

JAERI -Research
2003-007



JP0350067



ANALYTICAL STUDY OF TWO-REGION TCA CRITICAL
EXPERIMENTS WITH PWR-TYPE MOX FUEL BY USING
MONTE CARLO CODE MVP

March 2003

Mafizur RAHMAN*, Takenori SUZAKI and Takamasa MORI

日本原子力研究所
Japan Atomic Energy Research Institute

本レポートは、日本原子力研究所が不定期に公刊している研究報告書です。
入手の問合せは、日本原子力研究所研究情報部研究情報課（〒319-1195 茨城県那珂郡東海村）あて、お申し越しください。なお、このほかに財団法人原子力弘済会資料センター（〒319-1195 茨城県那珂郡東海村日本原子力研究所内）で複写による実費領布をおこなっております。

This report is issued irregularly.

Inquiries about availability of the reports should be addressed to Research Information Division, Department of Intellectual Resources, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 〒319-1195, Japan.

©Japan Atomic Energy Research Institute, 2003

編集兼発行 日本原子力研究所

Analytical Study of Two-Region TCA Critical Experiments with PWR-Type MOX Fuel by Using Monte Carlo Code MVP

Mafizur RAHMAN*, Takenori SUZAKI and Takamasa MORI

Department of Nuclear Energy System
Tokai Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken

(Received January 30, 2003)

A series of critical experiments with PWR-type MOX fuel conducted at the TCA facility of Japan Atomic Energy Research Institute have been analyzed. The cores were composed of a central 4.91 wt% plutonium enriched mixed-oxide ($PuO_2 \cdot UO_2$) 10x10 test lattice with water-to-fuel volume ratio of 2.40 or 2.96, surrounded by 2.6 wt% enriched UO_2 driver lattice with water-to-fuel volume ratio of 1.50. The fissile plutonium content was 91.4 wt%. The critical water level, the power distribution in MOX region, and the neutron activation distribution of Au-wire were measured for six different cores of which two contain soluble boron in 309.4 and 554.0 ppm, one contains four equidistant water holes in the central lattice and one contains a cross water gap at the core center. Calculation of corresponding effective multiplication factor, the fission reaction rate distribution, and the capture reaction rate distribution of Au have been performed using a continuous-energy Monte Carlo code MVP with two nuclear data sets based on JENDL-3.2 and JENDL-3.3. The calculated results agreed to the measurement within a maximum difference of 0.27% for the effective multiplication factors, 3.0% for power distributions, 5.9% for the thermal activation distributions throughout the whole region, and 4.3% for the epithermal activation distributions in the core region.

Keywords: TCA, Mixed-oxide, Two-region Core, Boron Concentration, Water Gap, Water Hole, Critical Water Level, Power Distribution, Activation Distribution, MVP, JENDL-3.2, JENDL-3.3

*Present affiliation: Institute of Nuclear Science and Technology, Bangladesh Atomic Energy Commission

PWR型MOX燃料を装荷したTCA2領域臨界実験に関する
モンテカルロコードMVPを用いた解析研究

日本原子力研究所東海研究所エネルギーシステム研究部
Mafizur RAHMAN*・須崎 武則・森 貴正

(2003年1月30日受理)

原研のTCAにおいてPWR型MOX燃料を含む炉心を用いて実施された一連の臨界実験について解析を行った。炉心中央にテスト格子として 10×10 本の4.91%富化MOX燃料棒を水対燃料体積比2.40又は2.96にて配列し、周囲に臨界調整用ドライバ領域として2.6%濃縮 UO_2 燃料棒を水対燃料体積比1.50にて配列した。核分裂性Puの含有率は91.4%であった。可溶性ほう素を309.4及び554.0ppm混入した2種の炉心、テスト格子中に等間隔で4個の水ホールを設けた炉心、及び中心に十字型水ギャップを有する炉心を含む6種の炉心について、臨界水位、MOX領域の出力分布、及び金線放射化率分布が測定された。これらの実験値に対応して、実効増倍率、核分裂率分布、及び金の捕獲反応率分布の計算を、連続エネルギーモンテカルロコードMVP及び2種の核データJENDL3.2及びJENDL3.3を用いて行った。計算結果は、実効増倍率について0.27%以下、出力分布について3.0%以下、全領域にわたる熱中性子放射化率分布について5.9%以下、及び炉心領域の熱外中性子放射化率分布について4.3%以下の差で実験値と一致した。

東海研究所：〒319-1195 茨城県那珂郡東海村白方白根2-4

*現所属：バングラディッシュ原子力委員会 核科学技術研究所

Contents

1. Introduction	1
2. Experimental Facility	1
2.1 Tank-type Critical Assembly (TCA)	1
2.2 Fuel Rods	2
2.3 Core Configurations	5
3. Measurement and Calculation	11
3.1 Criticality	11
3.2 Power Distributions	11
3.3 Flux Distributions	12
4. Results and Discussions	26
4.1 Criticality	26
4.2 Power Distributions	27
4.3 Flux Distributions	30
5. Conclusions	41
Acknowledgments	42
References	42
Appendix-A: Sample Input for MVP	44
Appendix-B: FORTRAN Program and MVP Input for Response Function Calculation	59

目 次

1. 序論	1
2. 実験装置	1
2.1 タンク型臨界集合体 (TCA)	1
2.2 燃料棒	2
2.3 炉心構成	5
3. 測定及び計算	11
3.1 臨界性	11
3.2 出力分布	11
3.3 中性子束分布	12
4. 結果及び議論	26
4.1 臨界性	26
4.2 出力分布	27
4.3 中性子束分布	30
5. 結論	41
謝辞	42
参照文献	42
Appendix-A: MVP用サンプルインプット	44
Appendix-B: 応答関数計算用フォートランプログラム及びMVPインプット	59

1. Introduction

From the viewpoint of economic fuel cycle of light water reactors, it is proved to be an effective strategy to utilize plutonium, supplied from reprocessing of spent fuels. Recently, use of plutonium in thermal reactors has become more important in the countries where reprocessing is the basis of the nuclear fuel cycle. Also, with the recent stagnation in the development of fast reactors, to utilize excess plutonium produced during the operation of nuclear power plants, urges us to use the MOX fuels in the existing thermal reactors. However, the physics characteristics of plutonium are inherently difficult to calculate than those for uranium enriched reactor. Problems, which occur in predicting the behavior of the uranium fueled reactors, are also present in the plutonium systems, because the fuel of interest is a mixture of the oxides of plutonium and uranium. Thus, it is required to conduct extensive validation works to improve evaluated nuclear data and neutronics codes and accumulate knowledge for the plutonium systems. Significant experimental and analytical programs concerned with the physics of plutonium recycling and fuel technology have been carried out at many laboratories throughout the world¹⁻⁶⁾.

In the present study, analysis of the critical experiments using light-water moderated, two region TCA lattices composed of UO₂ and PWR type MOX fuel rods have been performed to evaluate the accuracy of the nuclear data and the current neutronic calculation technique. In the experiment, the criticality, the power distribution and the flux equivalent neutron activation distribution of bare and Cd-covered Au-wire were measured for six different core configurations. Calculations of corresponding effective multiplication factor, the fission reaction rate distribution (MOX region), and the capture reaction rate distribution of Au throughout the two-region core have been performed using continuous-energy Monte Carlo code MVP⁷⁾. We have used two nuclear data sets of MVP based on JENDL-3.2⁸⁾ and recently released JENDL-3.3⁹⁾ in the study.

2. Experimental facility

2.1. Tank-type Critical Assembly (TCA)

The critical assembly TCA¹⁰⁾ composed of fuel rods, grid plates, and a core tank (1.832m ϕ x 2.078mh) has been used for the experiment. The light-water moderated experimental lattices were assembled at the center of the core tank. The fuel rods were vertically inserted and positioned by the upper and the lower grid plates. In the case of PuO₂-UO₂ lattices, an additional grid plate was set between the upper and lower grid plates. The

fuel rods were so arranged to form square lattices. The water-to-fuel volume ratio of the lattice was determined by the lattice pitch of the grid plates. The reactivity was controlled by changing water level by feeding water from the bottom of the core tank and no other control element was used to avoid undesirable neutron flux disturbance. The general view and the mechanical construction of TCA facility can be seen in reference 10.

2.2. Fuel rods

Two kinds of fuel rods were used in the experiment:

(1) PWR type MOX ($\text{PuO}_2\text{-UO}_2$) fuel rods

The enrichment of plutonium oxide in $\text{PuO}_2\text{-UO}_2$ fuel is 4.91 wt% and uranium is natural. The fissile content of plutonium was 91.39 wt% and the accumulation of ^{241}Am from beta-decay of ^{241}Pu was negligibly small. Sintered pellets of 0.858cm dia. were clad into zircaloy-4 tube with an active fuel length of 90.93 ± 0.5 cm.

(2) Uranium-oxide (UO_2) fuel rods

The enrichment of ^{235}U is 2.596 wt%. Pellets of 1.25cm dia. were clad into aluminum tube with an active fuel length of 144.15 ± 0.3 cm.

Details of their specifications are given in Table 1, Table 2 and Fig. 1.

Table 1
Fuel specifications

Fuel type	PWR-type MOX	Driver UO ₂
Pellet		
Density (g/cm ³)	Sintered 10.08 (91.7% T.D.)	10.40 (94.9%T.D.)
Diameter (cm)	0.8579	1.25
Enrichment (wt %)	4.91 (PuO ₂ / PuO ₂ +UO ₂)	2.596 (²³⁵ U/U)
Composition (wt %)		
U	Natural	
Pu-238	0.0454	
Pu-239	90.236	
Pu-240	8.480	
Pu-241	1.151	
Pu-242	0.086	
O/M ratio	2.00	2.04
Cladding	Zircaloy-4	Al
Inner dia. (cm)	0.872	1.265
Thickness (cm)	0.063	0.076
Active fuel length (cm)	90.93	144.15
Mass of Pu, g/rod	23.30	

Table 2
Fuel cell atomic number densities

Zone	Composition	Number densities (x 10 ⁻²⁴ cm ⁻³)	
		MOX	UO ₂
Fuel	U-234	1.2215E-6	No assayed data
	U-235	1.5203E-4	6.0831E-4
	U-238	2.0910E-2	2.2539E-2
	Pu-238	4.9397E-7	-----
	Pu-239	9.7764E-4	-----
	Pu-240	9.1496E-5	-----
	Pu-241	1.2364E-5	-----
	Pu-242	9.2016E-7	-----
	O-16	4.4289E-2	4.7228E-2
Clad	Al	-----	5.5840E-2
	Zr (Nat.)	3.8161E-2	-----
	Sn (Nat.)	5.5667E-4	-----
	Fe (Nat.)	8.5641E-5	-----
	Cr (Nat.)	4.6713E-5	-----
Water	H	6.6751E-2	
	O	3.3376E-2	

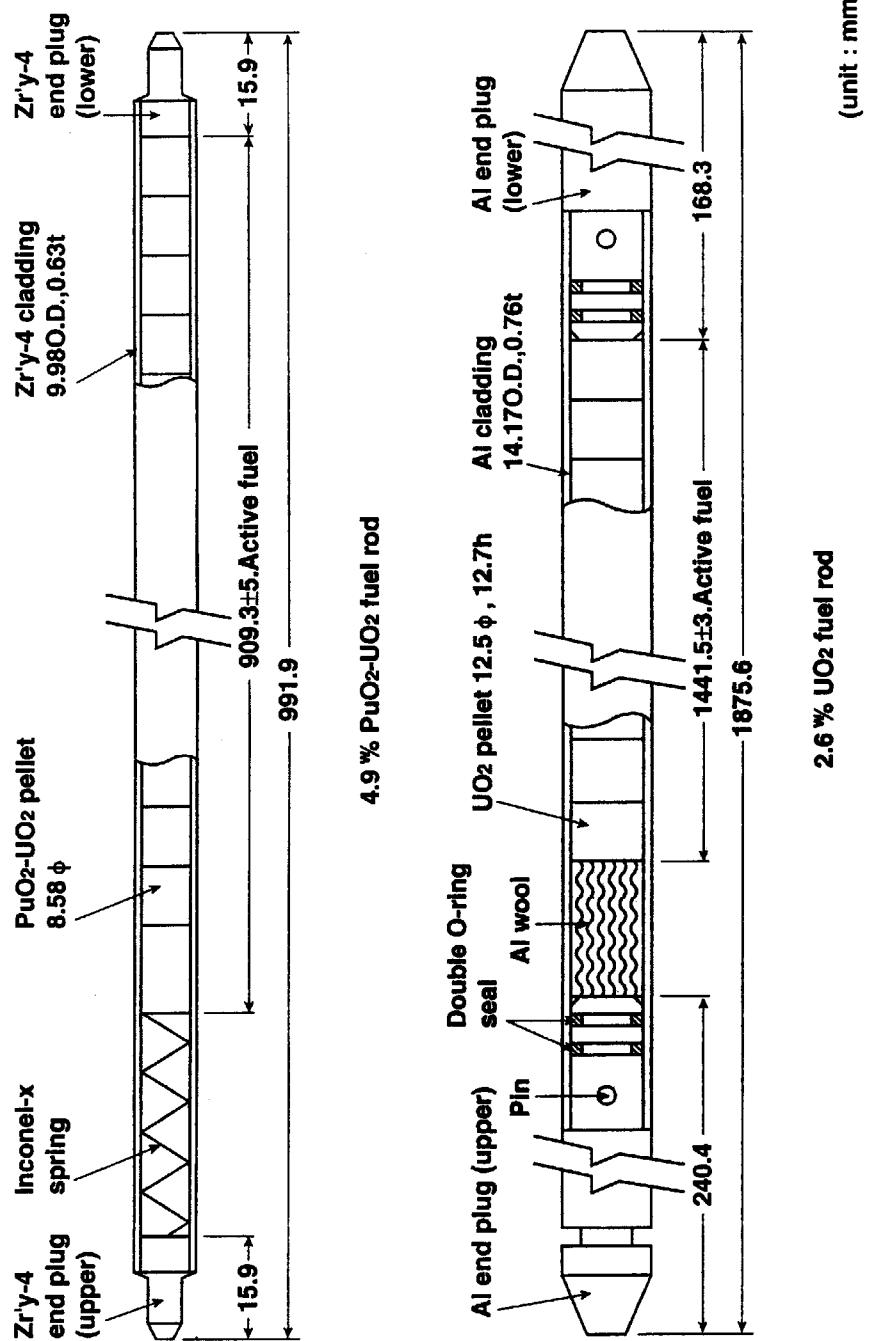


Fig. 1 Fuel rods

2.3. Core configurations

The six critical cores were so constructed that the plan view was a square (or almost square) to maintain the symmetry. The cores consisted of a central test region and a surrounding driver region, with a water gap in-between. The central test regions were formed in square lattice of 10x10 rod array. The water-to-fuel volume ratio of the test region was 2.40 for five cores and 2.96 for the sixth, while the same for the driver region was fixed to 1.50. Two of the six cores contained soluble boron in water (309.4ppm and 554.0ppm), one had four symmetric water holes and another had a cross water gap in the middle of the central test region. The number of driver fuels was adjusted to obtain a critical water level below the effective height of the MOX fuels. The vertical arrangement of the fuel rods is illustrated in Fig. 2. The name and parameters of the six cores are given in Table 3 and their configurations are shown in Fig. 3 through Fig. 8. In these figures, locations of Au wires for neutron flux measurements are also shown.

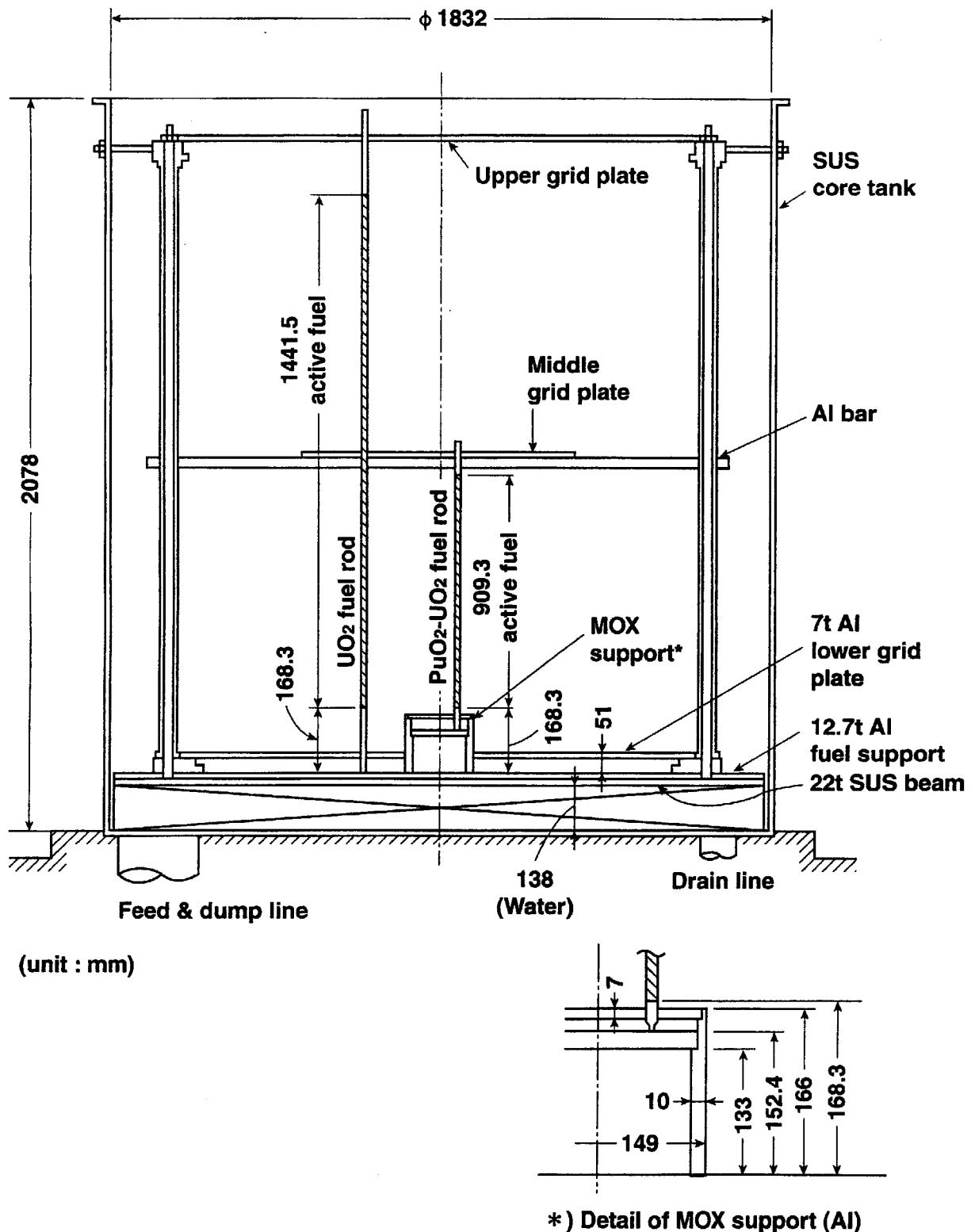


Fig. 2 Vertical arrangement of fuel rods

Table 3
Names and parameters of cores

Core name (Named after volume ratio)	Lattice pitch in MOX region (cm)	Lattice pitch in driver region (cm)	Water gap between the lattices (cm)	Boron concentra- tion (ppm)	Number of driver fuel rods	Critical * water level (cm)	Tempara- ture (°C)	Power distribution measure- ment	Flux distribution measure- ment
2.40Pu	1.473	1.849	0.031	0.0	224	83.66	21.0	Yes	Yes
2.40Pu-B1	1.473	1.849	0.031	309.40	336	90.80	22.6	No	No
2.40Pu-B2	1.473	1.849	0.031	554.00	444	84.71	23.0	Yes	Yes
2.40Pu /WH	1.473	1.849	0.031	0.0	224	78.70	21.7	Yes	No
2.40Pu/G	1.473	1.849	0.09 (1.731) **	0.0	180	83.67	21.0	Yes	Yes
2.96Pu	1.580	1.849	0.42	0.0	164	87.30	21.0	Yes	Yes

