of critical experiments are arrays of fuel pins in a light water moderator. Each configuration was examined at ambient and at an elevated temperature. Criticality control was achieved using boron dissolved in the moderator, and the water height. Three configurations were modelled:

(a) KRITZ 2:1 44x44 1.86% enriched UO_2 pins on a pitch of 1.485 cm
(b) KRITZ 2:13 40x40 1.86% enriched UO_2 pins on a pitch of 1.635cm
(c) KRITZ 2:19 25x24 0.16% enriched $U0_2$/1.5% PuO_2 pins on a pitch of 1.8 cm

The fuel pin data is taken from reference (1) and the reactor dimensions are taken from reference (2). Three libraries were used: the 1986 WIMS library in datagram format and the WIMS 94 libraries, based on the JEF evaluation in 69 and 172 groups

CODE VERSION USED

WIMS6 (BETA1)

RESULTS

EXPERIMENT	TEMPERATURE	k-effective		
		WIMS 86 (69 groups)	WIMS 94 JEF (69 groups)	WIMS 94 JEF (172 groups)
2:1	COLD	0.9970 ±0.0006	1.0003 ±0.0006	0.9997 ±0.0006
	HOT	0.9946* ±0.0007	0.9995 ±0.0008	0.9986 ±0.0006

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SECTION :
SHEET : 1 (2 of 5)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **D J Powney**
UPDATED :
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DATE : **November 1994**

EXPERIMENT	TEMPERATURE	k-effective		
		WIMS 86 (69 groups)	WIMS 94 JEF (69 groups)	WIMS 94 JEF (172 groups)
2:13	COLD	0.9982 ±0.0006	0.9995 ±0.0006	1.0002 ±0.0006
	HOT	0.9988* ±0.0006	0.9996 ±0.0006	0.9988 ±0.0006
2:19	COLD	0.9924 ±0.0006	1.0014 ±0.0006	1.0005 ±0.0006
	HOT	0.9908* ±0.0006	0.9981 ±0.0007	0.9979 ±0.0007

* P_1 data restricted to fast and resonance groups

EXPERIMENT	ΔT (°C)	Δk/ΔT (mN/°C)		
		WIMS 86 (69 groups)	WIMS 94 JEF (69 groups)	WIMS 94 JEF (172 groups)
2:1	228.8	-1.0±0.4	-0.3±0.4	-0.5±0.4
2:13	220.9	+0.3±0.4	0.0±0.4	-0.6±0.4
2:19	214.8	-0.7±0.4	-1.5±0.4	-1.2±0.4

ANALYSIS

The cold eigenvalues are predicted to within the statistical uncertainties using the JEF data. For the Pu core (2:19) in particular, this is a great improvement over the WIMS 86 library which is >700mN low. All of the calculations show much smaller errors in isothermal temperature coefficients than have been seen in previous analysis of these cores using deterministic codes (4). The chief differences between the analyses are that this analysis used the latest

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THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **D J Powney**
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internationally available data including lattice expansion coefficients, and that the previous analysis used LWRWIMS, with an equivalence resonance model. LWRWIMS calculations should be run using the experimental specification given in reference 2 in order to investigate this effect. An accurate determination of the isothermal temperature coefficients using the W-MONK module will require that a much larger sample of neutrons are taken so that the uncertainties can be reduced.

QUALIFICATIONS

No Qualifications

SECTION :
SHEET : 1 (4 of 5)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **D J Powney**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TEST CASE DETAILS:

DESCRIPTION

The W-MONK module of WIMS6 was used for all of the calculations. In each case, subgroup and P_1 data in the library group structure was used. The 1986 WIMS library has no P_1 data for the elevated temperature. Since use of P_0 data in the resonance region for this type of lattice is known to lead to an underestimate of leakage (see reference 3), and the P_1 data for the fast and resonance groups is almost independent of temperature, the runs using the 1986 library at elevated temperature used P_1 data at room temperature for the fast and resonance groups only. In all of the calculations a 2-D model with imposed axial buckling was used.

