ADDITIONS TO THE ICSBEP AND IRPHEP HANDBOOKS SINCE NCSD 2013

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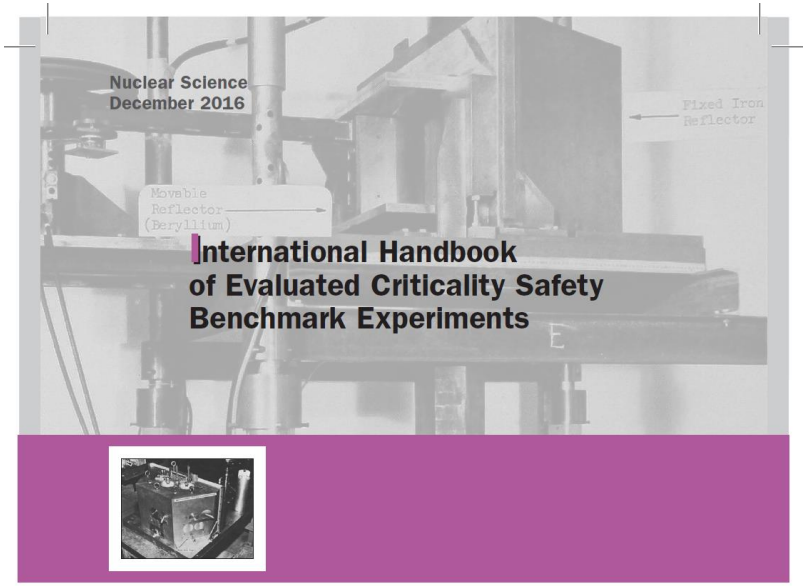
Acknowledgments

- The ICSBEP and IRPhEP are a collaborative effort
  - Scientists, engineers, administrative support, program sponsors
  - 25 different countries have participated
  - Without these dedicated individuals, these benchmark projects would not exist.

International Handbook of Evaluated Criticality Safety Benchmark Experiments

December 2016 Edition

- 22 Contributing Countries
- ~69,000 Pages
- 570 Evaluations
  - 4,913 Critical, Near-Critical, or Subcritical Configurations
  - 45 Criticality-Alarm-Placement/Shielding Configurations
  - 215 Configurations with Fundamental Physics Measurements
  - 829 Unacceptable Experiment Configurations



http://icsbep.inl.gov/

https://www.oecd-nea.org/science/wpncs/icsbep/

Breakdown of Current ICSBEP Benchmark Specifications

- 748 plutonium experiments
  - 36 compound
  - 123 metal
  - 589 solution
- 1435 highly enriched uranium experiments
  - 291 compound
  - 601 metal
  - 536 solution
  - 2 mixed compound/solution
  - 5 mixed metal/solution
- 268 intermediate- and mixed-enrichment uranium experiments
  - 156 compound
  - 47 metal
  - 65 solution
- 1662 low enriched uranium experiments
  - 1398 compound
  - 87 metal
  - 117 solution
  - 60 mixed compound/solution
- 244 ^{233}U experiments
  - 6 compound
  - 11 metal
  - 227 solution
- 536 mixed plutonium-uranium experiments
  - 301 compound
  - 52 metal
  - 86 solution
  - 76 mixed compound/solution
  - 21 mixed metal/compound
- 20 special isotope experiments
  - metal (^{237}Np, ^{238}Pu, ^{242}Pu, & ^{244}Cm)
- 9 criticality-alarm/shielding experiments
  - 45 unique configurations with numerous dose points
- 8 fundamental physics experiments
  - 215 unique measurements such as fission rates, transmission measurements, and subcritical neutron multiplication measurements