* Height of water level from the bottom end of the active fuel zone

** Cross water gap at the center of the core

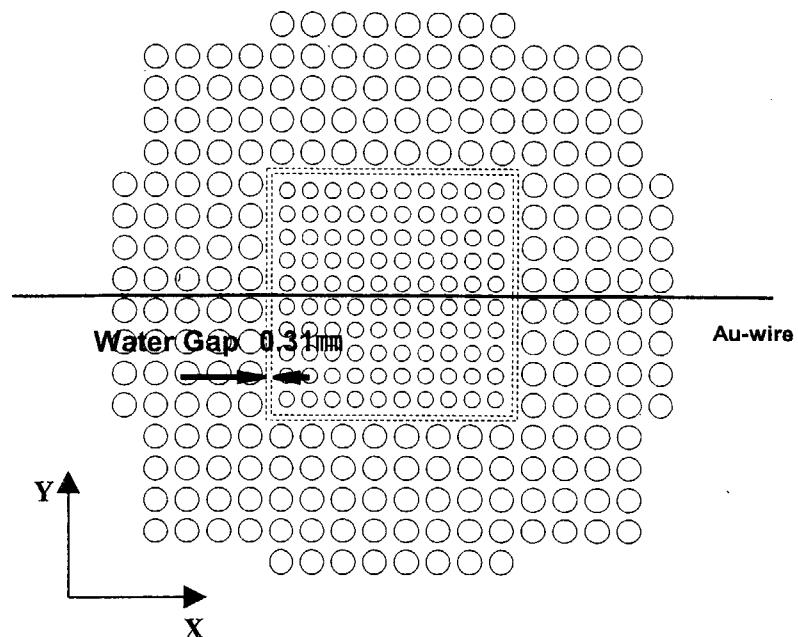


Fig. 3 2.40 Pu

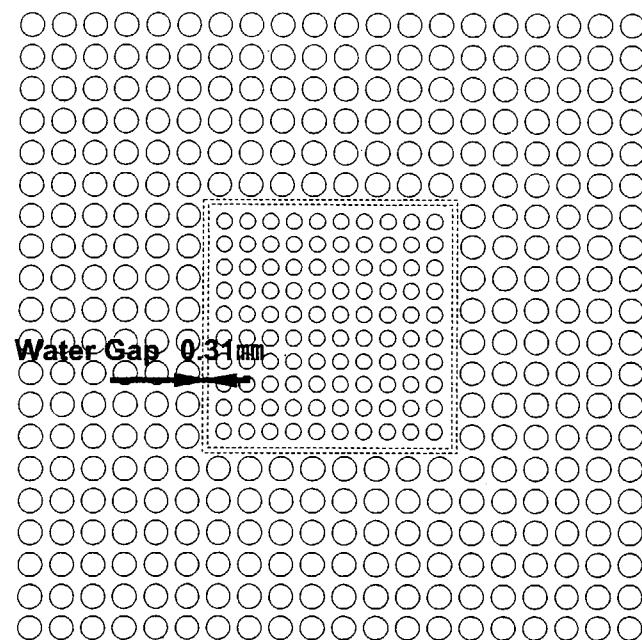


Fig. 4 2.40 Pu - B₁

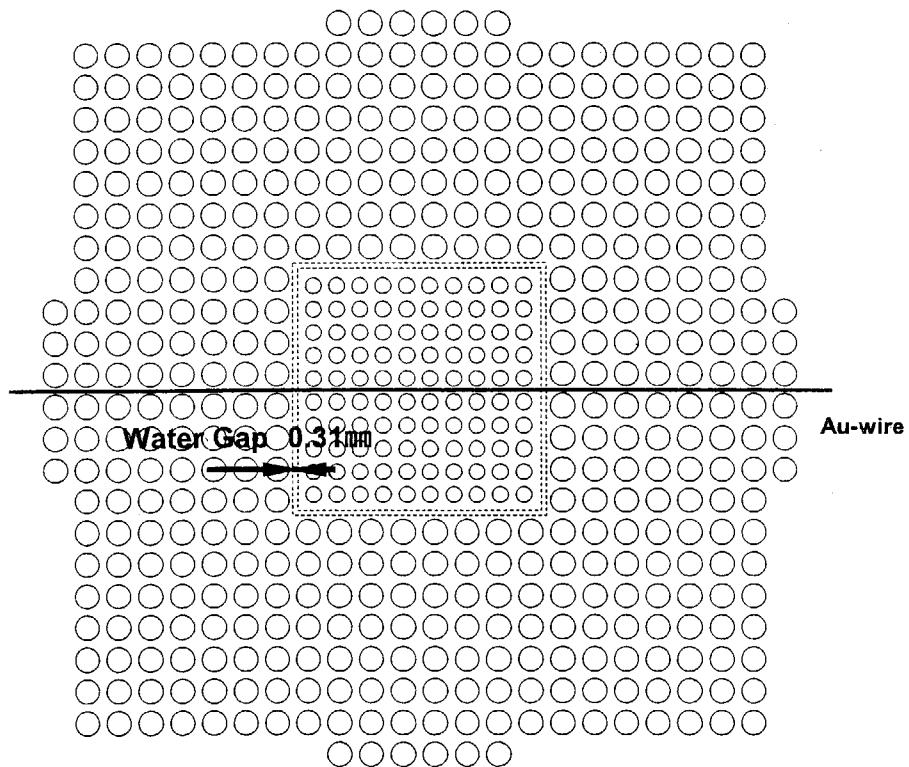


Fig. 5 2.40 Pu - B₂

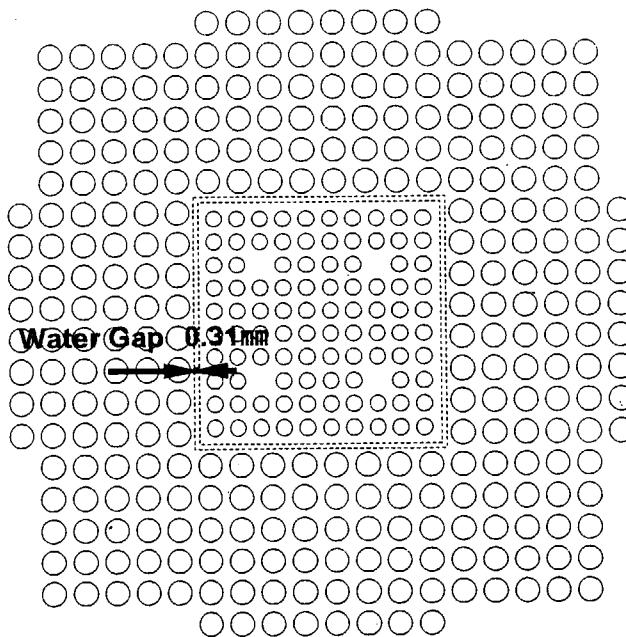


Fig. 6 2.40 Pu /WH

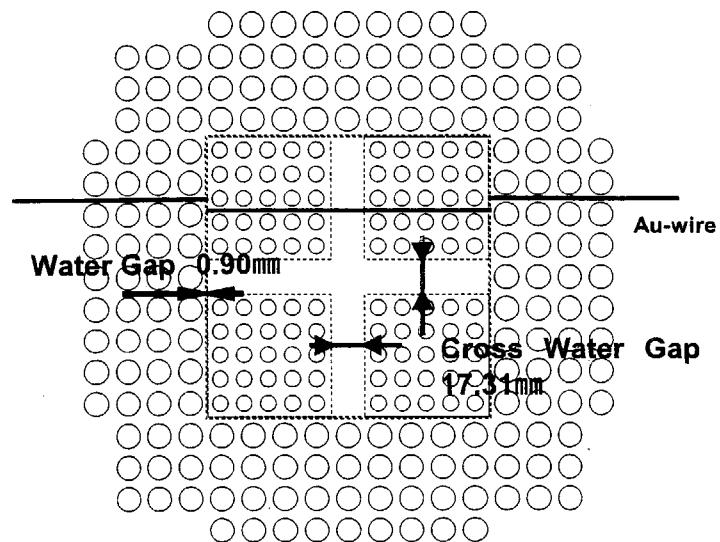


Fig. 7 2.40 Pu /G

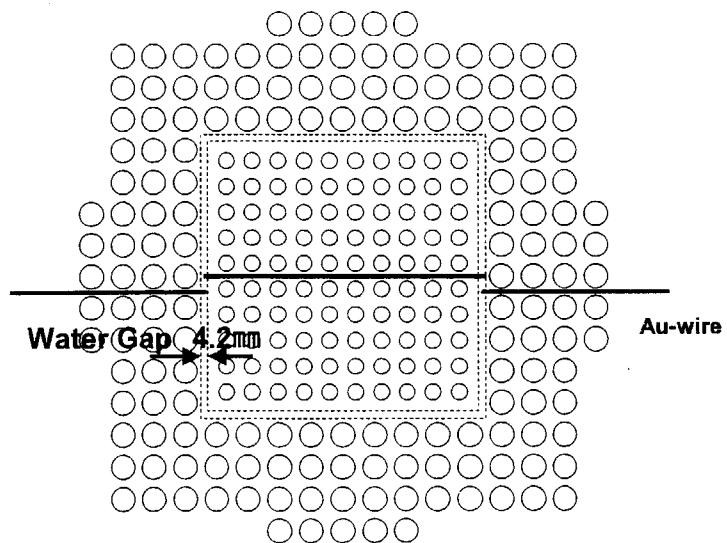


Fig. 8 2.96 Pu

3. Measurement and calculation

3.1. Criticality

The critical core configurations of the six lattices were determined by observing the steady state of neutron flux, which was monitored with two compensated ion-chambers. A waiting time of more than five minutes was allowed before the determination of the critical state to avoid premature observation of the transient terms and the reactor power was maintained above 1 watt to decrease the error due to the neutron source from spontaneous fissions of plutonium and (α , n) reactions of oxygen. During criticality measurements, the cores were free from elements like Au-wires for flux measurement. The measured quantities were the temperature, the number of the driver fuel rods and the water level, required to maintain the core critical i.e., critical water level. The critical water level is the distance from the bottom end of the active fuel zone to the critical water surface. The critical water level was determined to an accuracy of about 0.02 cm by means of a servo-manometer. The total absolute ambiguity of the critical water level was estimated to be about 0.05 cm, because the ambiguity of about 0.03 cm should have been taken into account on the correspondence between the bottom end of the active fuel and the reference reading of the servo-manometer. The measured critical water level is listed in Table 3.

The effective multiplication factors, k_{eff} for the six cores were calculated by MVP, with the geometries modeled as precisely as possible. The calculation were carried out with the JENDL-3.2 and the JENDL-3.3 based cross section libraries. The MVP inputs are given in Appendix-A.

3.2. Power distributions

The relative power distributions in five out of six lattices were obtained by measuring the fission-product γ -rays from the irradiated fuel rods after 100-200 W·min of reactor operation. Fission-product γ -rays above 0.6 MeV were counted by a NaI(Tl) scintillation detector in a cooling time of 30 min to 3 hr. The counting was made for 20 sec and repeated twice to watch the reproducibility. The decay of fission-product γ -activities was corrected by time-dependent factors previously obtained by other experiment¹¹⁾. The total experimental error was estimated to be $\pm 2.5\%$; the statistical error of counting was $\pm 1.0\%$ and the error of correction for the time decay of γ -activities was $\pm 2.0\%$. In the central 10x10 MOX region, the power distribution measurements were done for 30 fuel positions [one complete quarter (25 positions) and five diagonal positions of the opposite quarter], which we further averaged

among symmetric positions and ended up with a total of 15 different positions (i.e., one-eighth symmetry) for each of the five cores. The measured power distributions are listed in Tables 13 through 17 with the calculated ones in Sec. 4.2.

In MVP, the fission reaction-rate distributions in the central MOX region of the five lattices were calculated for one-eighth symmetry by using MVP options LATTICE and TALLY LATTICE.

3.3. Flux distributions

In four out of six lattices, the transverse neutron activation distributions were measured by activation of Au wires. Two Au wires of 0.05 cm dia. were stretched through the core and the reflector in the x-direction one of which was enclosed in a 0.0508 cm thick cadmium tube. After about 100-200 W·min. of irradiation, the wires were unloaded from the core and cut in most cases into segments of length $\frac{1}{2}$ and $\frac{1}{4}$ the lattice pitch in the core and near the core boundary, respectively. The accuracy of positioning the segments was $\pm 0.1\text{cm}$. The γ -rays above 0.3 MeV including a photo peak of 0.412 MeV of ^{198}Au were counted by a well-type NaI(Tl) scintillation detector. The segments were weighed thrice by a balance of sensitivity 0.01 mg. The weights were used to correct the relative sensitivity of the segments. The experimental error was within $\pm 2.0\%$ in most cases (counting statistics $\pm 1.5\%$, weighing error $\pm 0.5\%$). The measured thermal and epithermal activities (counts-per-min/mg-Au), arranged as point averages, zone averages and region averages to make suitable to compare with the calculated values, are given in Table 4 through Table 11. From now and on we call these measured activities as measured flux.

In MVP, the capture reaction-rate distributions for the four cores were calculated under the special tally option. The reaction rates in self-shielding conditions of bare and Cd-covered Au wires were obtained from group-wise infinite-dilution reaction rates multiplied by group-wise response functions f_g calculated in advance in a way as stated below. The flux tallies were defined in the exact locations as that of measurement and their dimensions were: (1) in the z-direction as the active core height, excluding 10 cm from both the top and bottom to avoid prominent flux perturbation at the core boundaries, (2) in the x-direction as $\frac{1}{4}$ the lattice pitch, and (3) in the y-direction, different values were used to adjust the tally volume in different regions (MOX, water gap, driver and reflector) as either equal or in exact multiple of each other. Averaging was done among the symmetric and equivalent positions by using MVP options: LATTICE, TALLY-LATTICE and the lattice parameter KSLAT. Finally, the zone average capture reaction rates corresponding to equal tally volume were obtained by

taking selective tallies into consideration, in attempts to go as much as closer to the measurements. In this report onward, we name the calculated reaction rates as the calculated flux.

The 108-group response functions f_g were calculated by first, executing MVP for the following three systems:

- i) Infinite dilution of Au in water,
- ii) Bare Au-wire submerged in water, and
- iii) Cd-covered Au-wire submerged in water.

The 108-group energy structure was composed of 107 groups of the SRAC system¹²⁾ and one group of higher energy than 10MeV.

Two sets of response functions for bare and Cd-covered Au wires were calculated as the ratio of respective shielded capture reaction-rates to those of infinite dilution case, as given in the following relation. These f_g 's were then multiplied with the corresponding infinite dilution capture cross-sections and summed up with two sets of response functions, representing the shielded environment of flux measurement by bare and Cd-covered Au wires in an actual core. The group-wise effective capture cross-sections, which yield the reaction rates in the shielded conditions by multiplying the infinite-dilution flux calculated in the cores, were expressed as follows:

$$\sigma_{cap,g}^{eff} = f_g \times \sigma_{cap,g}^{inf}, \quad f_g = RR_{cap,g}^{sh} / RR_{cap,g}^{inf},$$

where

- $\sigma_{cap,g}^{eff}$: effective capture cross section of g^{th} group,
- $RR_{cap,g}^{inf}$: infinite dilution capture reaction-rate of g^{th} group in the system i),
- $RR_{cap,g}^{sh}$: shielded capture reaction-rate of g^{th} group in the system ii) or iii),
- $\sigma_{cap,g}^{inf}$: infinite dilution capture cross section of g^{th} group.

A Fortran program is written to automate the reading of required data from MVP output files and to calculate the group-wise response functions. A listing of the program and the three MVP inputs of response function calculation are presented in Appendix-B.

Table 4
Arrangement of measured thermal flux in core: 2.40Pu

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.3	315.87	MX1 (1.473)	318.06	MOX (7.365)	310.10
0.437	314.33				
1.037	317.17				
1.173	324.87				
1.743	314.07		311.76		
1.91	315.44				
2.51	308.87				
2.646	308.67				
3.246	311.55		310.21		
3.383	306.25				
3.983	307.73	MX3 (1.473)			
4.119	315.29				
4.719	308.82		304.78		
4.764	304.83				
5.224	293.86				
5.364	301.01				
5.592	308.89				
5.824	311.28				
5.96	307.79		305.68		
6.192	304.26				
6.329	291.95	MX5 (1.473)			
6.56	290.84				
6.697	293.09				
6.929	308.91				
7.105	318.98				
7.297	329.59				
-----	-----	WG (0.031)	-----	Water gap (0.031)	-----
7.559	346.75	DR1 (1.849)	332.76	Driver (9.245)	301.45
7.705	343.19				
8.021	325.08				
8.159	323.13				
8.484	312.94				
8.621	326.54				
8.946	333.29				
9.084	351.13				
9.409	328.97	DR2 (1.849)	318.77		
9.546	347.85				
9.987	306.92				
10.009	310.58				
10.587	317.55				
10.796	300.72				

Table 4 (continued)

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
11.396	316.00	DR3 (1.849)	285.59		
11.721	269.23				
12.321	283.22				
12.646	273.89				
13.246	285.60	DR4 (1.849)	266.11		
13.571	254.81				
14.171	256.29				
14.496	267.72				
15.096	278.31	DR5 (1.849)	304.04		
15.421	278.87				
16.021	299.13				
16.346	359.83				
16.961	436.65	RF1 (1.849)	524.27	Reflector (12.943)	370.66
17.04	475.70				
17.502	524.60				
17.64	530.02				
17.965	562.12				
18.102	567.73				
18.427	573.06				
18.565	586.89				
18.89	582.75	RF2 (1.849)	570.88		
19.027	583.17				
19.352	568.79				
19.815	568.76				
20.277	534.94	RF3 (1.849)	502.51		
20.971	502.51				
22.821	378.84		378.84		
24.346	306.20				
25.271	254.65	RF4 (1.849)	256.33		
25.596	232.22				
26.196	219.13	RF5 (1.849)	219.13		
28.371	134.60	RF6 (1.849)	134.60		

Table 5
Arrangement of measured epithermal flux in core: 2.40Pu

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.3	155.39	MX1 (1.473)	155.00	MOX (7.365)	148.71
0.437	156.77				
1.037	154.69				
1.173	153.16				
1.773	156.70				
1.910	159.39				
2.646	154.59				
3.246	154.20				
3.383	150.55				
3.983	147.75				
4.119	147.02	MX3 (1.473)	149.88		
4.719	149.09				
4.856	143.63				
5.456	143.56				
5.592	143.98	MX4 (1.473)	145.07		
6.192	138.50				
6.329	138.12				
6.929	134.50				
7.124	135.65				
		WG (0.031)		Water Gap (0.031)	
7.724	129.12	DR1 (1.849)	124.66	Driver (12.943)	96.04
8.021	126.48				
8.621	123.11				
8.946	119.91				
9.546	117.88	DR2 (1.849)	111.12		
9.871	111.36				
10.471	109.08				
10.796	106.16				
11.396	104.68	DR3 (1.849)	96.47		
11.721	97.55				
12.321	93.42				
12.646	90.22				
13.246	89.15	DR4 (1.849)	81.17		
13.571	81.47				
14.171	79.04				
14.496	75.00				
15.096	73.09	DR5 (1.849)	66.77		
15.421	66.53				
16.021	64.83				
16.346	62.64				

Table 5 (continued)

Distance from core center(cm)	Point average flux	Zone name (Width,cm)	Zone average flux	Region name (Width, cm)	Region av. flux
16.946	59.84	RF1 (1.849)	54.70	Reflector (9.245)	29.71
17.271	56.23				
17.871	51.77				
18.196	50.95				
18.796	46.87	RF2 (1.849)	40.88		
19.121	41.18				
20.046	34.60				
20.971	27.08	RF3 (1.849)	27.08	RF6 (1.849)	
22.821	16.74	RF4 (1.849)	16.74		
25.596	9.16	RF5 (1.849)	9.16		
	-----	RF6 (1.849)	-----		
28.371	5.41	RF7 (1.849)	5.41	RF7 (1.849)	

Table 6
Arrangement of measured thermal flux in core: 2.40Pu-B2

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.30	305.95	MX1 (1.473)	305.68	MOX (7.365)	300.58
0.437	304.31				
1.037	302.05				
1.173	310.40				
1.773	304.91	MX2 (1.473)	305.75		
1.91	306.69				
2.51	305.21				
2.646	306.19				
3.246	305.35	MX3 (1.473)	297.07		
3.383	294.99				
3.983	288.32				
4.119	299.61				
4.719	300.84	MX4 (1.473)	295.68		
4.764	300.75				
5.224	290.28				
5.364	284.66				
4.592	291.56				
5.824	305.97				
5.960	296.84	MX5 (1.473)	298.71		
6.192	289.30				
6.329	279.23				
6.56	279.84				
6.697	286.94				
6.929	307.23				
7.105	316.60				
7.297	333.67				
-----	-----	WG (0.031)	-----	Water gap (0.031)	-----
7.559	335.04	DR1 (1.849)	328.85	Driver (14.792)	250.58
7.705	336.01				
8.021	322.89				
8.159	320.16				
8.484	314.58				
8.621	327.81				
8.946	329.31				
9.084	344.98				
9.409	333.50	DR2 (1.849)	320.63		
9.546	349.43				
9.987	302.67				
10.009	314.33				
10.587	322.91				
10.796	300.93				

Table 6 (continued)

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
11.396	319.45	DR3 (1.849)	293.61		
11.721	280.91				
12.321	292.56				
12.646	281.48				
13.246	282.59	DR4 (1.849)	262.73		
13.571	250.98				
14.496	254.61				
15.096	246.90	DR5 (1.849)	230.73		
15.421	229.16				
16.021	222.11				
16.346	224.76				
16.941	214.99	DR6 (1.849)	196.76		
17.271	198.09				
17.64	187.43				
18.102	195.44				
18.196	187.84				
18.565	195.42	DR7 (1.849)	183.69		
19.027	187.03				
19.121	175.82				
20.046	176.49	DR8 (1.849)	187.63		
20.971	165.03				
21.665	183.71				
22.127	214.16				
22.59	239.85	RF1 (1.849)	257.55	Reflector (9.245)	186.80
23.052	260.28				
23.515	264.85				
23.977	265.23				
24.346	258.51	RF2 (1.849)	248.33		
24.44	264.24				
24.902	255.23				
25.271	242.35				
25.365	241.25				
25.827	228.38				
26.196	216.49	RF3 (1.849)	205.40		
26.29	207.64				
26.752	192.08	RF4 (1.849)	141.41		
28.371	141.41	RF5 (1.849)	81.32		
31.146	81.32	RF6 (1.849)	-----	RF6 (1.849)	
-----	-----	RF7 (1.849)	42.66	RF7 (1.849)	
33.921	42.66				

Table 7
Arrangement of measured epithermal flux in core: 2.40Pu-B2

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.30	154.66	MX1 (1.473)	155.02	MOX (7.365)	148.96
0.437	154.59				
1.037	155.04				
1.173	155.77				
1.773	152.82	MX2 (1.473)	153.75		
1.91	153.48				
2.646	154.95				
3.246	155.73	MX3 (1.473)	150.89		
3.383	150.28				
3.983	151.33				
4.119	146.21				
4.719	149.65	MX4 (1.473)	146.33		
4.856	146.43				
5.456	146.05				
5.592	143.20				
6.192	142.49	MX5 (1.473)	138.82		
6.329	139.59				
6.929	137.40				
7.124	135.78				
-----	-----	WG (0.031)	-----	Water gap (0.031)	-----
7.724	134.32	DR1 (1.849)	128.67	Driver (14.792)	88.43
8.021	128.51				
8.621	128.07				
8.946	123.77				
9.546	123.33	DR2 (1.849)	118.63		
9.871	117.90				
10.471	117.53				
10.796	115.77				
11.396	109.82	DR3 (1.849)	106.61		
11.721	107.80				
12.321	106.05				
12.464	102.76				
13.246	101.07	DR4 (1.849)	95.65		
13.571	97.21				
14.171	93.27				
14.496	91.04				
15.096	88.41	DR5 (1.849)	84.37		
15.421	87.53				
16.021	80.89				
16.346	80.66				

Table 7 (continued)