QUALIFICATIONS

REFERENCES

SECTION :
SHEET : 1 (5 of 5)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **D J Powney**
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DATE : **November 1994**

REFERENCES

1 JOHANSSON E

Data and Results for the KRITZ Experiments on Regular H_2O/Fuel Pin Lattices at Temperatures up to 245 ^{O}C.

STUDSVIK/NS-90/133

26/11/1990

2 ROWLANDS J

JEF/DOC-457

Revised June 1994

3 HUTTON J L

An Investigation of Leakage Effects at Resonance Energies

NS/AEA/N107

4 POWNEY D J

Analysis of the KRITZ-2 Series of Experiments using LWRWIMS

AEA-RS-1105

7/2/92

SECTION :
SHEET : 1 (1 of 10)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **UNMODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TITLE: Lemur Criticality Safety Experiments with Low Enriched Low Moderated Uranium Oxide Fuel

DESCRIPTION

The four Lemur experiments examined here were conventional exponential experiments using an unreflected assembly.Each experiment had a different fuel material and experimental arrangement; they all involved a subcritical mass of fuel material which was irradiated by an external source of neutrons and the neutron flux distribution measurements made within the mass enabled the critical size of the fuel and the material bucklings to be determined. The experiments were set up as a source of accurate experimental information on the reactivity of 2% enriched UO_2 granules with three different (H/U) ratios in the range 0.1 to 0.4% by weight, and on the reactivity of 3% enriched UO_2 granules at an (H/U) ratio of about 2% by weight. The LEMUR exponential facility was designed to enable horizontal and vertical neutron flux distribution measurements to be carried out. It consisted of an aluminium tank with a number of horizontal and vertical tubes through which the distribution measurements were made using BF_3 counters. There were two types of detector used to measure the reaction rates, which are all quoted as the ratio of the reaction rate of the detector to that of the U235 fission rate. All measurements for reaction rates were taken at approximately mid-stack. The detectors used were;

1. Resonance detectors which were foils of manganese,copper,gold,tantalum and indium. These foils are chosen so that the main part of the activation for each foil comes from a different part of the neutron spectrum, so the foils when taken together give a check on the adequacy of the spectrum calculation by the theoretical method.

2. The use of U235,U238 and Pu239 fission chambers to measure the absolute fission rate within the system.These measurements not only check the spectrum calculation but also the fission cross section data for the fuel nuclides. Cadmium encased measurements were taken for U235 and Pu239 as a check on the calculation of the ratio above ~0.5eV to that over the whole system.To interpret the fission chamber measurements it is necessary to assess the perturbing effects of the steel chamber and also the effects of the cadmium cover.

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THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
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AUTHOR : **A W Butement**
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CODE AND LIBRARY VERSIONS USED

Development version of WIMS6 in /eagle/work/jan/WIMS6_v3.out (datcd 7/11/94).
1994 69 and 172 group libraries in /eagle2/jeflib/libraries/jef2/wims/w94dg69v1.dat, w94dg172v1.dat (both dated13/10/94).

RESULTS

Table 1.1
k-infinity and k-effective for the Lemur experiments 69 group library

Experiment	k-inf	k-eff
1	0.9018	0.9855
2	0.9511	0.9716
3	0.7443	0.9677
4	0.8988	0.9767
MEAN	0.8740	0.9753

Table 1.2
k-infinity and k-effective for the Lemur experiments 172 group library

Experiment	k-inf	k-eff
1	0.8996	0.9827
2	0.9494	0.9697
3	0.7396	0.9603
4	0.8967	0.9741
MEAN	0.8713	0.9717

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Table 2.1
Comparison of fission rates of U238 and Pu239 relative to U235 - 69 group library

Fission Ratio	Type	LEMUR1	LEMUR2	LEMUR3	LEMUR4
U238f / U235f	Calculated	5.33×10^{-3}	4.30×10^{-3}	6.97×10^{-3}	8.14×10^{-3}
	Experimental	$4.82 \times 10^{-3}\pm$	$4.10 \times 10^{-3}\pm$	$6.35 \times 10^{-3}\pm$	$7.12 \times 10^{-3}\pm$
		2.4%R;2.2%S	2.8%R;2.3%S	2.5%R;2.3%S	1.5%R;2.0%S
	(C/E) value	1.11	1.05	1.10	1.14
Pu239f / U235f	Calculated	2.42	2.44	2.02	2.14
	Experimental	2.47±	2.60±	2.19±	2.27±
		2.4%R;1.6%S	0.8%R;1.6%S	1.1%R;1.6%S	1.5%R;1.6%S
	(C/E) value	0.98	0.94	0.92	0.94