Plutonium and HEU Benchmarks

4 Plutonium Benchmarks:

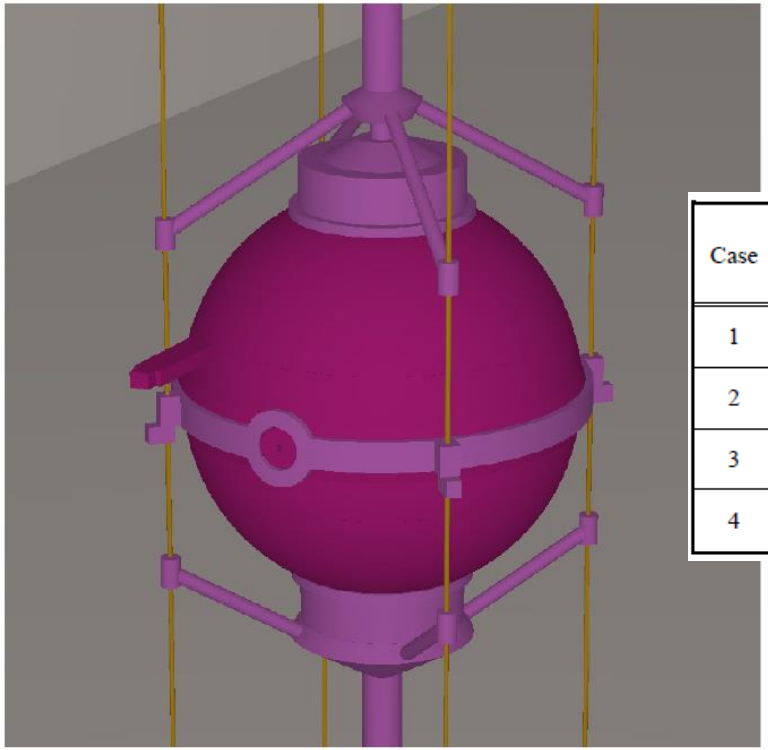
- Los Alamos National Laboratory (LANL) in the United States
- Argonne National Laboratory – West (ANL-W) in the United States
- Valduc Nuclear Center in France

5 Highly Enriched Uranium Benchmarks:

- Oak Ridge National Laboratory (ORNL) in the United States

Bare Sphere of Plutonium-239 Metal (4.5 wt.% ^{240}Pu, 1.02 wt.% Ga)

[PU-MET-FAST-001 Revision 4]



Case	Configuration	Calculated k_{eff}	Benchmark k_{eff}	Calc. – Bench. (pcm)	Calc. – Bench. (std. devs.)
1	A	1.00067 ± 0.00002	0.99999 ± 0.00110	68	0.61
2	B	1.00123 ± 0.00002	1.00016 ± 0.00110	107	0.96
3	C	1.00092 ± 0.00002	1.00020 ± 0.00110	72	0.64
4	D	1.00191 ± 0.00002	1.00128 ± 0.00110	63	0.56

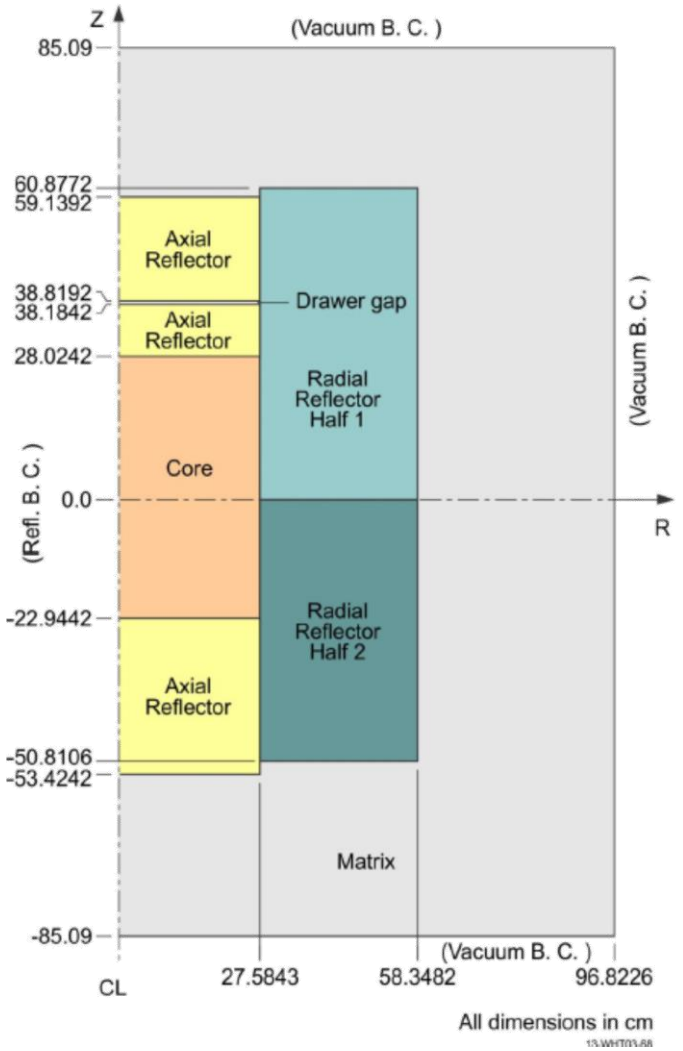
ZPR-3 Assembly 58: A Cylindrical Assembly of Plutonium Metal and Graphite with a Thick Depleted Uranium Reflector