Distance from core center(cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
16.946	75.24	DR6 (1.849)	69.79	Reflector (9.245)	20.04
17.271	71.12				
17.871	67.96				
18.196	64.84				
18.796	61.27		58.04		
19.121	59.18				
20.046	53.68				
20.971	46.98		45.67		
21.876	44.35	DR8 (1.849)			
22.821	38.09	RF1 (1.849)	35.65	Reflector (9.245)	20.04
23.746	33.21	RF2 (1.849)	25.85		
24.671	28.86	RF3 (1.849)	19.27		
25.596	22.83	RF4 (1.849)	13.82		
26.521	19.27	RF5 (1.849)	5.62		
28.371	13.82	RF6 (1.849)	-----		
31.146	5.62	RF7 (1.849)	2.86	RF6 (1.849)	
-----	-----			RF7 (1.849)	
33.921	2.86				

Table 8
Arrangement of measured thermal flux in core: 2.40Pu/G

Distance from core center (cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux		
0.0	1649.50	CWG (0.8655)	1587.95	Central water gap (0.8655)	1587.95		
0.332	1622.96						
0.681	1491.38						
1.05	1230.20	MX1 (1.473)	986.33	MOX (7.365)	740.86		
1.418	986.30						
1.786	884.86						
2.339	843.97						
3.075	725.79						
3.812	726.24	MX2 (1.473)	726.02				
4.548	676.02						
5.285	685.12						
6.021	644.92	MX3 (1.473)	680.57				
6.758	663.08						
7.494	620.84						
8.18	693.91	(1.473)	657.37				
-----	-----						
-----	-----	WG (0.09)	-----	Water gap (0.09)	-----		
8.39	682.73	DR1 (1.849)	668.50		670.46		
9.245	653.41						
10.17	669.36						
11.095	618.62	DR2 (1.849)	624.58				
12.02	630.54						
12.945	583.68	DR3 (1.849)	608.12				
13.87	632.55						
14.795	646.06	DR4 (1.849)	780.65				
15.72	915.24						
16.414	1141.70	RF1 (1.849)	1209.31		890.83		
16.876	1222.71						
17.339	1263.52						
17.801	1302.91	RF2 (1.849)	1271.87				
18.264	1296.42						
18.726	1264.60						
19.189	1223.55						
19.651	1168.59	RF3 (1.849)	1124.21				
20.30	1079.82						
22.195	822.48	RF4 (1.849)	822.48				
24.97	502.77	RF5 (1.849)	502.77				
25.895	414.36	RF6 (1.849)	414.36				
26.82	347.79	RF7 (1.849)	347.79	RF7 (1.849)			
29.594	187.68	RF8 (1.849)	187.68	RF8 (1.849)			

Table 9
Arrangement of measured epithermal flux in core: 2.40Pu/G

Distance from core center (cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.0	378.01	CWG (0.8655)	372.73	Center water gap (0.8655)	372.73
0.494	367.44				
0.987	354.69	MX1 (1.473)	340.04	MOX (7.365)	306.76
1.602	337.55				
2.339	327.88				
3.075	319.43	MX2 (1.473)	318.75		
3.812	318.06				
4.548	309.10	MX3 (1.473)	308.32		
5.285	307.53				
6.021	299.86	MX4 (1.473)	295.76		
6.758	291.67				
7.494	275.32	MX5 (1.473)	270.92		
8.18	266.53				
-----	-----	WG (0.09)	-----	Water gap (0.09)	-----
8.39	286.29	DR1 (1.849)	251.95	Driver (7.396)	189.51
9.245	241.83				
10.17	227.74				
11.095	208.02	DR2 (1.849)	202.13		
12.02	196.23				
12.945	172.05	DR3 (1.849)	167.77		
13.87	163.48				
14.975	139.26	DR4 (1.849)	136.18		
15.72	133.08				
16.645	118.05	RF1 (1.849)	109.06	Reflector (7.396)	67.19
17.57	100.07				
18.495	81.50	RF2 (1.849)	76.13		
19.42	70.75				
20.30	51.37	RF3 (1.849)	51.37		
22.195	32.18	RF4 (1.849)	32.18		
-----	-----	RF5 (1.849)	-----	RF5 (1.849)	
25.895	13.96	RF6 (1.849)	13.96	RF6 (1.849)	
-----	-----	RF7 (1.849)	-----	RF7 (1.849)	
29.595	6.63	RF8 (1.849)	6.63	RF8 (1.849)	

Table 10
Arrangement of measured thermal flux in core: 2.96Pu

Distance from core center (cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux		
0.0	227.28	MX1 (1.473)	222.55	MOX (7.365)	212.63		
0.79	211.94						
1.58	228.29						
2.37	210.35						
3.16	221.13						
3.95	201.38						
4.74	213.82						
5.53	195.62						
6.32	211.25						
7.11	199.04						
7.50	211.31	MX5 (1.473)	213.80	Water gap (0.42)	228.10		
7.90	231.07						
7.92	224.25						
8.31	228.69	WG (0.42)	228.10				
8.33	231.37						
8.78	216.66						
9.25	198.96	DR1 (1.849)	204.74	Driver (7.396)	188.35		
10.17	198.60						
11.10	172.61						
12.02	180.21	DR2 (1.849)	176.41				
12.95	156.27						
13.87	169.99						
14.80	174.97	DR3 (1.849)	163.13				
15.26	205.08						
15.72	247.31						
16.18	285.79	DR4 (1.849)	209.12	Reflector (11.094)	227.18		
16.65	310.74						
17.57	337.52						
18.50	330.39	RF2 (1.849)	320.25				
19.42	310.11						
20.35	280.20	RF3 (1.849)	280.20				
22.20	208.08	RF4 (1.849)	208.08				
24.05	145.16	RF5 (1.849)	145.16				
25.90	98.01	RF6 (1.849)	98.01				

Table 11
Arrangement of measured epithermal flux in core: 2.96Pu

Distance from core center (cm)	Point average flux	Zone name (Width, cm)	Zone average flux	Region name (Width, cm)	Region av. flux
0.0	94.48	MX1 (1.473)	94.29	MOX (7.365)	87.91
0.79	93.82				
1.58	94.56				
2.37	93.81		94.29		
3.16	94.77				
3.95	89.28		87.96		
4.74	86.65				
5.53	84.12		84.41		
6.32	84.70				
7.11	79.10		78.62		
7.50	79.17	MX5 (1.473)		Water gap (0.42)	76.05
7.90	77.60				
7.92	77.21		76.05		
8.31	74.82				
8.33	76.12	WG (0.42)		Driver (7.396)	53.57
8.78	72.97		69.59		
9.25	70.74				
10.17	65.07		57.56		
11.10	60.04	DR1 (1.849)		Reflector (11.094)	15.94
12.02	55.08		46.78		
12.95	48.94				
13.87	44.62		40.34		
14.80	41.04	DR2 (1.849)		Reflector (11.094)	15.94
15.72	39.64				
16.65	34.71		31.54		
17.57	28.36				
18.50	23.71	RF1 (1.849)	21.99	Reflector (11.094)	15.94
19.42	20.28				
20.35	16.29	RF3 (1.849)	16.29	Reflector (11.094)	15.94
22.20	11.45	RF4 (1.849)	11.45		
24.05	8.05	RF5 (1.849)	8.05		
25.90	6.33	RF6 (1.849)	6.33		

4. Results and discussions

4.1. Criticality

The calculated pairs (corresponding to the two data libraries) of effective multiplication factors for the six cores are given in Table 12. The measured values are always unity since the criticalities were achieved by adjusting the water level. The agreement between the measurement and calculation is quite satisfactory with maximum difference of 0.17 % (2.40Pu-B2) for JENDL-3.2 and -0.27 % (2.40Pu /WH) for JENDL-3.3.

Table 12
MVP calculated effective multiplication factors, K_{eff} for critical cores
[Values in parenthesis are percent differences; (C/E - 1) \times 100]

Core name	Data library	Histories completed	K_{eff}
2.40 Pu	JENDL-3.2	88,260,000	$0.999569 \pm 0.0076\%^*$ (-0.04)
	JENDL-3.3	91,440,000	$0.997498 \pm 0.0075\%$ (-0.25)
2.40 Pu-B1	JENDL-3.2	50,400,000	$1.00032 \pm 0.01010\%$ (0.03)
	JENDL-3.3	47,400,000	$0.998138 \pm 0.0106\%$ (-0.19)
2.40 Pu-B2	JENDL-3.2	127,640,000	$1.001660 \pm 0.00610\%$ (0.17)
	JENDL-3.3	139,940,000	$0.998807 \pm 0.0058\%$ (-0.12)
2.40 Pu /WH	JENDL-3.2	32,540,000	$0.999512 \pm 0.0127\%$ (-0.05)
	JENDL-3.3	40,700,000	$0.997315 \pm 0.0113\%$ (-0.27)
2.40 Pu /G	JENDL-3.2	81,480,000	$0.999414 \pm 0.0080\%$ (-0.05)
	JENDL-3.3	84,720,000	$0.998035 \pm 0.0078\%$ (-0.17)
2.96 Pu	JENDL-3.2	85,240,000	$0.999779 \pm 0.0079\%$ (-0.02)
	JENDL-3.3	89,260,000	$0.998490 \pm 0.0077\%$ (-0.15)

*Standard deviation in
Monte Carlo calculation

4.2. Power distributions

The measured as well as the calculated pairs (for two data libraries) of power distributions in the central MOX region for five cores are compared in Table 13 through Table 17. The calculational errors were always less than 0.2%. The average power in the MOX region was normalized to unity for both the measurement and calculation. The differences between the measurement and calculation are scattered in-between -3.0% to +2.9% and no significant difference is observed in calculated power distributions corresponding to the two libraries.

Table 13
Relative power distribution (MOX region) in core: 2.40Pu

Data given in the table below are:
 1st : E; measured value
 2nd : C; calculated value /JENDL-3.2
 3rd : C; calculated value /JENDL-3.3

[Values in parenthesis are percent differences; (C/E - 1)x 100]

				1.01 1.00 (-0.99) 1.00 (-0.99)
			0.95 0.94 (-1.05) 0.94 (-1.05)	0.98 0.98 (0.00) 0.98 (0.00)
		0.97 0.97 (0.00) 0.98 (1.03)	0.97 0.96 (-1.03) 0.96 (-1.03)	1.02 1.01 (-0.98) 1.01 (-0.98)
	1.02 1.02 (0.00) 1.02 (0.00)	0.99 0.99 (0.00) 1.00 (1.01)	0.99 0.98 (-1.01) 0.98 (-1.01)	1.03 1.03 (0.00) 1.03 (0.00)
1.03 1.04 (0.97) 1.04 (0.97)	1.03 1.03 (0.00) 1.03 (0.00)	1.00 1.01 (1.00) 1.01 (1.00)	0.98 0.99 (1.02) 0.99 (1.02)	1.04 1.04 (0.00) 1.03 (-0.96)

(Core center)

Table 14
Relative power distribution (MOX region) in core: 2.40Pu-B2

Data given in the table below have the same meaning as those in Table 13

				1.04 1.03 (-0.96) 1.03 (-0.96)
			0.95 0.95 (0.00) 0.95 (0.00)	1.00 1.00 (0.00) 1.00 (0.00)
		0.95 0.97 (2.11) 0.97 (2.11)	0.95 0.96 (1.05) 0.96 (1.05)	1.02 1.02(0.00) 1.02 (0.00)
	0.99 1.00 (1.01) 1.01 (2.02)	0.99 0.99 (0.00) 0.99 (0.00)	1.00 0.98 (-2.00) 0.97 (-3.00)	1.03 1.03 (0.00) 1.03 (0.00)
1.02 1.02 (0.00) 1.02 (0.00)	1.01 1.01 (0.00) 1.01 (0.00)	0.99 0.99 (0.00) 1.00 (1.01)	0.98 0.99 (1.02) 0.98 (0.00)	1.04 1.04 (0.00) 1.04 (0.00)

(Core center)

Table 15
Relative power distribution (MOX region) in core: 2.40Pu/WH

Data given in the table below have the same meaning as those in Table 13

				0.95 0.95 (0.00) 0.94 (-1.05)
			0.95 0.96 (1.05) 0.96 (1.05)	0.94 0.95 (1.06) 0.94 (0.00)
		WH	1.05 1.08 (2.86) 1.07 (1.90)	0.98 1.00 (2.04) 0.97 (-1.02)
	1.03 1.04 (0.97) 1.04 (0.97)	1.12 1.11 (-0.89) 1.11 (-0.89)	1.03 1.00 (-2.91) 1.00 (-2.91)	1.01 0.99 (-1.98) 0.99 (-1.98)
1.00 1.00 (0.00) 1.00 (0.00)	1.00 1.00 (0.00) 1.00 (0.00)	0.99 0.99 (0.00) 0.99 (0.00)	0.98 0.96 (-2.04) 0.96 (-2.04)	1.00 0.99 (-1.00) 0.99 (-1.00)

(Core center)

Table 16
Relative power distribution (MOX region) in core: 2.40Pu/G

Data given in the table below have the same meaning as those in Table 13

CWG				0.75 0.74 (-1.33) 0.74 (-1.33)
			0.71 0.71 (0.00) 0.71 (0.00)	0.73 0.74 (1.37) 0.74 (1.37)
		0.80 0.79 (-1.25) 0.79 (-1.25)	0.75 0.75 (0.00) 0.75 (0.00)	0.77 0.78 (1.30) 0.77 (0.00)
	0.99 1.01 (2.02) 1.01 (2.02)	0.89 0.89 (0.00) 0.90 (1.12)	0.86 0.84 (-2.33) 0.84 (-2.33)	0.84 0.85 (1.19) 0.85 (1.19)
	1.90 1.91 (0.53) 1.91 (0.53)	1.44 1.45 (0.69) 1.45 (0.69)	1.27 1.29 (1.57) 1.30 (2.36)	1.17 1.20 (2.56) 1.20 (2.56)
				1.13 1.12 (-0.88) 1.12 (-0.88)
			CWG*	

(Core center)

*Cross water gap

Table 17
Relative power distribution(MOX region) in core: 2.96Pu

Data given in the table below have the same meaning as those in Table 13

				1.00 0.99 (-1.00) 0.99 (-1.00)
			0.92 0.92 (0.00) 0.92 (0.00)	0.96 0.97 (1.04) 0.97 (1.04)
		0.97 0.97 (0.00) 0.97 (0.00)	0.95 0.95 (0.00) 0.95 (0.00)	1.00 1.01 (1.00) 1.01 (1.00)
	1.02 1.02 (0.00) 1.03 (0.98)	0.99 1.00 (1.01) 1.00 (1.01)	1.00 0.97 (-3.00) 0.97 (-3.00)	1.04 1.03 (-0.96) 1.03 (-0.96)
1.05 1.05 (0.00) 1.06 (0.95)	1.03 1.04 (0.97) 1.04 (0.97)	1.01 1.01 (0.00) 3.11 (0.00)	0.99 0.99 (0.00) 0.99 (0.00)	1.05 1.05 (0.00) 1.05 (0.00)

(Core center)

4.3. Flux distributions

The measured and calculated values of zone average thermal and epithermal flux distributions for two different data libraries along with the percent differences from the measurements are placed in Table 18 through Table 21. The calculational errors were less than 0.2% and 0.7% respectively for the thermal and epithermal flux calculations. The normalization of the measured as well as the calculated flux distributions was made with the average flux levels in the driver region. The point average fluxes of measurement and the zone average fluxes of both the measurement and calculation are compared in Fig. 9 through Fig. 16. The thermal fluxes in all the four cores and for the two data libraries are in good agreement between the measurement and calculation with the differences ranging from -5.9% (Table 19, 2.40Pu-B2, RF7) up to 5.8% (Table 21, 2.96Pu, RF6). The epithermal fluxes in the active core i.e., up to the driver region of all the four cores and for both the data libraries also show good agreement: The differences are scattered between -4.1% (Table 20, 2.40Pu/G, CWG) up to 4.3% (Table 21, 2.96Pu, MX3, JENDL-3.3) with small differences between the two libraries. In the reflector region, the calculated epithermal fluxes were corrected for flux variation in the radial direction, because, to have better statistics in the reflector region, we used larger dimension for tallies (in the y-direction) compared to MOX and driver regions. The calculated epithermal fluxes in the reflector region are also in good agreement with some exceptions for remote points where underestimation is observed in comparison with the measured ones. The reason behind the systematic underestimation in calculation of epithermal fluxes in the reflector region might be the very low activity closer to the background counts of measurement, leading to larger experimental uncertainties.

Table 18
Relative flux distribution in core: 2.40Pu

Data given in the table below are:

	1 st	2 nd	3 rd
	E; measured value	C; calculated value /JENDL-3.2	C; calculated value /JENDL-3.3

[Values in parenthesis are percent differences; (C/E - 1)x 100]

Zone name	Thermal flux	Epithermal flux
MX1	1.06	1.61
	1.06 (0.00)	1.61 (0.00)
	1.07 (0.94)	1.63 (1.24)
MX2	1.03	1.63
	1.05 (1.94)	1.59 (-2.45)
	1.06 (2.91)	1.61 (-1.23)
MX3	1.03	1.56
	1.02 (-0.97)	1.55 (-0.64)
	1.03(0.00)	1.56 (0.00)
MX4	1.01	1.51
	1.00 (-0.99)	1.49 (-1.32)
	1.01 (0.00)	1.51 (0.00)
MX5	1.01	1.42
	1.01 (0.00)	1.41 (-0.70)
	1.02 (0.99)	1.42 (0.00)
WG	-----	-----
	1.04	1.33
	1.05	1.34
DR1	1.10	1.30
	1.09 (-0.91)	1.29 (-0.77)
	1.09 (-0.91)	1.30 (0.00)
DR2	1.06	1.16
	1.05 (-0.94)	1.15 (-0.86)
	1.05 (-0.94)	1.16 (0.00)
DR3	0.95	1.00
	0.96 (1.05)	1.01 (1.00)
	0.96 (1.05)	1.00 (0.00)
DR4	0.88	0.85
	0.89 (1.14)	0.85 (0.00)
	0.89 (1.14)	0.85 (0.00)
DR5	1.01	0.70
	1.01 (0.00)	0.70 (0.00)
	1.01 (0.00)	0.70 (0.00)
RF1	1.74	0.57
	1.68 (-3.45)	0.58 (1.75)
	1.68 (-3.45)	0.58 (1.75)

Table 18 (continued)

Zone name	Thermal flux	Epithermal flux
RF2	1.89	0.43
	1.87 (-1.06)	0.43 (0.00)
	1.87 (-1.06)	0.43 (0.00)
RF3	1.67	0.28
	1.65 (-1.20)	0.28 (0.00)
	1.65 (-1.20)	0.28 (0.00)
RF4	1.26	0.17
	1.27 (0.79)	0.18 (5.88)
	1.27 (0.79)	0.18 (5.88)
RF5	0.88	0.10
	0.88 (0.00)	0.09 (-10.00)
	0.88 (0.00)	0.09 (-10.00)
RF6	0.73	----
	0.70 (-4.11)	0.06
	0.70 (-4.11)	0.06
RF7	0.45	0.06
	0.43 (-4.44)	0.04 (-33.33)
	0.44 (-2.22)	0.04 (-33.33)

Table 19

Relative flux distribution in core: 2.40Pu-B2

Data given in the table below have the same meaning as those in Table 18.

Zone name	Thermal flux	Epithermal flux
MX1	1.22	1.75
	1.23 (0.82)	1.72 (-1.71)
	1.24 (1.64)	1.74 (-0.57)
MX2	1.22	1.74
	1.21 (-0.82)	1.70 (-2.30)
	1.23 (0.82)	1.72 (-1.15)
MX3	1.19	1.71
	1.19 (0.00)	1.68 (-1.75)
	1.20 (0.84)	1.69 (-1.17)
MX4	1.18	1.65
	1.17 (-0.85)	1.62 (-1.82)
	1.18 (0.00)	1.64 (-0.61)
MX5	1.19	1.57
	1.20 (0.84)	1.55 (-1.27)
	1.20 (0.84)	1.56 (-0.64)
WG	----	----
	1.24	1.48
	1.25	1.49

Table 19 (continued)

Zone name	Thermal flux	Epithermal flux
DR1	1.31	1.46
	1.30 (-0.76)	1.45 (-0.68)
	1.31 (0.00)	1.46 (0.00)
DR2	1.28	1.34
	1.27 (-0.78)	1.33 (-0.75)
	1.28 (0.00)	1.34 (0.00)
DR3	1.17	1.21
	1.18 (0.85)	1.21 (0.00)
	1.18 (0.85)	1.21 (0.00)
DR4	1.05	1.08
	1.06 (0.95)	1.08 (0.00)
	1.06 (0.95)	1.07 (-0.93)
DR5	0.92	0.95
	0.93 (1.09)	0.94 (-1.05)
	0.93 (1.09)	0.94 (-1.05)
DR6	0.79	0.79
	0.81 (2.53)	0.79 (0.00)
	0.81 (2.53)	0.80 (1.27)
DR7	0.73	0.66
	0.71 (-2.74)	0.66 (0.00)
	0.70 (-4.11)	0.66 (0.00)
DR8	0.75	0.52
	0.73 (-2.67)	0.53 (1.92)
	0.73 (-2.67)	0.53 (1.92)
RF1	1.03	0.40
	1.01 (-1.94)	0.43 (4.88)
	1.01 (-1.94)	0.43 (4.88)
RF2	0.99	0.29
	0.98 (-1.01)	0.29 (0.00)
	0.98 (-1.01)	0.29 (0.00)
RF3	0.82	0.22
	0.82 (0.00)	0.21 (-4.55)
	0.82 (0.00)	0.21 (-4.55)
RF4	0.56	0.16
	0.58 (3.57)	0.14 (-12.50)
	0.58 (3.57)	0.14 (-12.50)
RF5	0.32	0.06
	0.32 (0.00)	0.06 (0.00)
	0.32 (0.00)	0.06 (0.00)
RF6	-----	-----
	0.23	0.05
	0.24	0.05
RF7	0.17	0.03
	0.16 (-5.88)	0.03 (0.00)
	0.16 (-5.88)	0.03 (0.00)

Table 20
 Relative flux distribution in core: 2.40Pu/G
 Data given in the table below have the same meaning as those in Table 18.