Table 2.2
Comparison of fission rates of U238 and Pu239 relative to U235 - 172 group library

Fission Ratio	Type	LEMUR1	LEMUR2	LEMUR3	LEMUR4
U238f / U235f	Calculated	5.17×10^{-3}	4.19×10^{-3}	6.73×10^{-3}	7.88×10^{-3}
	Experimental	$4.82 \times 10^{-3}\pm$	$4.10 \times 10^{-3}\pm$	$6.35 \times 10^{-3}\pm$	$7.12 \times 10^{-3}\pm$
		2.4%R;2.2%S	2.8%R;2.3%S	2.5%R;2.3%S	1.5%R;2.0%S
	(C/E) value	1.07	1.02	1.06	1.11

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THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
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Fission Ratio	Type	LEMUR1	LEMUR2	LEMUR3	LEMUR4
Pu23f / U235f	Calculated	2.43	2.45	2.02	2.14
	Experimental	2.47±	2.60±	2.19±	2.27±
		2.4%R;1.6%S	0.8%R;1.6%S	1.1%R;1.6%S	1.5%R;1.6%S
	(C/E) value	0.98	0.94	0.92	0.94

Table 3
Comparison of U238,Pu239 and BF_3 Cadmium ratios

Nuclide	Type	LEMUR 1	LEMUR 2	LEMUR 3	LEMUR 4
U235 Fission Chamber	Calculated	1.88	2.40	1.29	1.34
	Experimental	1.91 ± 2.8%R	2.39 ± 1.2%R	1.24 ± 2.1%R	1.45 ± 1.8%R
	(C/E) value	0.98	1.00	1.04	0.93
Pu239 Fission Chamber	Calculated	3.53	4.50	2.28	2.46
	Experimental	3.36 ± 2.5%R	4.17 ± 1.2%R	2.15 ± 2.1%R	2.49 ± 1.8%R
	(C/E) value	1.05	1.08	1.06	0.99
BF_3 Counter	Calculated	2.36	3.09	1.64	1.73
	Experimental	2.42 ± 0.5%R	3.08 ± 0.5%R	1.61 ± 0.5%R	1.71 ± 0.5%R
	(C/E) value	0.98	1.00	1.02	1.01

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THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **UNMODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

Table 4.1
Comparison of reaction rate ratios for the Lemur experiments - 69 group library

Detector Foil	Type	1	2	3	4	Mean (C/E)
Manganese	Calculated	0.0382	0.0341	0.0488	0.0466	
	Experimental	0.0408 ±3.0%R; 4.0%S	0.0386 ±3.1%R; 3.2%S	0.0571 ±2.3%R; 3.2%S	0.0512 ±2.0%R; 3.2%S	
	(C/E) value	0.94	0.88	0.85	0.91	0.90
Copper	Calculated	0.0136	0.0134	0.0206	0.0188	
	Experimental	0.0188 ±8.0%R; 5.0%S	0.0147 ±4.1%R; 3.2%S	0.0251 ±1.4%R; 3.2%S	0.0163 ±3.8%R; 3.2%S	
	(C/E) value	0.73	0.78	0.82	1.15	0.87
Tantalum	Calculated	0.527	0.417	0.748	0.716	
	Experimental	0.585 ±2.8%R; 2.3%S	0.478 ±1.1%R; 3.2%S	0.778 ±1.5%R; 3.2%S	0.766 ±1.4%R; 3.2%S	
	(C/E) value	0.90	0.87	0.96	0.93	0.92
Indium	Calculated	1.138	0.955	1.309	1.321	
	Experimental	1.075 ±3.0%R; 10%S	1.043 ±2.1%R; 10%S	1.179 ±1.8%R; 10%S	1.174 ±1.7%R; 10%S	
	(C/E) value	1.06	0.92	1.11	1.13	1.05
Gold	Calculated	0.595	0.501	0.734	0.718	
	Experimental	0.631 ±2.0%R; 1.8%S	0.546 ±1.3%R; 3.2%S	0.652 ±2.3%R; 3.2%S	0.674 ±1.2%R; 3.2%S	
	(C/E) value	0.94	0.92	1.13	1.07	1.01