[PU-MET-INTER-003 : ZPR-FUND-EXP-017]

	Case 1 – ZPR-3/58 Loading 12
Experimental k_{eff}	1.0002 ± 0.0012
Adjusted Experimental k_{eff}	1.0000 ± 0.0012
Monte Carlo Transformation of Model	-0.0158 ± 0.0010
Benchmark Model k_{eff}	0.9842 ± 0.0016

	MCNP5 (Continuous Energy ENDF/B-VII.1)
Case 1	0.9878 ± 0.0001

0.36 %Δk (~2.2σ)



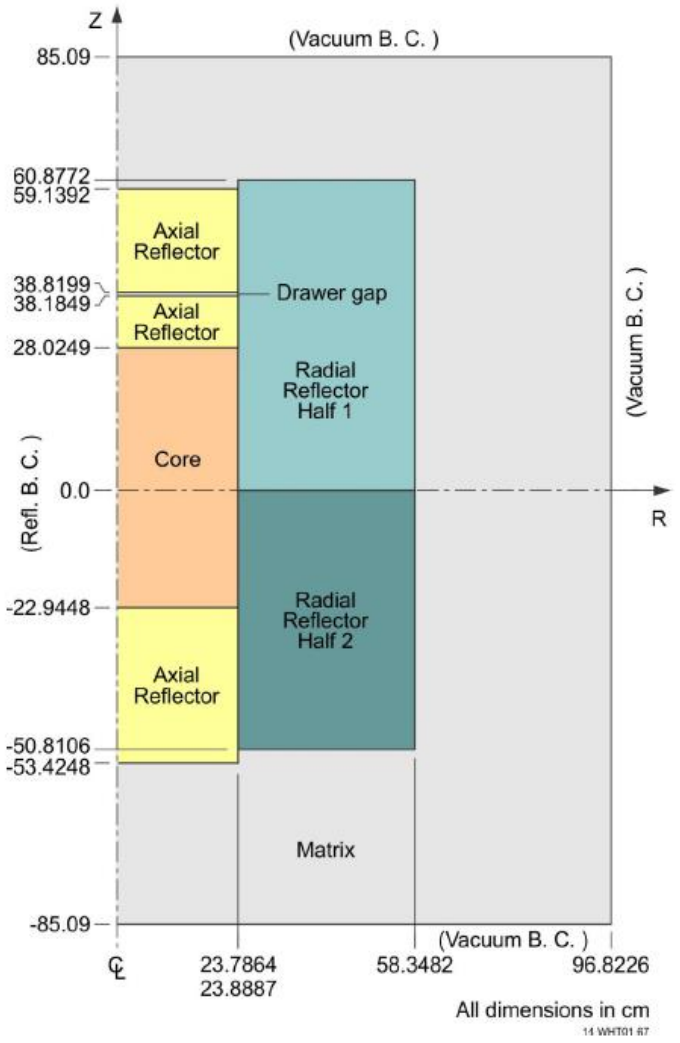
ZPR-3 Assembly 59: A Cylindrical Assembly of Plutonium Metal and Graphite with a Thick Lead Reflector