Zone name	Thermal flux	Epithermal flux
CWG	2.37	1.97
	2.39 (0.84)	1.89 (-4.06)
	2.41 (1.69)	1.89 (-4.06)
MX1	1.47	1.79
	1.43 (-2.72)	1.76 (-1.68)
	1.44 (-2.04)	1.77 (-1.12)
MX2	1.08	1.68
	1.12 (3.70)	1.67 (-0.60)
	1.13 (4.63)	1.70 (1.19)
MX3	1.02	1.63
	1.02 (0.00)	1.62 (-0.61)
	1.03 (0.98)	1.63 (0.00)
MX4	0.98	1.56
	0.98 (0.00)	1.54 (-1.28)
	0.99 (1.02)	1.55 (-0.64)
MX5	0.98	1.43
	0.97 (-1.02)	1.46 (2.10)
	0.99 (1.02)	1.45 (1.40)
WG	-----	-----
	1.05	1.41
	1.05	1.41
DR1	1.00	1.33
	1.00(0.00)	1.28 (-3.76)
	1.01 (1.00)	1.28 (-3.76)
DR2	0.93	1.07
	0.93 (0.00)	1.09 (1.87)
	0.93 (0.00)	1.08 (0.93)
DR3	0.91	0.89
	0.89 (-2.20)	0.91 (2.25)
	0.89 (-2.20)	0.91 (2.25)
DR4	1.16	0.72
	1.18 (1.72)	0.73 (1.39)
	1.18 (1.72)	0.72 (0.00)
RF1	1.80	0.58
	1.84 (2.22)	0.63 (8.62)
	1.83 (1.67)	0.62 (6.90)
RF2	1.90	0.40
	1.90 (0.00)	0.44 (10.0)
	1.90 (0.00)	0.43 (7.50)
RF3	1.68	0.27
	1.67 (-0.60)	0.31 (14.81)
	1.66 (-1.19)	0.30 (11.11)

Table 20 (continued)

Zone name	Thermal flux	Epithermal flux
RF4	1.23	0.17
	1.23 (0.00)	0.20 (17.65)
	1.23 (0.00)	0.19 (11.76)
RF5	0.75	----
	0.74 (-1.33)	0.12
	0.74 (-1.33)	0.12
RF6	0.62	0.07
	0.61 (-1.61)	0.08 (14.29)
	0.62 (0.00)	0.08 (14.29)
RF7	0.52	----
	0.51 (-1.92)	0.05
	0.51 (-1.92)	0.05
RF8	0.28	0.03
	0.28 (0.00)	0.03 (0.00)
	0.29 (3.57)	0.03 (0.00)

Table 21

Relative flux distribution in core: 2.96Pu

Data given in the table below have the same meaning as those in Table 18

Zone name	Thermal flux	Epithermal flux
MX1	1.18	1.76
	1.18 (0.00)	1.80 (2.27)
	1.19 (0.85)	1.82 (3.41)
MX2	1.15	1.76
	1.15 (0.00)	1.76 (0.00)
	1.16 (0.87)	1.77 (0.57)
MX3	1.10	1.64
	1.12 (1.82)	1.70 (3.66)
	1.13 (2.73)	1.71 (4.27)
MX4	1.08	1.58
	1.09 (0.93)	1.59(0.63)
	1.10 (1.85)	1.63 (3.16)
MX5	1.14	1.47
	1.14 (0.00)	1.50 (0.67)
	1.14 (0.00)	1.52 (2.61)
WG	1.21	1.42
	1.24 (2.48)	1.45 (2.11)
	1.25 (3.31)	1.46 (2.82)
DR1	1.09	1.30
	1.09 (0.00)	1.30 (0.00)
	1.10 (0.92)	1.31 (0.77)

Table 21 (continued)

Zone name	Thermal flux	Epithermal flux
DR2	0.94	1.07
	0.92 (-2.31)	1.08 (0.93)
	0.92 (-2.31)	1.08 (0.93)
DR3	0.87	0.87
	0.86 (-1.15)	0.89 (2.30)
	0.85 (-2.30)	0.89 (2.30)
DR4	1.11	0.75
	1.13 (1.80)	0.75 (0.00)
	1.13 (1.80)	0.75 (0.00)
RF1	1.65	0.59
	1.69 (2.42)	0.63 (6.78)
	1.69 (2.42)	0.62 (5.08)
RF2	1.70	0.41
	1.75 (2.94)	0.43 (4.88)
	1.75 (2.94)	0.44 (7.32)
RF3	1.49	0.30
	1.50 (0.67)	0.28 (-6.67)
	1.49 (0.00)	0.28 (-6.67)
RF4	1.10	0.21
	1.13 (2.73)	0.18 (-14.28)
	1.13 (2.73)	0.18 (-14.28)
RF5	0.77	0.15
	0.80 (3.90)	0.12 (-20.00)
	0.80 (3.90)	0.12 (-20.00)
RF6	0.52	0.12
	0.55 (5.76)	0.08 (-33.33)
	0.55 (5.76)	0.08 (-33.33)

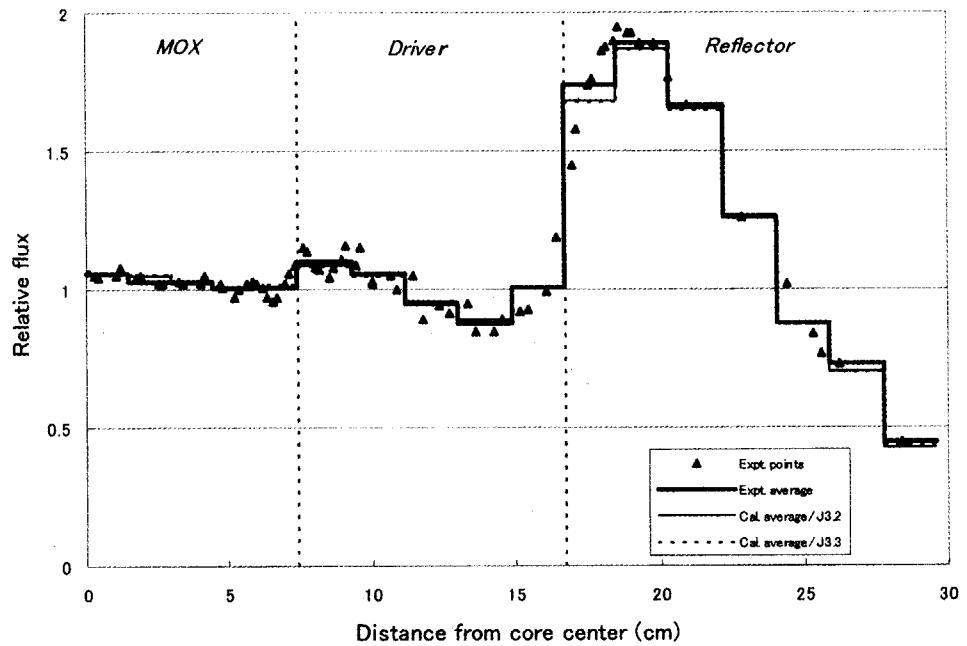


Fig. 9 Thermal flux distribution in core 2.40Pu

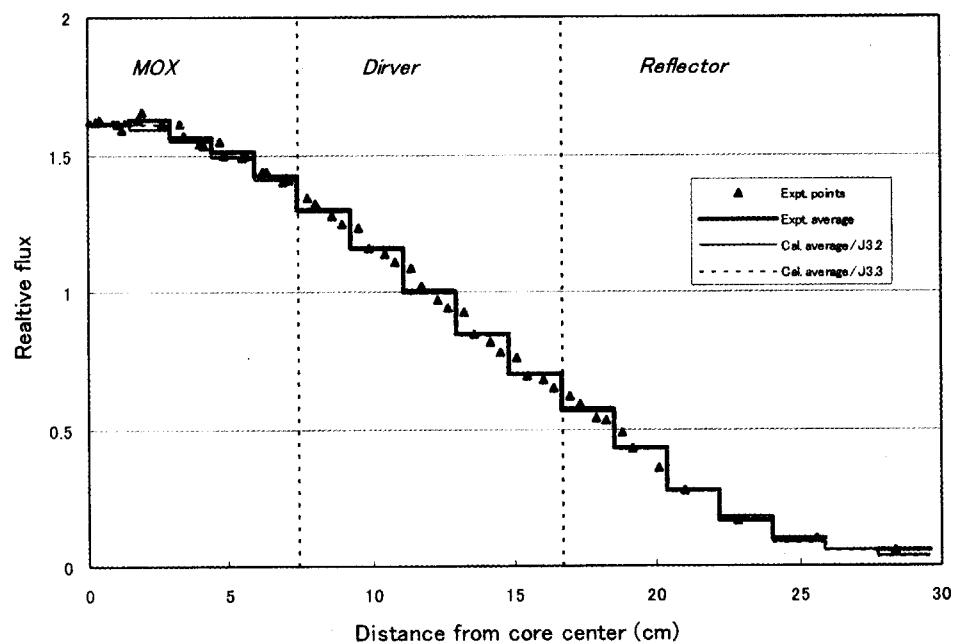


Fig. 10 Epithermal flux distribution in core 2.40Pu

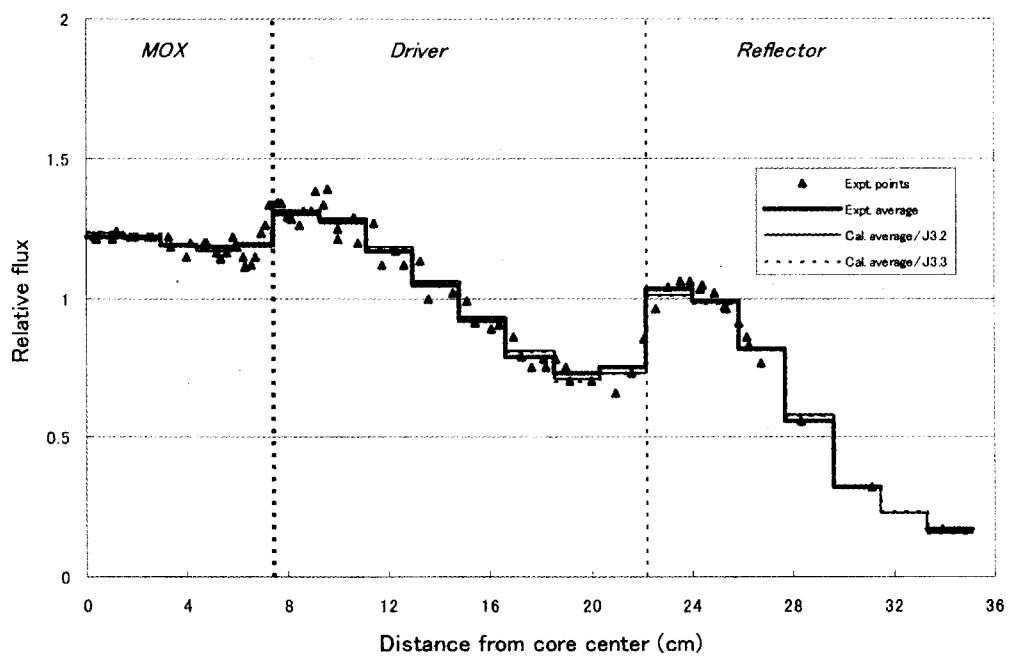


Fig. 11 Thermal flux distribution in core 2.40Pu-B2

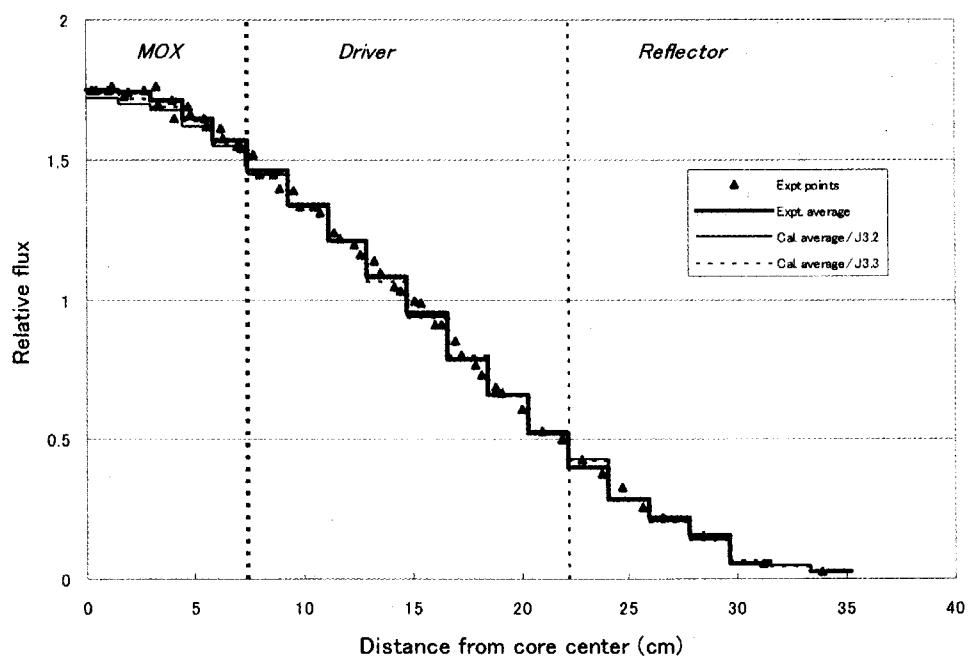


Fig. 12 Epithermal flux distribution in core 2.40Pu-B2

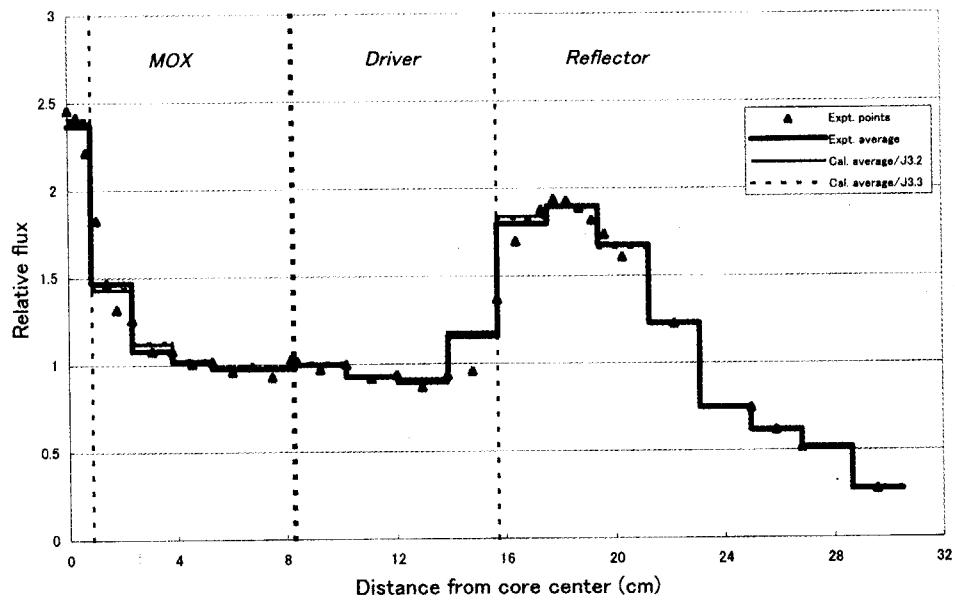


Fig. 13 Thermal flux distribution in core 2.40Pu /G

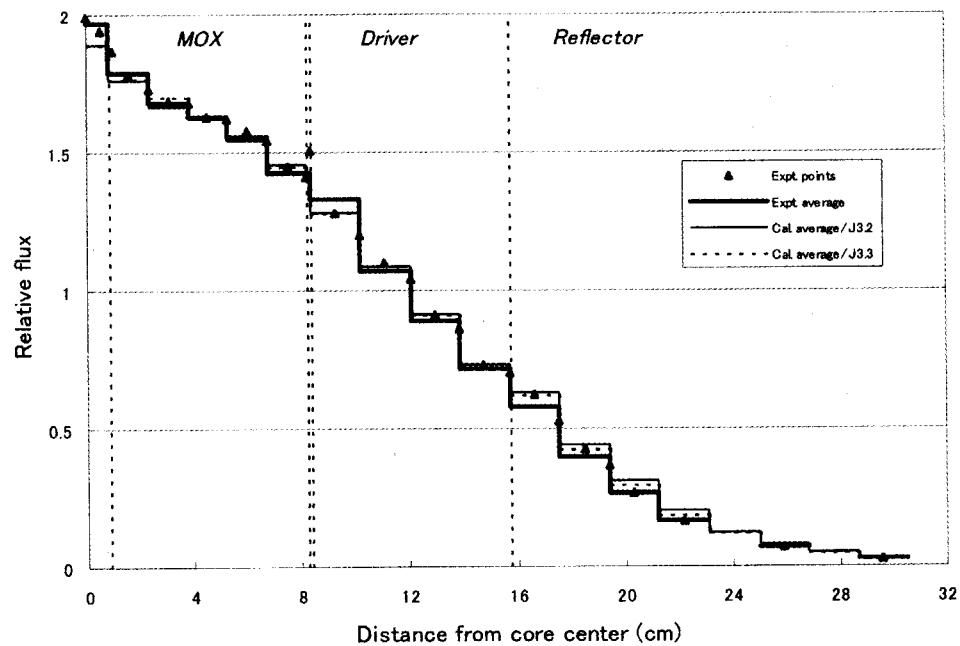


Fig. 14 Epithermal flux distribution in core 2.40Pu /G

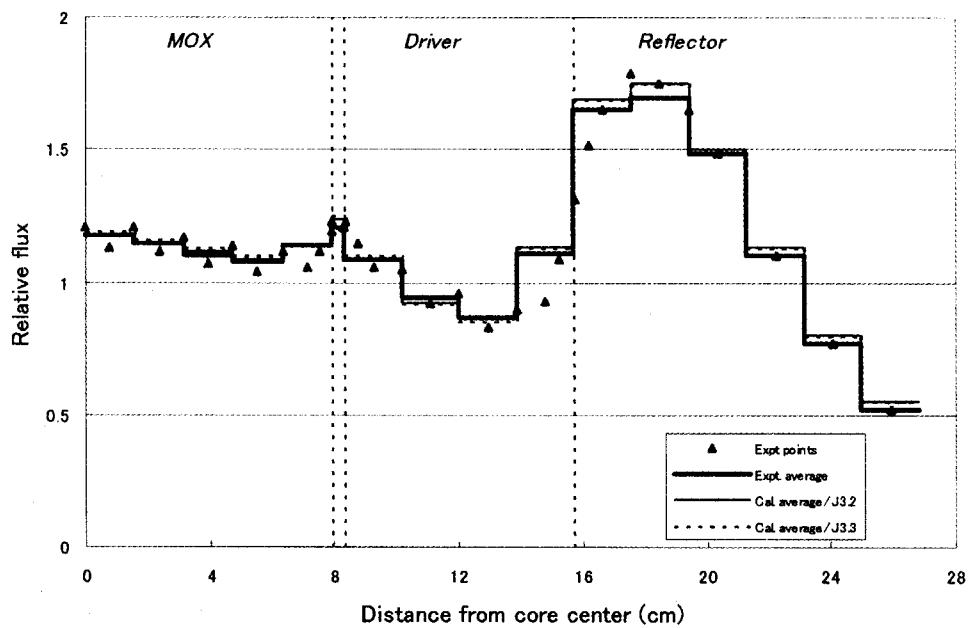


Fig. 15 Thermal flux distribution in core 2.96Pu

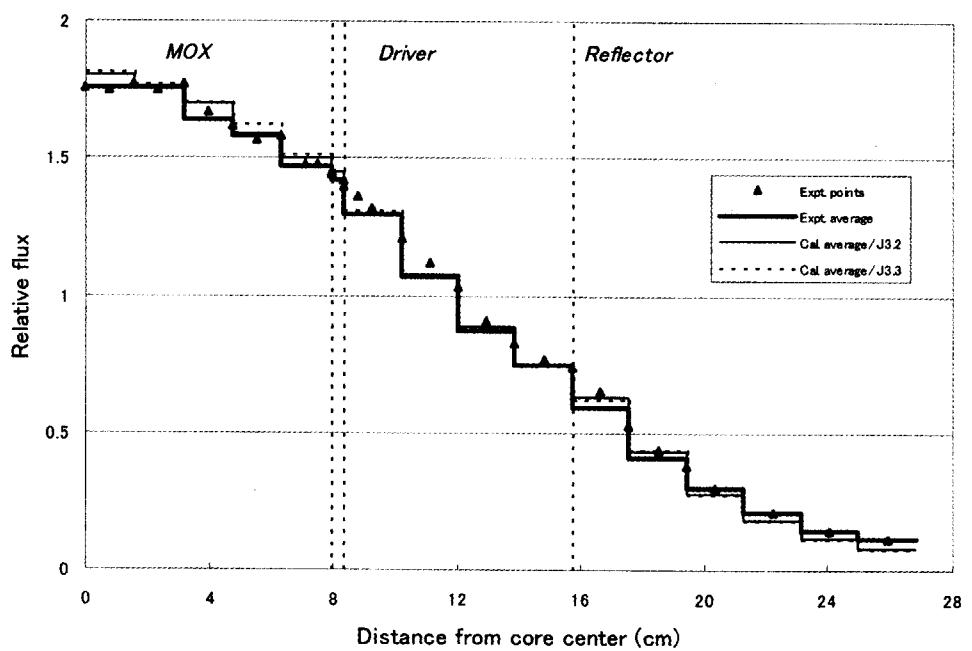


Fig. 16 Epithermal flux distribution in core 2.96Pu

5. Conclusions

Analyses of two-region TCA critical experiments with PWR-type MOX fuels have been performed to investigate the accuracy of the neutronic calculation methods and the associated nuclear data libraries. In the experiment, the criticality, the power distributions and the neutron flux distributions using bare and Cd-covered Au-wires were measured. The calculations have been conducted using the vectorized continuous energy Monte Carlo code MVP with two cross section libraries based on JENDL-3.2 and JENDL-3.3 respectively.