SECTION :
SHEET : 1 (6 of 10)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **UNMODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

Table 4.2
Comparison of reaction rate ratios for the Lemur experiments - 172 group library

Detector Foil	Type	1	2	3	4	Mean (C/E)
Manganese	Calculated	0.0394	0.0347	0.0519	0.0489	
	Experimental	0.0408 ±3.0%R; 4.0%S	0.0386 ±3.1%R; 3.2%S	0.0571 ±2.3%R; 3.2%S	0.0512 ±2.0%R; 3.2%S	
	(C/E) value	0.96	0.90	0.91	0.96	0.93
Copper	Calculated	0.0134	0.0113	0.0199	0.0184	
	Experimental	0.0188 ±8.0%R; 5.0%S	0.0147 ±4.1%R; 3.2%S	0.0251 ±1.4%R; 3.2%S	0.0163 ±3.8%R; 3.2%S	
	(C/E) value	0.71	0.77	0.79	1.13	0.85
Tantalum	Calculated	0.527	0.420	0.725	0.709	
	Experimental	0.585 ±2.8%R; 2.3%S	0.478 ±1.1%R; 3.2%S	0.778 ±1.5%R; 3.2%S	0.766 ±1.4%R; 3.2%S	
	(C/E) value	0.90	0.88	0.93	0.93	0.91
Indium	Calculated	1.133	0.953	1.299	1.315	
	Experimental	1.075 ±3.0%R; 10%S	1.043 ±2.1%R; 10%S	1.179 ±1.8%R; 10%S	1.174 ±1.7%R; 10%S	
	(C/E) value	1.05	0.91	1.10	1.12	1.05
Gold	Calculated	0.607	0.516	0.710	0.725	
	Experimental	0.631 ±2.0%R; 1.8%S	0.546 ±1.3%R; 3.2%S	0.652 ±2.3%R; 3.2%S	0.674 ±1.2%R; 3.2%S	
	(C/E) value	0.96	0.95	1.09	1.08	1.02

SECTION :
SHEET : 1 (7 of 10)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
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AUTHOR : **A W Butement**
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DATE : **November 1994**

Key to Tables

R = random error
S = systematic error

Note

To compare the values the random and systematic errors should be compounded in quadrature.

ANALYSIS

From tables 1.1 and 1.2 the mean values for k-eff are 0.9753 for the 1994 69 group library and 0.9717 for the 1994 172 group library. This should be compared with 0.9724 for the 1986 69 group library (Ref [1]). Initial values vary in the range -0.013 to 0.007 from those using the 1986 library. Hence the 1994 library predictions are close to those using the 1986 library. Both libraries appear to underpredict reactivity. Because of the low moderator content of these experiments this is probably due to overestimate of resonance events.

Using the experimental errors quoted in AEEW-R1450 a partial reanalysis indicated a range of standard deviations for the predicted k-eff to be from 0.006 to 0.008, which is broadly in agreement with the range 0.007 to 0.011 quoted in AEEW-R1450.

There is good agreement in all cases of the fission chamber and cadmium ratio comparisons in tables 2 and 3, considering the errors associated with the measurements. From tables 2.1 and 2.2

Mean U238/U235 fission rate = 1.10 (69 group), 1.07 (172 group)

Mean Pu239/U235 fission rate = 0.95 (69 group), 0.95 (172 group)

These should be compared with 1986 library results of 1.06 for U238 and 0.97 for Pu239.

The results suggest that the 1994 library is overestimating for U238 fissions but underestimating the Pu239 fission reaction rate for this type of system.