From the comparison between the measurement and calculation, we can conclude the followings:

- (1) The effective multiplication factors for the six cores are calculated with sufficient accuracy with a maximum difference of -0.3% from the measurement,
- (2) The calculated power distributions in the MOX region of five cores show fairly good agreement with the measured data within a maximum difference of -3.0%,
- (3) The thermal flux distributions throughout the regions (MOX, water gap, driver, and the reflector) of four cores are well calculated with a maximum difference of -5.9% from the measured value,
- (4) The calculated epithermal flux distributions in the core regions are also in good agreement with the measured ones, the maximum difference being 4.3%,

Finally, it is concluded that the calculation method and the data libraries employed in the present study posses good accuracy for neutronic calculation of cores containing PWR-type MOX fuels.

Acknowledgments

The first author would like to acknowledge the continued guidance and encouragement of Takamasa Mori and Takenori Suzaki towards successful accomplishment of the work. Thanks to Hiroshi Akie, Yasunobu Nagaya and Keisuke Okumura for technical assistance and to all the members of TCA for providing all the way an excellent working environment. The authors wish to thank Dr. K. Nakajima of Criticality Safety Research Laboratory for his valuable suggestions in reading the manuscript. Finally, the first author gratefully acknowledges the support and assistance of the authorities of the Japan Atomic Energy Research Institute, the Bangladesh Atomic Energy Commission and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. The MOX fuel rods for the present experiment were supplied by the Japan Nuclear Cycle Development Institute.

References:

1. H. Tsuruta, et al., "Critical experiments and analysis on 7x7 PuO₂-UO₂ lattices in light-water moderated UO₂ core", JAERI 1234, (1974).
2. I. Kobayashi, et al., "Critical Experiments on Light-Water Moderated Pu-O₂-UO₂ lattices", J. Nucl. Sci. Technol., Vol. 15(3), pp. 166-182 (1978).
3. A. Charlier, et al., "VENUS International Program(VIP): A Nuclear Data Package for LWR Pu Recycle", Proc. Int. Conf. on Physics of Reactor Operation, Design, and Computation (PHYSOR90), Marseille, France, April 23-26, 1990, Vol. 1, p VI.65-VI.72, (1990).
4. J. Mondot, et al., "EPICURE: An Experimental Program devoted to the Validation of the Calculational Schemes for Plutonium Recycling in PWR's", Proc. Int. Conf. on Physics of Reactor Operation, Design, and Computation (PHYSOR90), Marseille, France, April 23-26, 1990, Vol. 1, p VI.53-VI.64, (1990).
5. K. Nakajima, et al., "Determination of the Modified Conversion Ratio of Light-Water-Moderated Uranium-Plutonium Mixed-Oxide-Fuel Lattice", Nuclear Sci. Eng., Vol. 119, pp. 175-181 (1995).

6. T. Yamamoto, et al., "Core Physics Experiments of 100% MOX Core MISTRAL", Proc. Int. Conf. on Future Nuclear Systems, Global'97, Yokohama, Japan, October 5-10, 1997, Vol. 1, pp. 395-400 (1997).
7. T. Mori, et al., "Vectorization of Continuous Energy Monte-Carlo Method for Neutron Transport Calculation", J. Nucl. Sci. Technol., Vol. 29(4), pp. 325-336 (1992).
8. T. Nakagawa, et al., "Japanese Evaluated Nuclear Data Library Version-3, Revision-2 (JENDL-3.2)", J. Nucl. Sci. Technol., Vol. 32, pp. 1259-1271 (1995).
9. K. Shibata, "JENDL-3.3: A New Version of JENDL General-purpose Library," J. Nucl. Sci. Technol., Vol. 39, p. 1125 (2002).
10. H. Tsuruta, et al., "Critical sizes of Light-Water Moderated UO₂ and PuO₂-UO₂ Lattices", JAERI 1254, (1978).
11. S. Matsuura, et al., "PuO₂-UO₂ Critical Experiment (4) A Measurement of Decay Characteristics of PuO₂-UO₂ Fission Product Gamma-ray", JAERI-memo 3438(unclassified), PCNT-3127 (1969).
12. K. Tsuchihashi, et al., "Revised SRAC Code System", JAERI 1302, (1986).

APPENDIX- A
Sample input for MVP

MVP input for the 2.40Pu core with JENDL-3.2

```

TCA 2-Region(MOX /UO2) PWR core: 2.40Pu(Run 4045); JENDL-3.2
Vm/Vf: MOX(2.4), Driver(1.5); Keff, Power & Flux(response function)
      RESTART RESTART-FILE FISSION EIGEN-VALUE LATTICE
      RUSSIAN-ROULETTE FLUX-PRINT TALLY-LATTICE
      EDIT-MACROSCOPIC-DATA(44404000)
      NO-EDIT-MICROSCOPIC-DATA(11111111)
      DYNAMIC-MEMORY(500000000)

% NHIST = 20000 , NG = 108
% KBATCH = 5500 , NSKIP = 20
% NBATCH = KBATCH + NSKIP
*****
NGROUP(<NG>) NMEMO(80)
NSKIP(<NSKIP>) IRAND(200000909) TCPU( 355.0)
ETOP(2.0000E+7) ETHMAX(4.5) AMLIM(250.) EWCUT(0.0)
NPART(<-(NBATCH*NHIST)>) NHIST(<NHIST>) NBANK(<INT(1.250*NHIST)>)
*****
% MFUEL1 = 1, MCLAD1 = 2, MH2O = 3, MFUEL2= 4, MCLAD2 = 5, MAL = 6
% SUS = 7, CNCRE = 8, AU = 9, CAD =10, MH2OFT =11
% CTEMP = 273.00 + 21.00
% T = 293
$XSEC
* FUEL1 (1)
& IDMAT(<MFUEL1>)
  TEMPMT(<CTEMP>) /* Kelvin
U05003J3( 6.0831E-4 )
U08003J3( 2.2539E-2 )
O06003J3( 4.7228E-2 )
* CLAD1 (2)
& IDMAT(<MCLAD1>)
  TEMPMT(<CTEMP>) /* Kelvin
AL7003J3( 5.5840E-2 )
* H2O (3)
& IDMAT(<MH2O>)
  TEMPMT(<CTEMP>) /* Kelvin
H01H03J3( 6.6751E-2 )
O06003J3( 3.3376E-2 )
* FUEL2 (4)
& IDMAT(<MFUEL2>)
  TEMPMT(<CTEMP>) /* Kelvin
U04003J3( 1.2215E-6 )
U05003J3( 1.5203E-4 )
U08003J3( 2.0910E-2 )
PU8003J3( 4.9397E-7 )
PU9003J3( 9.7764E-4 )
PU0003J3( 9.1496E-5 )
PU1003J3( 1.2364E-5 )
PU2003J3( 9.2016E-7 )
O06003J3( 4.4289E-2 )
* CLAD2 (Zr-4) (5)
& IDMAT(<MCLAD2>)
  TEMPMT(<CTEMP>) /* Kelvin
ZRN003J3( 3.8161E-2 )
SNN003C2( 5.5667E-4 )
FEN003J3( 8.5641E-5 )
CRN003J3( 4.6713E-5 )
O06003J3( 4.3209E-5 )
* AL Plates (6)
& IDMAT(<MAL> )

```

```

TEMPMT(<CTEMP>) /* Kelvin
AL7003J3( 6.0224E-2 )
*Stainless (7)
& IDMAT(<SUS>
  TEMPMT(<CTEMP>) /* Kelvin
  C02003J3( 1.1928E-4 )
  SIN003J3( 1.7003E-3 )
  MN5003J3( 1.7385E-3 )
  P01003J3( 6.9381E-5 )
  SON003J3( 4.4673E-5 )
  NIN003J3( 8.9506E-3 )
  CRN003J3( 1.7450E-2 )
  FEN003J3( 5.7202E-2 )
*Concrete (8)
& IDMAT(<CNCRE>
  TEMPMT(<CTEMP>) /* Kelvin
  H01003J3( 1.3742E-2 )
  O06003J3( 4.5919E-2 )
  C02003J3( 1.1532E-4 )
  NA3003J3( 9.6395E-4 )
  MGN003J3( 1.2388E-4 )
  AL7003J3( 1.7409E-3 )
  SIN003J3( 1.6617E-2 )
  K0N003J3( 4.6052E-4 )
  CAN003J3( 1.5025E-3 )
  FEN003J3( 3.4492E-4 )
* AU wire (9)
*& IDMAT(<AU> )
* TEMPMT(<CTEMP>) /* Kelvin
* AU7003B6( 5.900862E-2 )
* Cd coating (10)
*& IDMAT(<CAD> )
* TEMPMT(<CTEMP>) /* Kelvin
* CDN003J3( 4.628663E-2 )
* H2O (11)
& IDMAT(<MH2OFT>
  TEMPMT(<CTEMP>) /* Kelvin
  H01H03J3( 6.6751E-2 )
  O06003J3( 3.3376E-2 )
END
$GEOM
% P1 = 1.849, P2 = 1.473, NP1 = 18, NP2= 10, F1 = 16.83
% HT1 = F1+144.15, PT1 = HT1+ 19.52, JT1 = PT1+0.7
% HT2 = F1+90.93, PT2= HT2+5.08, JT2 = PT2+0.7
% KT = 1.27+2.2+13.8+27.0
% WLEVEL = 83.66
% WH1 = F1+ 10.0
% WH2 = F1+ 73.66
% C1 = 1.25/2, D1 = 1.417/2, C2 = 0.8579/2, D2 = 0.998/2
% DH1 = NP1*P1, GH1 = DH1+60, DH2 = NP2*P2, GH2 = DH2+ 0.062
% CFUEL = F1+WLEVEL/2, ZCUT = F1 + WLEVEL
***** LATTICE DATA *****
IDLAT(100)
LTYP(1) NVLAT( <NP1> <NP1> 1 )
SZLAT( <P1> <P1> <PT1> )
*****
KLATT (
  3 3 3 3 3 1 1 1 1 1 1 1 1 1 3 3 3 3 3
  3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
  3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
  3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
  3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
  1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1
  1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1
  1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1

```



```
*****
 Bodies for Lattice 200
 RPP ( 20001 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> 15.24 <PT2>
 RPP ( 20002 <-DH2/2.> <DH2/2.> <-DH2/2.> <DH2/2.> 15.24 <PT2>
 RPP ( 20003 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> 15.94 16.64)
 RPP ( 20004 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> <JT2> <PT1> )
 RPP ( 20005 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> <PT2> <JT2> )
 ***** To divide water gap outside MOX axially into three parts
 % F2 = 15.24
 RPP ( 20011 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> <WH2> <ZCUT>
 RPP ( 20012 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> <WH1> <WH2>
 RPP ( 20013 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> <F2> <WH1>
 RPP ( 20021 <-DH2/2.> <DH2/2.> <-DH2/2.> <DH2/2.> <WH2> <ZCUT>
 RPP ( 20022 <-DH2/2.> <DH2/2.> <-DH2/2.> <DH2/2.> <WH1> <WH2>
 RPP ( 20023 <-DH2/2.> <DH2/2.> <-DH2/2.> <DH2/2.> <F2> <WH1>
 ***** Bodies for TCA base
 RPP ( 500 <-GH1/2.> <GH1/2.> <-GH1/2.> <GH1/2.> <-KT> 0.0)
 RPP ( 501 <-GH1/2.> <GH1/2.> <-GH1/2.> <GH1/2.> -1.27 0.0)
 RPP ( 502 <-GH1/2.> <GH1/2.> <-GH1/2.> <GH1/2.> -3.47 -1.27)
 RPP ( 503 <-GH1/2.> <GH1/2.> <-GH1/2.> <GH1/2.> -17.27 -3.47 )
 RPP ( 504 <-GH1/2.> <GH1/2.> <-GH1/2.> <GH1/2.> <-KT> -17.27 )
 ***** Bodies for MOX base
 RPP ( 400 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> 0.0 15.24)
 RPP ( 401 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> 13.24 15.24)
 RPP ( 402 <-GH2/2.> <GH2/2.> <-GH2/2.> <GH2/2.> 0.0 13.24)
 RPP ( 403 -6.5 6.5 -6.5 6.5 0.0 13.24 )
 ***** Bodies for cells 1 & 3
 RPP ( 1111 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> 0.0 <PT1> )
 RPP ( 1112 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <HT1> <PT1> )
 RPP ( 1113 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <ZCUT> <HT1> )
 RPP ( 11131 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <JT2> <HT1> )
 RPP ( 11132 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <PT2> <JT2> )
 RPP ( 11133 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <ZCUT> <PT2> )
 RPP ( 1114 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <F1> <ZCUT> )
 RPP ( 11141 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <WH2> <ZCUT> )
 RPP ( 11142 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <WH1> <WH2> )
 RPP ( 11143 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> <F1> <WH1> )
 RPP ( 1115 <-P1/2.> <P1/2.> <-P1/2.> <P1/2.> 0.0 <F1> )
 ***** Bodies for cell 2
 RPP ( 2221 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> 15.24 <PT2> )
 RPP ( 2222 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <HT2> <PT2> )
 RPP ( 2223 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <ZCUT> <HT2> )
 * RPP ( 2224 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <F1> <ZCUT> )
 RPP ( 22241 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <WH2> <ZCUT> )
 RPP ( 22242 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <WH1> <WH2> )
 RPP ( 22243 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> <F1> <WH1> )
 RPP ( 2225 <-P2/2.> <P2/2.> <-P2/2.> <P2/2.> 15.24 <F1> )
 ***** Bodies for cells 5,6, and 7
 % P1H =P1/2., P2H =P2/2., WB1 = P1H -0.0796647, WB2 = P2H -0.1
 % WB3=4.7516129, P1Q=P1/4., P2Q=P2/4.
 ***** To insert Water zone (at y=0.0) for flux calculation
 * RPP ( 101 <-P1H> < P1H> <-P1H> <-WB1> <WH1> <WH2> )
 RPP ( 1011 <-P1H> <-P1Q> <-P1H> <-WB1> <WH1> <WH2> )
 RPP ( 1012 <-P1Q> 0.0 <-P1H> <-WB1> <WH1> <WH2> )
 RPP ( 1013 0.0 < P1Q> <-P1H> <-WB1> <WH1> <WH2> )
 RPP ( 1014 < P1Q> < P1H> <-P1H> <-WB1> <WH1> <WH2> )
 * RPP ( 201 <-P2H> < P2H> <-P2H> <-WB2> <WH1> <WH2> )
 RPP ( 2011 <-P2H> <-P2Q> <-P2H> <-WB2> <WH1> <WH2> )
 RPP ( 2012 <-P2Q> 0.0 <-P2H> <-WB2> <WH1> <WH2> )
 RPP ( 2013 0.0 < P2Q> <-P2H> <-WB2> <WH1> <WH2> )
 RPP ( 2014 < P2Q> < P2H> <-P2H> <-WB2> <WH1> <WH2> )
 RPP ( 301 <-GH2/2.> <-DH2/2.> <-WB3> < WB3> <WH1> <WH2> )
 RPP ( 302 < DH2/2.> < GH2/2.> <-WB3> < WB3> <WH1> <WH2> )
 % WB4=64*0.0796647, DH=DH1/2.
 RPP ( 611 <-DH> <-(DH+P1Q)> <-WB4> < WB4> <WH1> <WH2> )
 RPP ( 612 <-(DH+P1Q)> <-(DH+2*P1Q)> <-WB4> < WB4> <WH1> <WH2> )
```

***** Bodies for cylindrical parts of cells 1 2 & 3

CYL (11 0.0 0.0 0.0 <PT1> <C1>)
CYL (12 0.0 0.0 0.0 <PT1> <D1>)

```

CYL ( 21   0.0 0.0 0.0      <PT2>  <C2> )
CYL ( 22   0.0 0.0 0.0      <PT2>  <D2> )
END

***** ZONE DEFINITIONS *****
ETV :    : -1000 :-40000
IV :IV1  : 0   : 40000 -10000 -30001 -30002 -500
IV :IV2  : 0   : 20004
IV :IV3  : 0   : 20001 -20002 -10000
GRD:TGP :<MAL> : 30001
GRD:MGP :<MAL> : 20005
* GRD:BGP1 :<MAL> : 30003 -400
* GRD:BGP2 :<MAL> : 20003
GRD:MOXSP:<MAL> : 401
GRD:FSP  :<MAL> : 501
GRD:MOXBX:<MAL> : 402 -403
SUS:SUS  :<SUS> : 502
CON:CON  :<CNCRE>: 504
WG :WG01  :<MH2O>   : 20011 -20021
WG :WGFTL :<MH2OFT> : 20012 -20022   301
WG :WGFTR :<MH2OFT> : 20012 -20022   302
WG :WG02  :<MH2O>   : 20012 -20022 -301 -302
WG :WG03  :<MH2O>   : 20013 -20023
RF :RF611 :<MH2OFT> : 611
RF :RF612 :<MH2OFT> : 612
RF :RF613 :<MH2OFT> : 613
RF :RF614 :<MH2OFT> : 614
RF :RF621 :<MH2OFT> : 621
RF :RF622 :<MH2OFT> : 622
RF :RF623 :<MH2OFT> : 623
RF :RF624 :<MH2OFT> : 624
RF :RF631 :<MH2OFT> : 631
RF :RF632 :<MH2OFT> : 632
RF :RF633 :<MH2OFT> : 633
RF :RF634 :<MH2OFT> : 634
RF :RF641 :<MH2OFT> : 641
RF :RF642 :<MH2OFT> : 642
RF :RF643 :<MH2OFT> : 643
RF :RF644 :<MH2OFT> : 644
RF :RF651 :<MH2OFT> : 651
RF :RF652 :<MH2OFT> : 652
RF :RF653 :<MH2OFT> : 653
RF :RF654 :<MH2OFT> : 654
RF :RF661 :<MH2OFT> : 661
RF :RF662 :<MH2OFT> : 662
RF :RF663 :<MH2OFT> : 663
RF :RF664 :<MH2OFT> : 664
RF :RF671 :<MH2OFT> : 671
RF :RF672 :<MH2OFT> : 672
RF :RF673 :<MH2OFT> : 673
RF :RF674 :<MH2OFT> : 674
RF :RF681 :<MH2OFT> : 681
RF :RF682 :<MH2OFT> : 682
RF :RF683 :<MH2OFT> : 683
RF :RF684 :<MH2OFT> : 684
RF :RF811 :<MH2OFT> : 811
RF :RF812 :<MH2OFT> : 812
RF :RF813 :<MH2OFT> : 813
RF :RF814 :<MH2OFT> : 814
RF :RF821 :<MH2OFT> : 821
RF :RF822 :<MH2OFT> : 822
RF :RF823 :<MH2OFT> : 823
RF :RF824 :<MH2OFT> : 824
RF :RF831 :<MH2OFT> : 831
RF :RF832 :<MH2OFT> : 832

```

```

RF :RF833 :<MH2OFT> : 833
RF :RF834 :<MH2OFT> : 834
RF :RF841 :<MH2OFT> : 841
RF :RF842 :<MH2OFT> : 842
RF :RF843 :<MH2OFT> : 843
RF :RF844 :<MH2OFT> : 844
RF :RF851 :<MH2OFT> : 851
RF :RF852 :<MH2OFT> : 852
RF :RF853 :<MH2OFT> : 853
RF :RF854 :<MH2OFT> : 854
RF :RF861 :<MH2OFT> : 861
RF :RF862 :<MH2OFT> : 862
RF :RF863 :<MH2OFT> : 863
RF :RF864 :<MH2OFT> : 864
RF :RF871 :<MH2OFT> : 871
RF :RF872 :<MH2OFT> : 872
RF :RF873 :<MH2OFT> : 873
RF :RF874 :<MH2OFT> : 874
RF :RF881 :<MH2OFT> : 881
RF :RF882 :<MH2OFT> : 882
RF :RF883 :<MH2OFT> : 883
RF :RF884 :<MH2OFT> : 884
REF:WRF1 :<MH2O> : 10000 -20000
          -611 -612 -613 -614 -621 -622 -623 -624
          -631 -632 -633 -634 -641 -642 -643 -644
          -651 -652 -653 -654 -661 -662 -663 -664
          -671 -672 -673 -674 -681 -682 -683 -684
          -811 -812 -813 -814 -821 -822 -823 -824
          -831 -832 -833 -834 -841 -842 -843 -844
          -851 -852 -853 -854 -861 -862 -863 -864
          -871 -872 -873 -874 -881 -882 -883 -884

REF:WRF2 :<MH2O> : 403
REF:WRF3 :<MH2O> : 503
*****
COR1:LAT1: -100 : 30002 -30004
#SUBFRAME
  NAMES ( D R  D3 D4 D5 D6 D7 )
*****
  SPACE (
    2 2 2 2 2 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    7 6 5 4 3 0 0 0 0 0 0 0 0 0 0 3 4 5 6 7
    7 6 5 4 3 0 0 0 0 0 0 0 0 0 0 3 4 5 6 7
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
    2 2 2 2 2 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 )
#END SUBFRAME
  COR2:LAT2 : -200 : 20002
#SUBFRAME
  NAMES ( A0
    B0 B1
    C0 C1 C2
    D0 D1 D2 D3
    E0 E1 E2 E3 E4

```

```

A4 B4 C4 D4 )
*****
SPACE ( 1 2 4 7 16 16 7 4 2 1
        2 3 5 8 17 17 8 5 3 2
        4 5 6 9 18 18 9 6 5 4
        7 8 9 10 19 19 10 9 8 7
        11 12 13 14 15 15 14 13 12 11
        11 12 13 14 15 15 14 13 12 11
        7 8 9 10 19 19 10 9 8 7
        4 5 6 9 18 18 9 6 5 4
        2 3 5 8 17 17 8 5 3 2
        1 2 4 7 16 16 7 4 2 1 )
#END SUBFRAME
***** FUEL1 PIN CELL *****
#CELL ID(1) TYPE(BOX)
C110:    : -999 : -1111
C111:TOP11 : 0   : 1111 -12   +1112
C112:TOP12 :<MCLAD1> : 1111 12 -11 +1112
C113:TOP13 : 0   : 1111 11   +1112
C114:DRY11 :<MFUEL1> : 1111 11   +11131
C115:DRY12 :<MCLAD1> : 1111 12 -11 +11131
C116:DRY13 : 0   : 1111 -12   +11131
C117:DRY14 :<MFUEL1> : 1111 11   +11132
C118:DRY15 :<MCLAD1> : 1111 12 -11 +11132
C119:DRY16 : <MAL> : 1111 -12   +11132
C120:DRY17 :<MFUEL1> : 1111 11   +11133
C121:DRY18 :<MCLAD1> : 1111 12 -11 +11133
C122:DRY19 : 0   : 1111 -12   +11133
C123:WET111:<MFUEL1> : 1111 11   +11141
C124:WET112:<MCLAD1> : 1111 12 -11 +11141
C125:WET113:<MH2O> : 1111 -12   +11141
C123:WET121:<MFUEL1> : 1111 11   +11142
C124:WET122:<MCLAD1> : 1111 12 -11 +11142
C125:WET123:<MH2O> : 1111 -12   +11142
C123:WET141:<MFUEL1> : 1111 11   +11143
C124:WET142:<MCLAD1> : 1111 12 -11 +11143
C125:WET143:<MH2O> : 1111 -12   +11143
C126:BOT11 :<MCLAD1> : 1111 12   +1115
C127:BOT12 :<MH2O> : 1111 -12   +1115 -30003
C128:BOT13 :<MAL> : 1111 -12   +1115 30003
***** FUEL2 PIN CELL *****
#CELL ID(2) TYPE(BOX)
C210:    : -999 : -2221
C211:TOP21 : 0   : 2221 -22   +2222
C212:TOP22 :<MCLAD2> : 2221 22 -21 +2222
C213:TOP23 : 0   : 2221 21   +2222
C214:DRY21 :<MFUEL2> : 2221 21   +2223
C215:DRY22 :<MCLAD2> : 2221 22 -21 +2223
C216:DRY23 : 0   : 2221 -22   +2223
C217:WET211:<MFUEL2> : 2221 21   +22241
C218:WET212:<MCLAD2> : 2221 22 -21 +22241
C219:WET213:<MH2O> : 2221 -22   +22241
C220:WET221:<MFUEL2> : 2221 21   +22242
C221:WET222:<MCLAD2> : 2221 22 -21 +22242
C222:WET223:<MH2O> : 2221 -22   +22242
C223:WET241:<MFUEL2> : 2221 21   +22243
C224:WET242:<MCLAD2> : 2221 22 -21 +22243
C225:WET243:<MH2O> : 2221 -22   +22243
C226:BOT21 :<MCLAD2> : 2221 22   +2225
C227:BOT22 :<MH2O> : 2221 -22   +2225 -20003
C228:BOT23 :<MAL> : 2221 -22   +2225 20003
***** WATER PIN CELL *****
#CELL ID(3) TYPE(BOX)
C310:    : -999 : -1111
C311:TOP3 : 0   : +1112

```

```

C312:DRY3   :   0   : +1113
C313:WET3   : <MH2O>   : +1114
C314:BOT3   : <MH2O>   : +1115
#CELL ID(6) TYPE(BOX)
C610:      : -999   : -1111
C611:TOP61  :   0   : 1111 -12   +1112
C612:TOP62  : <MCLAD1> : 1111 12 -11 +1112
C613:TOP63  :   0   : 1111 11   +1112
C614:DRY61  : <MFUEL1> : 1111 11   +11131
C615:DRY62  : <MCLAD1> : 1111 12 -11 +11131
C616:DRY63  :   0   : 1111 -12   +11131
C617:DRY64  : <MFUEL1> : 1111 11   +11132
C618:DRY65  : <MCLAD1> : 1111 12 -11 +11132
C619:DRY66  : <MAL>   : 1111 -12   +11132
C620:DRY67  : <MFUEL1> : 1111 11   +11133
C621:DRY68  : <MCLAD1> : 1111 12 -11 +11133
C622:DRY69  :   0   : 1111 -12   +11133
C623:WET611 : <MFUEL1> : 1111 11   +11141
C624:WET612 : <MCLAD1> : 1111 12 -11 +11141
C625:WET613 : <MH2O>   : 1111 -12   +11141
C623:WET621 : <MFUEL1> : 1111 11   +11142
C624:WET622 : <MCLAD1> : 1111 12 -11 +11142
C625:WET6231:<MH2OFT> : 1111 1011 +11142
C625:WET6232:<MH2OFT> : 1111 1012 +11142
C625:WET6233:<MH2OFT> : 1111 1013 +11142
C625:WET6234:<MH2OFT> : 1111 1014 +11142
C625:WET624 : <MH2O>   : 1111 -12 -1011 -1012 -1013 -1014 +11142
C623:WET631 : <MFUEL1> : 1111 11   +11143
C624:WET632 : <MCLAD1> : 1111 12 -11 +11143
C625:WET633 : <MH2O>   : 1111 -12   +11143
C626:BOT61  : <MCLAD1> : 1111 12   +1115
C627:BOT62  : <MH2O>   : 1111 -12   +1115 -30003
C628:BOT63  : <MAL>   : 1111 -12   +1115  30003
#CELL ID(7) TYPE(BOX)
C710:      : -999   : -2221
C711:TOP71  :   0   : 2221 -22   +2222
C712:TOP72  : <MCLAD2> : 2221 22 -21 +2222
C713:TOP73  :   0   : 2221 21   +2222
C714:DRY71  : <MFUEL2> : 2221 21   +2223
C715:DRY72  : <MCLAD2> : 2221 22 -21 +2223
C716:DRY73  :   0   : 2221 -22   +2223
C717:WET711 : <MFUEL2> : 2221 21   +22241
C718:WET712 : <MCLAD2> : 2221 22 -21 +22241
C719:WET713 : <MH2O>   : 2221 -22   +22241
C720:WET721 : <MFUEL2> : 2221 21   +22242
C721:WET722 : <MCLAD2> : 2221 22 -21 +22242
C720:WET7231:<MH2OFT> : 2221      2011 +22242
C720:WET7232:<MH2OFT> : 2221      2012 +22242
C720:WET7233:<MH2OFT> : 2221      2013 +22242
C720:WET7234:<MH2OFT> : 2221      2014 +22242
C720:WET724 : <MH2O>   : 2221 -22 -2011 -2012 -2013 -2014 +22242
C723:WET731 : <MFUEL2> : 2221 21   +22243
C724:WET732 : <MCLAD2> : 2221 22 -21 +22243
C725:WET733 : <MH2O>   : 2221 -22   +22243
C726:BOT71  : <MCLAD2> : 2221 22   +2225
C727:BOT72  : <MH2O>   : 2221 -22   +2225 -20003
C728:BOT73  : <MAL>   : 2221 -22   +2225  20003
#END CELL
***** TALLY REGION DATA *****
#TALLY REGION
***** Total power of 100 MOX fuels
DEFINE @MOXPOT (LAT2:A*!WET221 LAT2:B*!WET221
                 LAT2:C*!WET221 LAT2:D*!WET221
                 LAT2:E*!WET721 )
***** POWER TALLY; Fission reaction Rates

```

```

DEFINE @MXRA0 (!LAT2:A0!WET221 )
DEFINE @MXRB0 (!LAT2:B0!WET221 )
DEFINE @MXRB1 (!LAT2:B1!WET221 )
DEFINE @MXRC0 (!LAT2:C0!WET221 )
DEFINE @MXRC1 (!LAT2:C1!WET221 )
DEFINE @MXRC2 (!LAT2:C2!WET221 )
DEFINE @MXRD0 (!LAT2:D0!WET221 )
DEFINE @MXRD1 (!LAT2:D1!WET221 )
DEFINE @MXRD2 (!LAT2:D2!WET221 )
DEFINE @MXRD3 (!LAT2:D3!WET221 )
DEFINE @MXRE0 (!LAT2:E0!WET721 !LAT2:A4!WET221 )
DEFINE @MXRE1 (!LAT2:E1!WET721 !LAT2:B4!WET221 )
DEFINE @MXRE2 (!LAT2:E2!WET721 !LAT2:C4!WET221 )
DEFINE @MXRE3 (!LAT2:E3!WET721 !LAT2:D4!WET221 )
DEFINE @MXRE4 (!LAT2:E4!WET721 )
***** FLUX TALLY; Capture reaction rate *****
DEFINE @BAUMXTOT (!LAT2:E0!WET723*
                  !LAT2:E1!WET723*
                  !LAT2:E2!WET723*
                  !LAT2:E3!WET723*
                  !LAT2:E4!WET723*)
DEFINE @BAUMXE4 (!LAT2:E4!WET723*)
DEFINE @BAUMXE41 (!LAT2:E4!WET7231)
DEFINE @BAUMXE42 (!LAT2:E4!WET7232)
DEFINE @BAUMXE43 (!LAT2:E4!WET7233)
DEFINE @BAUMXE44 (!LAT2:E4!WET7234)
DEFINE @BAUMXE3 (!LAT2:E3!WET723*)
DEFINE @BAUMXE31 (!LAT2:E3!WET7231)
DEFINE @BAUMXE32 (!LAT2:E3!WET7232)
DEFINE @BAUMXE33 (!LAT2:E3!WET7233)
DEFINE @BAUMXE34 (!LAT2:E3!WET7234)
DEFINE @BAUMXE2 (!LAT2:E2!WET723*)
DEFINE @BAUMXE21 (!LAT2:E2!WET7231)
DEFINE @BAUMXE22 (!LAT2:E2!WET7232)
DEFINE @BAUMXE23 (!LAT2:E2!WET7233)
DEFINE @BAUMXE24 (!LAT2:E2!WET7234)
DEFINE @BAUMXE1 (!LAT2:E1!WET723*)
DEFINE @BAUMXE11 (!LAT2:E1!WET7231)
DEFINE @BAUMXE12 (!LAT2:E1!WET7232)
DEFINE @BAUMXE13 (!LAT2:E1!WET7233)
DEFINE @BAUMXE14 (!LAT2:E1!WET7234)
DEFINE @BAUMXE0 (!LAT2:E0!WET723*)
DEFINE @BAUMXE01 (!LAT2:E0!WET7231)
DEFINE @BAUMXE02 (!LAT2:E0!WET7232)
DEFINE @BAUMXE03 (!LAT2:E0!WET7233)
DEFINE @BAUMXE04 (!LAT2:E0!WET7234)
DEFINE @WGFTLR (WGFTL WGFTR)
DEFINE @BAUDRTOT (!LAT1:D3!WET623*
                  !LAT1:D4!WET623*
                  !LAT1:D5!WET623*
                  !LAT1:D6!WET623*
                  !LAT1:D7!WET623*)
DEFINE @BAUDR3 (!LAT1:D3!WET623*)
DEFINE @BAUDR31 (!LAT1:D3!WET6231)
DEFINE @BAUDR32 (!LAT1:D3!WET6232)
DEFINE @BAUDR33 (!LAT1:D3!WET6233)
DEFINE @BAUDR34 (!LAT1:D3!WET6234)
DEFINE @BAUDR4 (!LAT1:D4!WET623*)
DEFINE @BAUDR41 (!LAT1:D4!WET6231)
DEFINE @BAUDR42 (!LAT1:D4!WET6232)
DEFINE @BAUDR43 (!LAT1:D4!WET6233)
DEFINE @BAUDR44 (!LAT1:D4!WET6234)
DEFINE @BAUDR5 (!LAT1:D5!WET623*)
DEFINE @BAUDR51 (!LAT1:D5!WET6231)
DEFINE @BAUDR52 (!LAT1:D5!WET6232)

```

```

DEFINE @BAUDR53 (!LAT1:D5!WET6233)
DEFINE @BAUDR54 (!LAT1:D5!WET6234)
DEFINE @BAUDR6 (!LAT1:D6!WET623*)
DEFINE @BAUDR61 (!LAT1:D6!WET6231)
DEFINE @BAUDR62 (!LAT1:D6!WET6232)
DEFINE @BAUDR63 (!LAT1:D6!WET6233)
DEFINE @BAUDR64 (!LAT1:D6!WET6234)
DEFINE @BAUDR7 (!LAT1:D7!WET623*)
DEFINE @BAUDR71 (!LAT1:D7!WET6231)
DEFINE @BAUDR72 (!LAT1:D7!WET6232)
DEFINE @BAUDR73 (!LAT1:D7!WET6233)
DEFINE @BAUDR74 (!LAT1:D7!WET6234)
* DEFINE @BAURFTOT (RF*)
DEFINE @BAURFTOT (RF61* RF62* RF63* RF64* RF65* RF66* RF67*
                  RF81* RF82* RF83* RF84* RF85* RF86* RF87*)
DEFINE @CAURFTOT (RF61* RF62* RF63* RF64* RF65*
                  RF81* RF82* RF83* RF84* RF85*)
DEFINE @BAURF1 (RF61* RF81*)
DEFINE @BAURF11 (RF611 RF811)
DEFINE @BAURF12 (RF612 RF812)
DEFINE @BAURF13 (RF613 RF813)
DEFINE @BAURF14 (RF614 RF814)
DEFINE @BAURF2 (RF62* RF82*)
DEFINE @BAURF21 (RF621 RF821)
DEFINE @BAURF22 (RF622 RF822)
DEFINE @BAURF23 (RF623 RF823)
DEFINE @BAURF24 (RF624 RF824)
DEFINE @BAURF3 (RF63* RF83*)
DEFINE @BAURF31 (RF631 RF831)
DEFINE @BAURF32 (RF632 RF832)
DEFINE @BAURF33 (RF633 RF833)
DEFINE @BAURF34 (RF634 RF834)
DEFINE @BAURF4 (RF64* RF84*)
DEFINE @BAURF41 (RF641 RF841)
DEFINE @BAURF42 (RF642 RF842)
DEFINE @BAURF43 (RF643 RF843)
DEFINE @BAURF44 (RF644 RF844)
DEFINE @BAURF5 (RF65* RF85*)
DEFINE @BAURF51 (RF651 RF851)
DEFINE @BAURF52 (RF652 RF852)
DEFINE @BAURF53 (RF653 RF853)
DEFINE @BAURF54 (RF654 RF854)
DEFINE @BAURF6 (RF66* RF86*)
DEFINE @BAURF61 (RF661 RF861)
DEFINE @BAURF62 (RF662 RF862)
DEFINE @BAURF63 (RF663 RF863)
DEFINE @BAURF64 (RF664 RF864)
DEFINE @BAURF7 (RF67* RF87*)
DEFINE @BAURF71 (RF671 RF871)
DEFINE @BAURF72 (RF672 RF872)
DEFINE @BAURF73 (RF673 RF873)
DEFINE @BAURF74 (RF674 RF874)
DEFINE @BAURF8 (RF68* RF88*)
DEFINE @BAURF81 (RF681 RF881)
DEFINE @BAURF82 (RF682 RF882)
DEFINE @BAURF83 (RF683 RF883)
DEFINE @BAURF84 (RF684 RF884)
DEFINE @TOTAL (!*:!* *)

$END GEOM
***** Initial Source ( for zero-step )
$SOURCE
*#SOURCE-START
& NEUTRON
  RATIO( 1.0 )
  @E = #FISSION(PU9* 2.53E-02) ;

```

```

@X = #UNIFORM( <-DH1/2.> <DH1/2.> ) ;
@Y = #UNIFORM( <-DH1/2.> <DH1/2.> ) ;
@Z = #COSINE( <F1> <F1+WLEVEL> ) ;
*#SOURCE-END
$END SOURCE
*
***** RESPONCE PARAMETERS *****
NRESP(2)
RESP.N(
2.38132e-03 1.10242e-03 2.93120e-03 6.60401e-03 1.14989e-02
2.12718e-02 3.37835e-02 5.30515e-02 6.73920e-02 7.50607e-02
8.38236e-02 9.46273e-02 1.17162e-01 1.50540e-01 1.83527e-01
2.24972e-01 2.48426e-01 2.66152e-01 2.88732e-01 3.14969e-01
3.52048e-01 4.01247e-01 4.50257e-01 5.34763e-01 6.04457e-01
6.68673e-01 8.14608e-01 9.89079e-01 1.14346e+00 1.43548e+00
1.80258e+00 1.56554e+00 2.05514e+00 1.93685e+00 3.10501e+00
3.71652e+00 4.74516e+00 6.75791e+00 7.15541e+00 9.38153e+00
7.67530e+00 1.06973e+01 8.89769e+00 7.48289e+00 3.79264e+00
1.50280e+01 5.21137e+00 8.13953e-01 1.10804e+01 3.46523e+01
7.00235e-01 2.65433e-01 3.30329e-01 5.36848e-01 1.00668e+00
2.23762e+00 6.12243e+00 2.37547e+01 1.75337e+02 2.64129e+02
8.13928e+01 4.11080e+01 2.94273e+01 2.53873e+01 2.45831e+01
2.34221e+01 2.27097e+01 2.24119e+01 2.25299e+01 2.30692e+01
2.34845e+01 2.39239e+01 2.47884e+01 2.56460e+01 2.63828e+01
2.74453e+01 2.80449e+01 2.85215e+01 2.88484e+01 2.96022e+01
3.03871e+01 3.13355e+01 3.21153e+01 3.26178e+01 3.41201e+01
3.54676e+01 3.64322e+01 3.77463e+01 3.92394e+01 4.06471e+01
4.28430e+01 4.49113e+01 4.71985e+01 4.99865e+01 5.29298e+01
5.64099e+01 6.04696e+01 6.50827e+01 7.05325e+01 7.71466e+01
8.49541e+01 9.48915e+01 1.07482e+02 1.24280e+02 1.46541e+02
1.78653e+02 2.24941e+02 2.70109e+02
2.42430e-03 1.10985e-03 2.94317e-03 6.63906e-03 1.16112e-02
2.14233e-02 3.39483e-02 5.36385e-02 6.81770e-02 7.60822e-02
8.58294e-02 9.64894e-02 1.19898e-01 1.52700e-01 1.85311e-01
2.27294e-01 2.52607e-01 2.70258e-01 2.89824e-01 3.13571e-01
3.52229e-01 4.00366e-01 4.54568e-01 5.31563e-01 6.00303e-01
6.68534e-01 8.13347e-01 9.83406e-01 1.15188e+00 1.43850e+00
1.80427e+00 1.56851e+00 2.09124e+00 2.00223e+00 2.97738e+00
3.65300e+00 4.53678e+00 6.71006e+00 7.18454e+00 9.28353e+00
7.93405e+00 1.03520e+01 8.91807e+00 7.70504e+00 4.14881e+00
1.48098e+01 5.44878e+00 8.42281e-01 1.12573e+01 3.46207e+01
7.25510e-01 2.64699e-01 3.25490e-01 5.34472e-01 1.00560e+00
2.24741e+00 6.08034e+00 2.39683e+01 1.78498e+02 2.59527e+02
8.16026e+01 4.10510e+01 2.92858e+01 2.53769e+01 2.37046e+01
2.24484e+01 2.22873e+01 2.15426e+01 2.10998e+01 2.08477e+01
2.00872e+01 1.93094e+01 1.79004e+01 1.56935e+01 1.25239e+01
9.73289e+00 7.75222e+00 5.55463e+00 3.49440e+00 1.78073e+00
7.13437e-01 1.89842e-01 3.17342e-02 1.74281e-03 0.00000e+00
0.00000e+00 0.00000e+00 0.00000e+00 0.00000e+00 0.00000e+00
5.61074e-04 1.61004e-03 5.00879e-03 1.51567e-02 2.67004e-02
4.30696e-02 5.81267e-02 6.68539e-02 6.87116e-02 6.07504e-02
4.59620e-02 2.97556e-02 1.15211e-02 3.85990e-03 1.39577e-03
0.00000e+00 0.00000e+00 0.00000e+00 )
$TALLY
& ID(1)
  IRESP (1)
  LABEL(BAU)
  EVENT (TRACK)
  DIMENSION (REGION)
  REGION (@BAUMXTOT
    @BAUMXE4 @BAUMXE41 @BAUMXE42 @BAUMXE43 @BAUMXE44
    @BAUMXE3 @BAUMXE31 @BAUMXE32 @BAUMXE33 @BAUMXE34
    @BAUMXE2 @BAUMXE21 @BAUMXE22 @BAUMXE23 @BAUMXE24
    @BAUMXE1 @BAUMXE11 @BAUMXE12 @BAUMXE13 @BAUMXE14
    @BAUMXE0 @BAUMXE01 @BAUMXE02 @BAUMXE03 @BAUMXE04