The mean C/E values in table 3 are 0.99 (U235), 1.04 (Pu239), 1.00 (BF3), using the 1994 69

group library, which suggests that the ratio of the reaction rate below 0.5 eV to that above 0.5 eV is well predicted by WIMS for this fuel. For U235 this is an improvement on the value of 1.02 using the 1986 library, but for Pu239 the value is worse than the value of 0.98 using the 1986 library.

The detector reaction rate ratios in tables 4.1 and 4.2 are reasonably satisfactory, when the problems of counting and interpreting the count rates are taken into consideration, leading to large errors in the results. For copper, manganese and gold mean values of calculated reaction rate/experimental reaction rate are closer to unity using the 1994 library with 69 or 172 groups than they were using the 1986 library with 69 groups. For tantalum and indium, however, values are further from unity with the 1994 library.

A detailed analysis of the experimental results can be found in report AEEW-R 1450.

QUALIFICATIONS

All calculated values use self shielding factors as listed in table 5, since the WIMS code does not actually calculate the shielding effects of the detector foils. Also in the report, AEEW-R 1450, from which the experimental details were taken, there is mention of up to a 2% correction for the position of the foil holder and for the effect of the fission chamber walls on the U235 fission chamber, in the calculated values, but there was insufficient information about these corrections to know how to apply them to our results.No allowances for errors were made in the calculation of the self shielding factors, taken from report AEEW-R 1450.

Table 5
Self shielding factors for the Lemur experiments

Experiment	Gold	Tantalum	Manganese	Indium	Copper
LEMUR1	3.22	2.07	1.26	3.8	1.16
LEMUR2	3.26	2.12	1.22	3.9	1.16
LEMUR3	2.92	1.89	1.36	3.5	1.16
LEMUR4	3.17	1.98	1.33	3.7	1.16

SECTION :
SHEET : 1 (9 of 10)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **UNMODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TEST CASE DETAILS:

DESCRIPTION

The calculations were done in 69 groups (and 172 groups except for cadmium rates) using CRITIC and WIRE for k-eff and detector rates and DSN and CRITIC for cadmium ratios. Three testcases were set up [2], each covering aspects of the four experiments. One used a homogeneous mixture with input bucklings, another was used to determine the effects of the walls of the fission chamber and the third was used to calculate the cadmium ratios.

QUALIFICATIONS

No qualifications.

REFERENCES

The WIMS6 (1994 library) testcases are currently in the directory

/everest/adrian/JEF_BENCHMARK

LEMUR/KEFF

run6_v3 intface datsets_94_69 datsets_94_172 lemur_ip_94_69

lemur_ip_94_172 lemur_op_m1_94_69 lemur_op_m1_94_172

LEMUR/CADMIUM/ABSENT

run6_v3 intface datsets_lem_wall_94_69 lem_wall_w6_ip_94_69

lem_wall_w6_op_94_69

LEMUR/CADMIUM/PRESENT

run6_v3 intface datsets_lem_cad_94_69 lem_cad_w6_ip_94_69

lem_cad_w6_op_94_69

SECTION :
SHEET : 1 (10 of 10)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **UNMODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

REFERENCES

1 Section 3.1.4, Sheet 4, "Lemur experiments [- WIMSD 2A and 1986 Library]", in "WIMS/MONK Validation Manual", AEEW-R 2447, 1992.

2 The WIMSD (1986 library) testcases are in the directory
/usr2/QAdb/VAL/EXPERIMENT/H20-MOD
in the WIMS database and are called
lemur1_buckling, lemur2_buckling, lemur3_buckling, lemur4_buckling, lemur1_cadmiumfilter, lemur2_cadmiumfilter, lemur3_cadmiumfilter, lemur4_cadmiumfilter, lemur1_chamberwalls, lemur2_chamberwalls, lemur3_chamberwalls and lemur4_chamberwalls.