```

```

@WGFTLR
@BAUDRTOT
@BAUDR3 @BAUDR31 @BAUDR32 @BAUDR33 @BAUDR34
@BAUDR4 @BAUDR41 @BAUDR42 @BAUDR43 @BAUDR44
@BAUDR5 @BAUDR51 @BAUDR52 @BAUDR53 @BAUDR54
@BAUDR6 @BAUDR61 @BAUDR62 @BAUDR63 @BAUDR64
@BAUDR7 @BAUDR71 @BAUDR72 @BAUDR73 @BAUDR74
@BAURFTOT
@BAURF1 @BAURF11 @BAURF12 @BAURF13 @BAURF14
@BAURF2 @BAURF21 @BAURF22 @BAURF23 @BAURF24
@BAURF3 @BAURF31 @BAURF32 @BAURF33 @BAURF34
@BAURF4 @BAURF41 @BAURF42 @BAURF43 @BAURF44
@BAURF5 @BAURF51 @BAURF52 @BAURF53 @BAURF54
@BAURF6 @BAURF61 @BAURF62 @BAURF63 @BAURF64
@BAURF7 @BAURF71 @BAURF72 @BAURF73 @BAURF74
@BAURF8 @BAURF81 @BAURF82 @BAURF83 @BAURF84 )

& ID(2)
IRESP (2)
LABEL(CAU)
EVENT (TRACK)
DIMENSION (REGION)
REGION (@BAUMXTOT
        @BAUMXE4 @BAUMXE41 @BAUMXE42 @BAUMXE43 @BAUMXE44
        @BAUMXE3 @BAUMXE31 @BAUMXE32 @BAUMXE33 @BAUMXE34
        @BAUMXE2 @BAUMXE21 @BAUMXE22 @BAUMXE23 @BAUMXE24
        @BAUMXE1 @BAUMXE11 @BAUMXE12 @BAUMXE13 @BAUMXE14
        @BAUMXE0 @BAUMXE01 @BAUMXE02 @BAUMXE03 @BAUMXE04
@WGFTLR
@BAUDRTOT
@BAUDR3 @BAUDR31 @BAUDR32 @BAUDR33 @BAUDR34
@BAUDR4 @BAUDR41 @BAUDR42 @BAUDR43 @BAUDR44
@BAUDR5 @BAUDR51 @BAUDR52 @BAUDR53 @BAUDR54
@BAUDR6 @BAUDR61 @BAUDR62 @BAUDR63 @BAUDR64
@BAUDR7 @BAUDR71 @BAUDR72 @BAUDR73 @BAUDR74
@CAURFTOT
@BAURF1 @BAURF11 @BAURF12 @BAURF13 @BAURF14
@BAURF2 @BAURF21 @BAURF22 @BAURF23 @BAURF24
@BAURF3 @BAURF31 @BAURF32 @BAURF33 @BAURF34
@BAURF4 @BAURF41 @BAURF42 @BAURF43 @BAURF44
@BAURF5 @BAURF51 @BAURF52 @BAURF53 @BAURF54
@BAURF6 @BAURF61 @BAURF62 @BAURF63 @BAURF64
@BAURF7 @BAURF71 @BAURF72 @BAURF73 @BAURF74
@BAURF8 @BAURF81 @BAURF82 @BAURF83 @BAURF84 )

$END TALLY
***** VARIANCE REDUCTION P2PARAMETERS *****
% NR = %NREG, NRG=NR*NG
WKIL( <NRG>(0.25) )
WSRV( <NRG>(0.50) )
***** FISSION NEUTRON GENERATION *****
WGTF( <NR>(0.80) )
***** TALLY ENERGY BOUNDARIES *****
* ----- 108 group energy bin -----
ENGYB( 2.0000E+07
      1.0000E+07 7.7880E+06 6.0653E+06 4.7237E+06 3.6788E+06
      2.8650E+06 2.2313E+06 1.7377E+06 1.3534E+06 1.0540E+06
      8.2085E+05 6.3928E+05 4.9787E+05 3.8774E+05 3.0197E+05
      2.3518E+05 1.8316E+05 1.4264E+05 1.1109E+05 8.6517E+04
      6.7380E+04 5.2475E+04 4.0868E+04 3.1828E+04 2.4788E+04
      1.9304E+04 1.5034E+04 1.1709E+04 9.1188E+03 7.1017E+03
      5.5308E+03 4.3074E+03 3.3546E+03 2.6126E+03 2.0347E+03
      1.5846E+03 1.2341E+03 9.6112E+02 7.4852E+02 5.8295E+02
      4.5400E+02 3.5358E+02 2.7536E+02 2.1445E+02 1.6702E+02
      1.3007E+02 1.0130E+02 7.8893E+01 6.1442E+01 4.7851E+01
      3.7266E+01 2.9023E+01 2.2603E+01 1.7604E+01 1.3710E+01
      1.0677E+01 8.3153E+00 6.4759E+00 5.0435E+00 3.9279E+00

```

```

3.0590E+00 2.3824E+00 1.8554E+00 1.6374E+00 1.4450E+00
1.2752E+00 1.1253E+00 9.9312E-01 8.7643E-01 7.7344E-01
6.8256E-01 6.0236E-01 5.3158E-01 4.6912E-01 4.1399E-01
3.8926E-01 3.6528E-01 3.4206E-01 3.1961E-01 2.9792E-01
2.7699E-01 2.5683E-01 2.3742E-01 2.1878E-01 2.0090E-01
1.8378E-01 1.6743E-01 1.5183E-01 1.3700E-01 1.2293E-01
1.0963E-01 9.7080E-02 8.5397E-02 7.4276E-02 6.4017E-02
5.4520E-02 4.5785E-02 3.7813E-02 3.0602E-02 2.4154E-02
1.8467E-02 1.3543E-02 9.3805E-03 5.9804E-03 3.3423E-03
1.4663E-03 3.5238E-04 1.0000E-05 )

*****
* ----- 3 GROUP ENERGY BIN -----
* ENGYB( 2.0000E+07 5.5308E+03 1.8554E+00 1.0000E-05 )
*****  

/
% TH1 = 50.0, TH2 = 60.0
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY
PAPER ( -10.0 -2.5 <TH2> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 5.0 5.0 )
LEVEL (2)
* SCAN ( 0 3 )
SCAN ( 3 0 )
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY
PAPER ( 7.0 -1.0 <TH2> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 5.0 2.0 )
LEVEL (2)
/
*
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY
PAPER ( 14.0 -8.0 <TH2> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 25.0 16.0 )
LEVEL (2)
/
*
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
PAPER ( -10.0 -2.50 <TH1> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 5.0 5.0 )
LEVEL (2)
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
PAPER ( 7.0 -1.0 <TH1> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 5.0 2.0 )
LEVEL (2)
/
*
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY
PAPER ( 14.0 -6.0 <TH1> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 25.0 12.0 )
LEVEL (2)
/
*
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY
PAPER ( -50.0 -50.0 <TH1> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 100.00 100.0 )
LEVEL (2)
SPTYP (2)
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
* VX VY VZ AX AY AZ BX BY BZ DY

```

```
PAPER ( -50.0 -50.0 106. 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 100.00 100.0 )
LEVEL (2)
SPTYP (2)
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ DY
PAPER ( -50.0 -50.0 108. 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 100.00 100.0 )
LEVEL (2)
SPTYP (2)
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XY cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ DY
PAPER ( -00.01 -1.0 <TH1> 1.0 0.0 0.0 0.0 1.0 0.0 -1 )
XMAX ( 20.00 20.0 )
LEVEL (2)
SPTYP (2)
/
TITLE ( 2.40Pu <Run #4045> TCA two-region core XZ cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ DY
PAPER ( -25.0 <P1/2-.5> -5.0 1.0 0.0 0.0 0.0 0.0 1.0 -1 )
XMAX ( 50.  50.0 )
LEVEL (2)
SPTYP (2)
/
```

APPENDIX- B
FORTRAN program and MVP input for response function calculation

1. FORTRAN program for response function calculation

```

PROGRAM RESPONSE
C   A PROGRAM TO CALCULATE ENERGY=WISE RESPONSE FUNCTIONS FOR BARE
C   AND CD-COVERED AU-WIRE, READING DATA FROM MVP OUTPUT FILE
CHARACTER*30 REC0
CHARACTER*56 REC1, REC2, REC3, REC4, REC5, REC6, REC7
INTEGER*4 NO(108)
REAL*4 FLXINF(108),FLXB(108),FLXC(108),FLXCD(108),FLXBW(108),
1   FLXVD(108),FLXCW(108),RRINF1(108),RRINF2(108),RRB1(108),
2   RRB2(108),RRC1(108),RRC2(108),XSINF(108),XSB(108),XSC(108),
3   RFB(108),RFC(108),RXB(108),RXC(108),FXINF(108),FXB(108),
4   FXC(108),RRRB1(108),RRRB2(108),RRRC1(108),RRRC2(108),SFB1(108),
5   SFB2(108),SFC1(108),SFC2(108),XSHB1(108),XSHB2(108),XSHC1(108),
6   XSHC2(108),LTG(108),LTW(108),ENB(109),NDINF,NDSH,VLINF,VLSH,FACT
OPEN(1,FILE='auil.out')
OPEN(2,FILE='ausb1.out')
OPEN(3,FILE='ausc1.out')
C   OPEN(1,FILE='aui0.out')
C   OPEN(2,FILE='ausb0.out')
C   OPEN(3,FILE='ausc0.out')
OPEN(4,FILE='sff.out', STATUS='UNKNOWN')
OPEN(5,FILE='sffx.out',STATUS='UNKNOWN')
NG=108
ENB(109)=1.000E-05
NDINF = 1.0E-12
NDSH = 5.900862E-02
VLINF = 1000.
VLSH = 1.9634954E-02
VLBW = 1000.0-1.9634954E-02
VLCW = 1000.0-4.10433058E-01
FACT1 = (NDINF)/(NDSH*VLSH)
FACT2 = (NDINF*VLINF)/(NDSH*VLSH)
REC0='FLUX BY TRACK LENGTH ESTIMATOR'
REC1=' <AU7003B6294> === T-REG.    1 === REACTION RATE ==='
REC2=' <AU7003B6294> === T-REG.    1 === CROSS SECTION =='
REC3=' <AU7003B6294> === T-REG.    2 === REACTION RATE ==='
REC4=' <AU7003B6294> === T-REG.    2 === CROSS SECTION =='
C ****
10 READ (1, 69, END=51) REC5
IF( REC5 .EQ. REC0) GO TO 17
GO TO 10
51 WRITE(*,*) 'NO MATCH IN FILE11'
GOTO 99
17 DO 11 I=1,5
READ (1,*)
11 CONTINUE
DO 12 J=1,NG
READ(1, 61) NO(J), ENB(J), FLXINF(J)
C   WRITE(4, 61) NO(J), ENB(J), FLXINF(J)
READ(1,*)
12 CONTINUE
20 READ (1, 68, END=52) REC5
IF( REC5 .EQ. REC1) GO TO 18
GO TO 20
52 WRITE(*,*) 'NO MATCH IN FILE12'
GOTO 99
18 DO 13 J=1,3
READ(1,*)
13 CONTINUE
DO 14 K=1,NG
READ(1, 61) NO(K), ENB(K), RRINF2(K)

```

```

C      WRITE(4, 61) NO(K), ENB(K), RRINF2(K)
14    READ(1,*)
CONTINUE
30    READ (1, 68, END=53) REC5
IF( REC5 .EQ. REC2) GO TO 19
GO TO 30
53    WRITE(*,*) 'NO MATCH IN FILE13'
GOTO 99
19    DO 15 J=1,3
READ(1,*)
15    CONTINUE
DO 16 K=1,NG
READ(1, 61) NO(K), ENB(K), XSINF(K)
C      WRITE(4, 61) NO(K), ENB(K), XSINF(K)
READ(1,*)
16    CONTINUE
40    READ (2, 69, END=54) REC6
IF( REC6 .EQ. REC0) GO TO 27
GO TO 40
54    WRITE(*,*) 'NO MATCH IN FILE21'
GOTO 99
27    DO 21 L=1,5
READ (2,*)
21    CONTINUE
DO 22 M=1,NG
READ(2, 62) NO(M), ENB(M), FLXB(M), FLXBW(M)
C      WRITE(4, 61) NO(M), ENB(M), FLXB(M)
READ(2,*)
22    CONTINUE
50    READ (2, 68, END=55) REC6
IF( REC6 .EQ. REC1) GO TO 28
GO TO 50
55    WRITE(*,*) 'NO MATCH IN FILE22'
GOTO 99
28    DO 23 J=1,3
READ(2,*)
23    CONTINUE
DO 24 K=1,NG
READ(2, 61) NO(K), ENB(K), RRB2(K)
C      WRITE(4, 61) NO(K), ENB(K), RRB2(K)
READ(2,*)
24    CONTINUE
60    READ (2, 68, END=56) REC6
IF( REC6 .EQ. REC2) GO TO 29
GO TO 60
56    WRITE(*,*) 'NO MATCH IN FILE23'
GOTO 99
29    DO 25 J=1,3
READ(2,*)
25    CONTINUE
DO 26 K=1,NG
READ(2, 61) NO(K), ENB(K), XSB(K)
C      WRITE(4, 61) NO(K), ENB(K), XSB(KJ)
READ(2,*)
26    CONTINUE
70    READ (3, 69, END=57) REC7
IF( REC7 .EQ. REC0) GO TO 37
GO TO 70
57    WRITE(*,*) 'NO MATCH IN FILE31'
GOTO 99
37    DO 31 N=1,5
READ (3,*)
31    CONTINUE
DO 32 II=1,NG
READ(3,63) NO(II),ENB(II),FLXCD(II),FLXC(II),FLXVD(II),FLXCW(II)

```

```

C      WRITE(4, 61) NO(II), ENB(II), FLXC(II)
      READ(3,*)
 32    CONTINUE
 80    READ (3, 68, END=58) REC7
      IF( REC7 .EQ. REC3) GO TO 38
      GO TO 80
 58    WRITE(*,*) 'NO MATCH IN FILE32'
      GOTO 99
 38    DO 33 J=1,3
      READ(3,*)
 33    CONTINUE
      DO 34 K=1,NG
      READ(3, 61) NO(K), ENB(K), RRC2(K)
C      WRITE(4, 61) NO(K), ENB(K), RRC2(K)
      READ(3,*)
 34    CONTINUE
 90    READ (3, 68, END=59) REC7
      IF( REC7 .EQ. REC4) GO TO 39
      GO TO 90
 59    WRITE(*,*) 'NO MATCH IN FILE33'
      GOTO 99
 39    DO 35 J=1,3
      READ(3,*)
 35    CONTINUE
      DO 36 K=1,NG
      READ(3, 61) NO(K), ENB(K), XSC(K)
C      WRITE(4, 61) NO(K), ENB(K), XSC(K)
      READ(3,*)
 36    CONTINUE
C *** XS AVERAGING
      XSINFT=0.0
      XSBT=0.0
      XSCT=0.0
      DO 41 I=1,NG
      XSINFT=XSINFT+XSINF(I)
      XSBT=XSBT+XSB(I)
      XSCT=XSBT+XSC(I)
 41    CONTINUE
      AVXSINF= XSINFT/NG
      AVXSB= XSBT/NG
      AVXSC= XSCT/NG
      DO 42 JJ=1,NG
C*****FLUX PER UNIT VOLUME
      FLXINF(JJ)=FLXINF(JJ)/VLINF
      FLXB(JJ)=FLXB(JJ)/VLSH
      FLXC(JJ)=FLXC(JJ)/VLSH
      FLXBW(JJ)=FLXBW(JJ)/VLBW
      FLXCW(JJ)=FLXCW(JJ)/VLCW
C*****SHIELDING FACTOR AND SHIELDED X-SECTION FROM FLUX & X-SEC RATIO
      RFB(JJ)=FLXB(JJ)/FLXINF(JJ)
      RXB(JJ)=XSB(JJ)/XSINF(JJ)
      SFB1(JJ)= RFB(JJ) * RXB(JJ)
      XSHB1(JJ)=SFB1(JJ) *XSINF(JJ)
      RFC(JJ)=FLXC(JJ)/FLXINF(JJ)
      RXC(JJ)=XSC(JJ)/XSINF(JJ)
      SFC1(JJ)= RFC(JJ) * RXC(JJ)
      XSHC1(JJ)=SFC1(JJ) *XSINF(JJ)
 42    CONTINUE
C *****FLUX AVERAGEING FOR NORMALIZATION *****
      FLXBT=0.0
      FLXCT=0.0
      FLXIT=0.0
      DO 43 JJ=1,NG
      FLXIT=FLXIT+FLXINF(JJ)
      FLXBT=FLXBT+FLXB(JJ)

```

```

FLXCT=FLXCT+FLXC(JJ)
AVFLXI= FLXIT/NG
AVFLXB= FLXBT/NG
AVFLXC= FLXCT/NG
RFLXBI = AVFLXI/AVFLXB
RFLXCI = AVFLXI/AVFLXC
C     FLXB(JJ)= FLXB(JJ) * RFLXBI
C     FLXC(JJ)= FLXC(JJ) * RFLXCI
43    CONTINUE
C *****REACTION-RATE CALCULATION
C     *** SHIELDING EFFECT OF RESONANCE X-SECTIONS *****
C     FXINF(1)=1.0
C     FXB(1)=1.0
C     FXC(1)=1.0
DO 44 II=1,NG
C     FXINF(II)=(XSINF(II+1)/XSINF(II))/(ENB(II+1)/ENB(II))
C     FXB(II)=(XSB(II+1)/XSB(II))/(ENB(II+1)/ENB(II))
C     FXC(II)=(XSC(II+1)/XSC(II))/(ENB(II+1)/ENB(II))
C ****
C     LTG(II)= LOG(ENB(II))
C     LTW(II) = LOG(ENB(II)/ENB(II+1))
C     RRINF1(II)=FLXINF(II)*LTW(II)*NDINF*VLINF*XSINF(II)
C     RRB1(II) =FLXB(II)*LTW(II)*NDSH*VLSH*XSB(II)
C     RRC1(II) =FLXC(II)*LTW(II)*NDSH*VLSH*XSC(II)
44    CONTINUE
DO 45 JJ=1,NG
RRRB1(JJ)=RRB1(JJ)/RRINF1(JJ)
C     SFB1(JJ)=RRRB1(JJ)*FACT1
SFB1(JJ)=RRRB1(JJ)*FACT2
XSHB1(JJ)=SFB1(JJ)*XSINF(JJ)
RRRC1(JJ)=RRC1(JJ)/RRINF1(JJ)
C     SFC1(JJ)=RRRC1(JJ)*FACT1
SFC1(JJ)=RRRC1(JJ)*FACT2
XSHC1(JJ)=SFC1(JJ)*XSINF(JJ)
RRRB2(JJ)=RRB2(JJ)/RRINF2(JJ)
SFB2(JJ)=RRRB2(JJ)*FACT2
XSHB2(JJ)=SFB2(JJ)*XSINF(JJ)
RRRC2(JJ)=RRC2(JJ)/RRINF2(JJ)
SFC2(JJ)=RRRC2(JJ)*FACT2
XSHC2(JJ)=SFC2(JJ)*XSINF(JJ)
45    CONTINUE
      WRITE(4,*)' GNO          XSINF        SFB2        XEFFB        SFFC2
1           XEFFC'
C      WRITE(4,*)' SLN          ENB          RRINF        RRB
C      1RRC'
      DO 46 KK=1,NG
      WRITE(4,64) NO(KK), XSINF(KK), SFB2(KK), XSHB2(KK), SFC2(KK),
1           XSHC2(KK)
C      WRITE(4,65) NO(KK), SFB1(KK), SFC1(KK)
C      WRITE(4,65) NO(KK), SFB2(KK), SFC2(KK)
46    CONTINUE
      DO 47 LL=1,NG
C      WRITE(4,66) NO(LL),RRINF1(LL),RRB1(LL),RRC1(LL)
C      WRITE(4,66) NO(LL),RRINF2(LL),RRB2(LL),RRC2(LL)
C      WRITE(4,66) NO(LL),XSINF(LL),XSB(LL),XSC(LL)
C      WRITE(4,66) NO(LL),FLXINF(LL),FLXB(LL),FLXBW(LL),
C      1           FLXC(LL),FLXCW(LL)
47    CONTINUE
      WRITE(5,67) (XSHB2(MM),MM=1,108)
      WRITE(5,67) (XSHC2(MM),MM=1,108)
C      WRITE(5,67) (XSHB1(MM),MM=1,108)
C      WRITE(5,67) (XSHC1(MM),MM=1,108)
61    FORMAT(I5,E11.4,E13.5)
62    FORMAT(I5,E11.4,2(E13.5))
63    FORMAT(I5,E11.4,4(E13.5))

```

```

64   FORMAT( I5,1PE15.5,1PE13.4, 1PE15.5, 1PE13.4, 1PE15.5)
65   FORMAT( I5,2(1PE12.5))
66   FORMAT( I5, 5(1PE12.5))
67   FORMAT(5(1PE13.5))
68   FORMAT(A56)
69   FORMAT(24X,A30)
99   STOP
END

```

2. MVP input for Au infinitely diluted in water / JENDL-3.2

For calculation of shielded capture x-section (Response function)

```

NO-RESTART      FISSION      FIXED-SOURCE    NO-LATTICE
               RUSSIAN-ROULETTE    FLUX-PRINT     NO-TALLY-LATTICE
NO-EDIT-MACROSCOPIC-DATA(33333333)
               EDIT-MICROSCOPIC-DATA(00004000)
               DYNAMIC-MEMORY(500000000)

% NHIST = 20000 , NG = 108
% KBATCH =10000 , NSKIP = 0
% NBATCH = KBATCH + NSKIP
*****NGROUP(<NG>)      NMEMO(20)
NSKIP(<NSKIP>)  IRAND(200000909)    TCPU(177.0)
ETOP(2.0000E+7)  ETHMAX(4.5)        AMLIM(250.)    EWCUT(0.0)
NPART(<NBATCH*NHIST>) NHIST(<NHIST>)  NBANK(<INT(1.250*NHIST)>)
*****% MH2OAU =1
% CTEMP = 273.00 + 21.00
% T = 293
$XSEC
* H2O+AU (1)
& IDMAT(<MH2OAU>)
  TEMPMT(<CTEMP>) /* Kelvin
H01H03J3( 6.6751E-2 )
O06003J3( 3.3376E-2 )
AU7003B6( 1.0000E-12)
END
$GEOM
% P = 10.0
***** BODY DEFINITION *****
RPP ( 10000 <-P/2.> <P/2.> <-P/2.> <P/2.> <-P/2.> <P/2.> )
END
***** ZONE DEFINITIONS *****
EXWB :          : -3000   :-10000
CUBE : CUBE : <MH2OAU> : 10000
***** TALLY REGION DATA *****
$END GEOM
*TRVOL(1000)
***** Initial Source ( for zero-step )
$SOURCE
*#SOURCE-START
& NEUTRON
  RATIO( 1.0 )
  @E = #MAXWELL( 1.4727E6 ) ;
  @X = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Y = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Z = #UNIFORM( <-P/2.> <P/2.> ) ;
*#SOURCE-END
$END SOURCE
*
***** VARIANCE REDUCTION P2ARAMETERS *****
% NR = %NREG, NRG=NR*NG

```

```

WKIL( <NRG>(0.25) )
WSRV( <NRG>(0.50) )
***** FISSION NEUTRON GENERATION *****
WGTF( <NR>(0.80) )
***** TALLY ENERGY BOUNDARIES *****
* ----- 108 group energy bin -----
ENGYB( 2.0000E+07
      1.0000E+07 7.7880E+06 6.0653E+06 4.7237E+06 3.6788E+06
      2.8650E+06 2.2313E+06 1.7377E+06 1.3534E+06 1.0540E+06
      8.2085E+05 6.3928E+05 4.9787E+05 3.8774E+05 3.0197E+05
      2.3518E+05 1.8316E+05 1.4264E+05 1.1109E+05 8.6517E+04
      6.7380E+04 5.2475E+04 4.0868E+04 3.1828E+04 2.4788E+04
      1.9304E+04 1.5034E+04 1.1709E+04 9.1188E+03 7.1017E+03
      5.5308E+03 4.3074E+03 3.3546E+03 2.6126E+03 2.0347E+03
      1.5846E+03 1.2341E+03 9.6112E+02 7.4852E+02 5.8295E+02
      4.5400E+02 3.5358E+02 2.7536E+02 2.1445E+02 1.6702E+02
      1.3007E+02 1.0130E+02 7.8893E+01 6.1442E+01 4.7851E+01
      3.7266E+01 2.9023E+01 2.2603E+01 1.7604E+01 1.3710E+01
      1.0677E+01 8.3153E+00 6.4759E+00 5.0435E+00 3.9279E+00
      3.0590E+00 2.3824E+00 1.8554E+00 1.6374E+00 1.4450E+00
      1.2752E+00 1.1253E+00 9.9312E-01 8.7643E-01 7.7344E-01
      6.8256E-01 6.0236E-01 5.3158E-01 4.6912E-01 4.1399E-01
      3.8926E-01 3.6528E-01 3.4206E-01 3.1961E-01 2.9792E-01
      2.7699E-01 2.5683E-01 2.3742E-01 2.1878E-01 2.0090E-01
      1.8378E-01 1.6743E-01 1.5183E-01 1.3700E-01 1.2293E-01
      1.0963E-01 9.7080E-02 8.5397E-02 7.4276E-02 6.4017E-02
      5.4520E-02 4.5785E-02 3.7813E-02 3.0602E-02 2.4154E-02
      1.8467E-02 1.3543E-02 9.3805E-03 5.9804E-03 3.3423E-03
      1.4663E-03 3.5238E-04 1.0000E-05 )
***** -----
* ----- 3 GROUP ENERGY BIN -----
* ENGYB( 2.0000E+07 5.5308E+03 1.8554E+00 1.0000E-05 )
***** / *
* TITLE ( ExP2. TCA P2u242 Core XY cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ   DY
PAPER (-6.     -6.     0.    1.0   .0   .0   .0   1.0   .0   -1 )
XMAX ( 12.0   12. )
LEVEL (1)
SPTYP (1)
SCAN ( 0 3 )
* SCAN ( 3 0 )
/
TITLE ( ExP2. TCA P2u242 Core XY cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ   DY
PAPER (-3.5   -3.5   0.    1.0   .0   .0   .0   1.0   .0   -1 )
XMAX ( 7.     7. )
LEVEL (2)
SPTYP (1)
/
TITLE ( ExP2. TCA P2u242 Core XZ cross section )
*      VX   VY   VZ   AX   AY   AZ   BX   BY   BZ   DY
PAPER (-6.     0.    -6.0   1.0   .0   .0   .0   0.    1.   -1)
XMAX ( 12.    12. )
LEVEL (1)
SPTYP (1)
/

```

3. MVP input for bare Au wire submerged in water / JENDL-3.2

For calculation of shielded capture x-section (Response function)
RESTART RESTART-FILE FISSION FIXED-SOURCE NO-LATTICE

```

RUSSIAN-ROULETTE      FLUX-PRINT     NO-TALLY-LATTICE
NO-EDIT-MACROSCOPIC-DATA(00004000)
EDIT-MICROSCOPIC-DATA(00004000)
DYNAMIC-MEMORY(500000000)

% NHIST = 20000 , NG = 108
% KBATCH =10000 , NSKIP = 0
% NBATCH = KBATCH + NSKIP
***** ****
NGROUP(<NG>)      NMEMO(20)
NSKIP(<NSKIP>)    IRAND(200000909)   TCPU (355.0)
ETOP(2.0000E+7)    ETHMAX(4.5)       AMLIM(250.)   EWCUT(0.0)
NPART(<-(NBATCH*NHIST)>) NHIST(<NHIST>) NBANK(<INT(1.250*NHIST)>)
***** ****

% MH2O =1, AU =2
% CTEMP = 273.00 + 21.00
% T = 293
$XSEC
* H2O (1)
& IDMAT(<MH2O>)
  TEMPMT(<CTEMP>) /* Kelvin
H01H03J3( 6.6751E-2 )
O06003J3( 3.3376E-2 )
* AU (2)
& IDMAT(<AU>)
  TEMPMT(<CTEMP>) /* Kelvin
AU7003B6( 5.900862E-2 )
END
$GEOM
% P = 10.0, R =0.025
***** BODY DEFINITION *****
RPP ( 10000 <-P/2.> <P/2.> <-P/2.> <P/2.> <-P/2.> <P/2.> )
RCC ( 100 <-P/2.> 0.0 0.0 <P> 0.0 0.0 <R> )
END
***** ZONE DEFINITIONS *****
EXWB :          : -3000  :-10000
AUWR : AUWR : <AU> : 100
CUBE : CUBE : <MH2O> : 10000 -100
***** TALLY REGION DATA *****
*#TALLY REGION
*  DEFINE @AUWTR (LAT:2!C22 LAT:2!C23 LAT:2!C24)
$END GEOM
***** Initial Source ( for zero-step )
$SOURCE
*#SOURCE-START
& NEUTRON
  RATIO( 1.0 )
  @E = #MAXWELL( 1.4727E6 ) ;
  @X = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Y = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Z = #UNIFORM( <-P/2.> <P/2.> ) ;
*#SOURCE-END
$END SOURCE
*
***** VARIANCE REDUCTION P2ARAMETERS *****
% NR = %NREG, NRG=NR*NG
  WKIL( <NRG>(0.25) )
  WSRV( <NRG>(0.50) )
***** FISSION NEUTRON GENERATION *****
  WGTF( <NR>(0.80) )
***** TALLY ENERGY BOUNDARIES *****
* ----- 108 group energy bin -----
  ENGYB( 2.0000E+07
        1.0000E+07 7.7880E+06 6.0653E+06 4.7237E+06 3.6788E+06
        2.8650E+06 2.2313E+06 1.7377E+06 1.3534E+06 1.0540E+06

```

```

8.2085E+05 6.3928E+05 4.9787E+05 3.8774E+05 3.0197E+05
2.3518E+05 1.8316E+05 1.4264E+05 1.1109E+05 8.6517E+04
6.7380E+04 5.2475E+04 4.0868E+04 3.1828E+04 2.4788E+04
1.9304E+04 1.5034E+04 1.1709E+04 9.1188E+03 7.1017E+03
5.5308E+03 4.3074E+03 3.3546E+03 2.6126E+03 2.0347E+03
1.5846E+03 1.2341E+03 9.6112E+02 7.4852E+02 5.8295E+02
4.5400E+02 3.5358E+02 2.7536E+02 2.1445E+02 1.6702E+02
1.3007E+02 1.0130E+02 7.8893E+01 6.1442E+01 4.7851E+01
3.7266E+01 2.9023E+01 2.2603E+01 1.7604E+01 1.3710E+01
1.0677E+01 8.3153E+00 6.4759E+00 5.0435E+00 3.9279E+00
3.0590E+00 2.3824E+00 1.8554E+00 1.6374E+00 1.4450E+00
1.2752E+00 1.1253E+00 9.9312E-01 8.7643E-01 7.7344E-01
6.8256E-01 6.0236E-01 5.3158E-01 4.6912E-01 4.1399E-01
3.8926E-01 3.6528E-01 3.4206E-01 3.1961E-01 2.9792E-01
2.7699E-01 2.5683E-01 2.3742E-01 2.1878E-01 2.0090E-01
1.8378E-01 1.6743E-01 1.5183E-01 1.3700E-01 1.2293E-01
1.0963E-01 9.7080E-02 8.5397E-02 7.4276E-02 6.4017E-02
5.4520E-02 4.5785E-02 3.7813E-02 3.0602E-02 2.4154E-02
1.8467E-02 1.3543E-02 9.3805E-03 5.9804E-03 3.3423E-03
1.4663E-03 3.5238E-04 1.0000E-05 )
*****
* ----- 3 GROUP ENERGY BIN -----
*   ENGYB( 2.0000E+07 5.5308E+03 1.8554E+00 1.0000E-05 )
*****
/
*
*   TITLE ( ExP2. TCA P2u242 Core XY cross section )
*   VX    VY    VZ    AX    AY    AZ    BX    BY    BZ    DY
PAPER (-5.     -5.     0.     1.0    .0    .0     .0     1.0    .0   -1 )
XMAX ( 10.0   10. ) 
LEVEL (1)
SPTYP (1)
SCAN ( 0 3 )
*   SCAN ( 3 0 )
/
*   TITLE ( ExP2. TCA P2u242 Core XY cross section )
*   VX    VY    VZ    AX    AY    AZ    BX    BY    BZ    DY
PAPER (-5.     -5.     0.     1.0    .0    .0     .0     1.0    .0   -1 )
XMAX ( 7.      7.  )
LEVEL (2)
SPTYP (1)
/
*   TITLE ( ExP2. TCA P2u242 Core XZ cross section )
*   VX    VY    VZ    AX    AY    AZ    BX    BY    BZ    DY
PAPER (-2.5    0.    -2.5    1.0    .0    .0     .0     0.     1.   -1)
XMAX ( 5.      5.  )
LEVEL (1)
SPTYP (1)
/

```

4. MVP input for Cd-covered Au wire submerged in water / JENDL-3.2

```

For calculation of shielded capture x-section (Response function)
RESTART  RESTART-FILE    FISSION    FIXED-SOURCE  NO-LATTICE
RUSSIAN-ROULETTE    FLUX-PRINT    NO-TALLY-LATTICE
NO-EDIT-MACROSCOPIC-DATA(33333333)
EDIT-MICROSCOPIC-DATA(00004000)
DYNAMIC-MEMORY(500000000)

# NHIST = 20000 , NG = 108
# KBATCH =10000 , NSKIP = 0
# NBATCH = KBATCH + NSKIP
*****
```

```

NGROUP(<NG>)      NMEMO(20)
NSKIP(<NSKIP>)   IRAND(200000909)    TCPU(355.0)
ETOP(2.0000E+7)   ETHMAX(4.5)        AMLIM(250.)   EWCUT(0.0)
NPART(<-(NBATCH*NHIST)>) NHIST(<NHIST>) NBANK(<INT(1.250*NHIST)>)
*****
% MH2O =1, AU =2, CAD =3
% CTEMP = 273.00 + 21.00
% T = 293
$XSEC
* H2O (1)
& IDMAT(<MH2O>)
  TEMPMT(<CTEMP>) /* Kelvin
  H01H03J3( 6.6751E-2 )
  O06003J3( 3.3376E-2 )
* AU (2)
& IDMAT(<AU>)
  TEMPMT(<CTEMP>) /* Kelvin
  AU7003B6( 5.900862E-2 )
* Cd (3)
& IDMAT(<CAD>)
  TEMPMT(<CTEMP>) /* Kelvin
  CDN003J3( 4.628663E-2 )
END
$GEOM
% P = 10.0, R1 =0.05/2., R2 = 0.127/2., R3 =0.2286/2.
***** BODY DEFINITION *****
RPP ( 10000 <-P/2.> <P/2.> <-P/2.> <P/2.> <-P/2.> <P/2.> )
RCC ( 100 <-P/2.> 0.0 0.0 <P> 0.0 0.0 <R1> )
RCC ( 200 <-P/2.> 0.0 0.0 <P> 0.0 0.0 <R2> )
RCC ( 300 <-P/2.> 0.0 0.0 <P> 0.0 0.0 <R3> )
END
***** ZONE DEFINITIONS *****
EXWB :          : -3000  :-10000
AUWR : AUWR : <AU> : 100
VOID : VOID : 0 : 200 -100
CAD : CAD : <CAD> : 300 -200
WCUBE:WCUBE : <MH2O> : 10000 -300.
***** TALLY REGION DATA *****
*#TALLY REGION
*  DEFINE @AUWTR (LAT:2!C22 LAT:2!C23 LAT:2!C24)
SEND GEOM
***** Initial Source ( for zero-step )
$SOURCE
*#SOURCE-START
& NEUTRON
  RATIO( 1.0 )
  @E = #MAXWELL( 1.4727E6 ) ;
  @X = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Y = #UNIFORM( <-P/2.> <P/2.> ) ;
  @Z = #UNIFORM( <-P/2.> <P/2.> ) ;
*#SOURCE-END
SEND SOURCE
*
***** VARIANCE REDUCTION P2PARAMETERS *****
% NR = %NREG, NRG=NR*NG
  WKIL( <NRG>(0.25) )
  WSRV( <NRG>(0.50) )
***** FISSION NEUTRON GENERATION *****
  WGTF( <NR>(0.80) )
***** TALLY ENERGY BOUNDARIES *****
* ----- 108 group energy bin -----
  ENGYB( 2.0000E+07
         1.0000E+07 7.7880E+06 6.0653E+06 4.7237E+06 3.6788E+06
         2.8650E+06 2.2313E+06 1.7377E+06 1.3534E+06 1.0540E+06
         8.2085E+05 6.3928E+05 4.9787E+05 3.8774E+05 3.0197E+05

```

```

2.3518E+05 1.8316E+05 1.4264E+05 1.1109E+05 8.6517E+04
6.7380E+04 5.2475E+04 4.0868E+04 3.1828E+04 2.4788E+04
1.9304E+04 1.5034E+04 1.1709E+04 9.1188E+03 7.1017E+03
5.5308E+03 4.3074E+03 3.3546E+03 2.6126E+03 2.0347E+03
1.5846E+03 1.2341E+03 9.6112E+02 7.4852E+02 5.8295E+02
4.5400E+02 3.5358E+02 2.7536E+02 2.1445E+02 1.6702E+02
1.3007E+02 1.0130E+02 7.8893E+01 6.1442E+01 4.7851E+01
3.7266E+01 2.9023E+01 2.2603E+01 1.7604E+01 1.3710E+01
1.0677E+01 8.3153E+00 6.4759E+00 5.0435E+00 3.9279E+00
3.0590E+00 2.3824E+00 1.8554E+00 1.6374E+00 1.4450E+00
1.2752E+00 1.1253E+00 9.9312E-01 8.7643E-01 7.7344E-01
6.8256E-01 6.0236E-01 5.3158E-01 4.6912E-01 4.1399E-01
3.8926E-01 3.6528E-01 3.4206E-01 3.1961E-01 2.9792E-01
2.7699E-01 2.5683E-01 2.3742E-01 2.1878E-01 2.0090E-01
1.8378E-01 1.6743E-01 1.5183E-01 1.3700E-01 1.2293E-01
1.0963E-01 9.7080E-02 8.5397E-02 7.4276E-02 6.4017E-02
5.4520E-02 4.5785E-02 3.7813E-02 3.0602E-02 2.4154E-02
1.8467E-02 1.3543E-02 9.3805E-03 5.9804E-03 3.3423E-03
1.4663E-03 3.5238E-04 1.0000E-05 )
*****
* ----- 3 GROUP ENERGY BIN -----
* ENGYB( 2.0000E+07 5.5308E+03 1.8554E+00 1.0000E-05 )
*****
/
*
TITLE ( ExP2. TCA P2u242 Core XY cross section )
*   VX      VY      VZ      AX      AY      AZ      BX      BY      BZ      DY
PAPER (-5.      -5.      0.      1.0     .0      .0      .0      1.0     .0     -1 )
XMAX ( 10.0    10. )
LEVEL (1)
SPTYP (1)
SCAN ( 0 3 )
*   SCAN ( 3 0 )
/
TITLE ( ExP2. TCA P2u242 Core XY cross section )
*   VX      VY      VZ      AX      AY      AZ      BX      BY      BZ      DY
PAPER (-5.      -5.      0.      1.0     .0      .0      .0      1.0     .0     -1 )
XMAX ( 7.      7. )
LEVEL (2)
SPTYP (1)
/
TITLE ( ExP2. TCA P2u242 Core XZ cross section )
*   VX      VY      VZ      AX      AY      AZ      BX      BY      BZ      DY
PAPER (-2.5     0.     -2.5     1.0     .0      .0      .0      0.      1.     -1)
XMAX ( 5.      5. )
LEVEL (1)
SPTYP (1)
/

```

国際単位系(SI)と換算表

表1 SI基本単位および補助単位

量	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光强度	カンデラ	cd
平面角	ラジアン	rad
立体角	ステラジアン	sr

表3 固有の名称をもつSI組立単位

量	名称	記号	他のSI単位による表現
周波数	ヘルツ	Hz	s ⁻¹
力	ニュートン	N	m·kg/s ²
圧力、応力	パスカル	Pa	N/m ²
エネルギー、仕事、熱量	ジュール	J	N·m
工率、放射束	ワット	W	J/s
電気量、電荷	クーロン	C	A·s
電位、電圧、起電力	ボルト	V	W/A
静電容量	ファラード	F	C/V
電気抵抗	オーム	Ω	V/A
コンダクタンス	ジーメンス	S	A/V
磁束密度	ウェーバ	Wb	V·s
磁束密度	テスラ	T	Wb/m ²
インダクタンス	ヘンリー	H	Wb/A
セルシウス温度	セルシウス度	°C	
光束度	ルーメン	lm	cd·sr
照度	ルクス	lx	lm/m ²
放射能	ベクレル	Bq	s ⁻¹
吸収線量	グレイ	Gy	J/kg
線量当量	シーベルト	Sv	J/kg

表2 SIと併用される単位

名称	記号
分、時、日	min, h, d
度、分、秒	°, ', "
リットル	l, L
トントン	t
電子ボルト	eV
原子質量単位	u

$$1 \text{ eV} = 1.60218 \times 10^{-19} \text{ J}$$

$$1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg}$$

表4 SIと共に暫定的に維持される単位

名称	記号
オングストローム	Å
バーン	b
バール	bar
ガル	Gal
キュリ	Ci
レンントゲン	R
ラド	rad
レム	rem

$$1 \text{ Å} = 0.1 \text{ nm} = 10^{-10} \text{ m}$$

$$1 \text{ b} = 100 \text{ fm}^2 = 10^{-28} \text{ m}^2$$

$$1 \text{ bar} = 0.1 \text{ MPa} = 10^5 \text{ Pa}$$

$$1 \text{ Gal} = 1 \text{ cm/s}^2 = 10^{-2} \text{ m/s}^2$$

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$$

$$1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$$

$$1 \text{ rad} = 1 \text{ cGy} = 10^{-2} \text{ Gy}$$

$$1 \text{ rem} = 1 \text{ cSv} = 10^{-2} \text{ Sv}$$

表5 SI接頭語

倍数	接頭語	記号
10^{18}	エクサ	E
10^{15}	ペタ	P
10^{12}	テラ	T
10^9	ギガ	G
10^6	メガ	M
10^3	キロ	k
10^2	ヘクト	h
10^1	デカ	da
10^{-1}	デシ	d
10^{-2}	センチ	c
10^{-3}	ミリ	m
10^{-6}	マイクロ	μ
10^{-9}	ナノ	n
10^{-12}	ピコ	p
10^{-15}	フェムト	f
10^{-18}	アト	a

(注)

- 表1～5は「国際単位系」第5版、国際度量衡局1985年刊行による。ただし、1eVおよび1uの値はCODATAの1986年推奨値によった。
- 表4には海里、ノット、アール、ヘクタールも含まれているが日常の単位なのでここでは省略した。
- barは、JISでは流体の圧力を表わす場合に限り表2のカテゴリーに分類されている。
- EC閣僚理事会指令ではbar、barnおよび「血圧の単位」mmHgを表2のカテゴリーに入れている。

換算表

力	N(=10 ⁵ dyn)	kgf	lbf
	1	0.101972	0.224809
	9.80665	1	2.20462
	4.44822	0.453592	1

$$\text{粘度 } 1 \text{ Pa}\cdot\text{s}(N\cdot\text{s}/\text{m}^2) = 10 \text{ P(ボアズ)}(\text{g}/(\text{cm}\cdot\text{s}))$$

$$\text{動粘度 } 1 \text{ m}^2/\text{s} = 10^4 \text{ St(ストークス)}(\text{cm}^2/\text{s})$$

圧	MPa(=10 bar)	kgf/cm ²	atm	mmHg(Torr)	lbf/in ² (psi)
	1	10.1972	9.86923	7.50062 × 10 ³	145.038
力	0.0980665	1	0.967841	735.559	14.2233
	0.101325	1.03323	1	760	14.6959
	1.33322×10^{-4}	1.35951×10^{-3}	1.31579×10^{-3}	1	1.93368×10^{-2}
	6.89476×10^{-3}	7.03070×10^{-2}	6.80460×10^{-2}	51.7149	1

エネルギー・仕事・熱量	J(=10 ⁷ erg)	kgf·m	kW·h	cal(計量法)	Btu	ft · lbf	eV	1 cal = 4.18605 J(計量法)	
	1	0.101972	2.77778×10^{-7}	0.238889	9.47813 × 10 ⁻⁴	0.737562	6.24150×10^{18}	= 4.184 J (熱化学)	
	9.80665	1	2.72407×10^{-6}	2.34270	9.29487×10^{-3}	7.23301	6.12082×10^{19}	= 4.1855 J (15 °C)	
	3.6×10^6	3.67098×10^5	1	8.59999×10^5	3412.13	2.65522×10^6	2.24694×10^{25}	= 4.1868 J(国際蒸気表)	
	4.18605	0.426858	1.16279×10^{-6}	1	3.96759×10^{-3}	3.08747	2.61272×10^{19}	仕事率 1 PS(仮馬力)	
	1055.06	107.586	2.93072×10^{-4}	252.042	1	778.172	6.58515×10^{21}	= 75 kgf·m/s	
	1.35582	0.138255	3.76616×10^{-7}	0.323890	1.28506×10^{-3}	1	8.46233×10^{18}	= 735.499 W	
	1.60218×10^{-19}	1.63377×10^{-20}	4.45050×10^{-26}	3.82743×10^{-20}	1.51857×10^{-22}	1.18171×10^{-19}	1		

放射能	Bq	Ci	吸収線量	Gy	rad
	1	2.70270×10^{-11}		1	100
	3.7×10^{10}	1		0.01	1

照射線量	C/kg	R	線量当量	Sv	rem
	1	3876		1	100
	2.58×10^{-4}	1		0.01	1

(86年12月26日現在)

R100

古紙配合率100%
白色度70%再生紙を使用しています。