SECTION :
SHEET : 5 (1 of 4)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TITLE: Esada Lattices with Plutonium Dioxide Fuel

DESCRIPTION

This section documents a series of Westinghouse critical PuO_2/UO_2 pin-cell light water lattice experiments. The fuels used were mixed PuO_2 and UO_2, with an enrichment of 2.0 w/o PuO_2. The lattice pitch was varied over a wide range, with the fuel pin radii remaining constant at 0.6414cm, and in some experiments the moderator was poisoned with boron. The supplied radial and axial measured bucklings have been used in the WIMS calculations

Experiment Number	Fuel Type	Lattice Pitch (cm)	Water/Fuel Vol. Ratio	Boron ppm	B_r^2	B_z^2
1	8%Pu240	1.7526	1.125	0	61.00	8.56
3	8%Pu240	1.9050	1.557	0	81.00	8.97
4	8%Pu240	2.4785	3.500	0	95.25	9.47
6	8%Pu240	2.6942	4.366	0	88.90	9.47
7	8%Pu240	3.5052	8.257	0	40.75	9.52
8	8%Pu240	1.7526	1.125	261	53.82	8.73
9	8%Pu240	2.4785	3.500	261	74.19	9.53
10	8%Pu240	1.7526	1.125	526	49.39	8.95
11	8%Pu240	2.4785	3.500	526	53.46	9.64
12	20%Pu240	2.4785	3.500	0	70.00	9.44
13	20%Pu240	2.6942	4.366	0	63.70	9.64

CODE AND LIBRARY VERSIONS USED

Development version of WIMS6 in /eagle/work/jan/WIMS6_v4.out (dated 11/11/94).
1994 69 group library in /eagle2/jeflib/libraries/jef2/wims/w94dg69v1.dat (dated13/10/94).

SECTION :
SHEET : 5 (2 of 4)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

RESULTS

Experiment Number	k-inf	k-eff corrected* B1/Benoist D
1	1.302339	0.993333
3	1.358492	0.990230
4	1.378958	1.00300
6	1.346617	1.00216
7	1.156255	0.987930
8	1.277729	0.999400
9	1.288147	0.993435
10	1.253968	0.999600
11	1.208982	0.989315
12	1.285411	1.001360
13	1.254904	0.999030
MEAN		0.995927

* Note the "corrected" K-eff have been adjusted by a lattice (assumed) independent bias of -0.0058 to allow for plutonium grain shield effects

ANALYSIS

The 'best' calculated values of k-eff are taken to be the corrected B1 Benoist values. The mean value of this best estimate is 0.996 ±0.005, which is an improvement on the value of 0.989 obtained using the 1986 library [1].There seems to be a systematic variation in the B1 Benoist values with lattice pitch in the borated experiments, but in the unborated experiments the B1 Benoist values gets closer to 1.0 as k-inf increases. The results obtained with 20% Pu240 do not seem significantly different from those calculated with 8% Pu240.

SECTION :
SHEET : 5 (3 of 4)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

QUALIFICATIONS

The bias of -0.0058 applied to the B1 Benoist k-eff values as an approximation to take account of the grain shielding effects in plutonium should probably be lattice dependent, but no information is readily available on the magnitude of this variation so we assumed the effect to be lattice independent.The experiments have high leakage conditions and so there will be quite a high uncertainty in the prediction of k-eff.

SECTION :
SHEET : 5 (4 of 4)

THEME : **WIMS6 EXPERIMENTAL COMPARISONS**
TOPIC : **REACTOR TYPE**
SUB-TOPIC : **LIGHT WATER MODERATED**

AUTHOR : **A W Butement**
UPDATED :
CHECKED : **J L Hutton**
DATE : **November 1994**

TEST CASE DETAILS:

DESCRIPTION

Pincell WIMS6 calculations were done using DSN, SMEAR and CRITIC. The calculations were done in 69 groups.

QUALIFICATIONS

No qualifications.

REFERENCES

1 Section 3.1.2, Sheet 5, "Esada Lattices [- WIMSD 2A and 1986 Library]", in "WIMS/ MONK Validation Manual", AEEW-R2447, 1992.

2 The WIMSD (1986 library) testcase is in the directory
/usr2/QAdb/VAL/EXPERIMENT/H20-MOD
in the WIMS database and is called
wd4esada69

The WIMS6 (1994 library) testcase is in
/everest/les/VALIDATION_MANUAL
run6 datsets.esada.1994 intface input.esada.1994 output.esada.1994

3 The experimental details were taken from the Westinghouse report WCAP-3726-1