[PU-MET-INTER-004 : ZPR-FUND-EXP-018]

	Case 1 – ZPR-3/59 Loading 6
Experimental k_{eff}	1.0008 ± 0.0018
Adjusted Experimental k_{eff}	0.9944 ± 0.0023
Monte Carlo Transformation of Model	-0.0221 ± 0.0010
Benchmark Model k_{eff}	0.9723 ± 0.0025

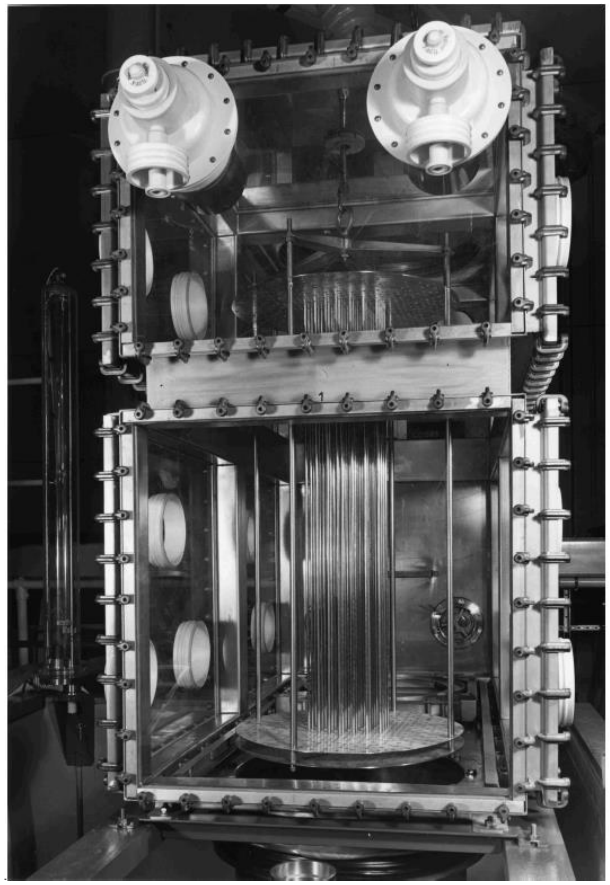
	MCNP5 (Continuous Energy ENDF/B-VII.1)
Case 1	0.97472 ± 0.00009

0.24 %Δk (~1σ)



Arrays of UO_2 PHENIX Pins Containing 26 wt% of Plutonium ($^{240}Pu/Pu$=16 wt%) in a Plutonium ($^{240}Pu/Pu$=19 wt%) Nitrate Solution

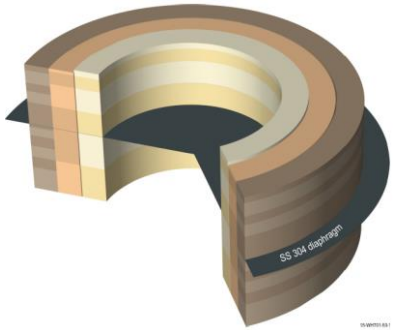
[PU-SOL-THERM-040 : MIX-MISC-THERM-007]

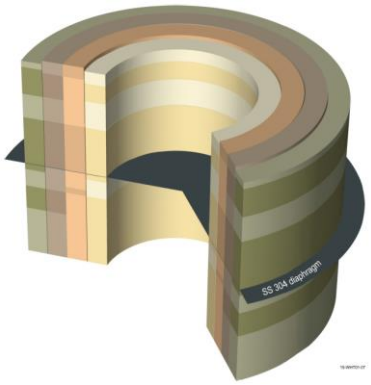


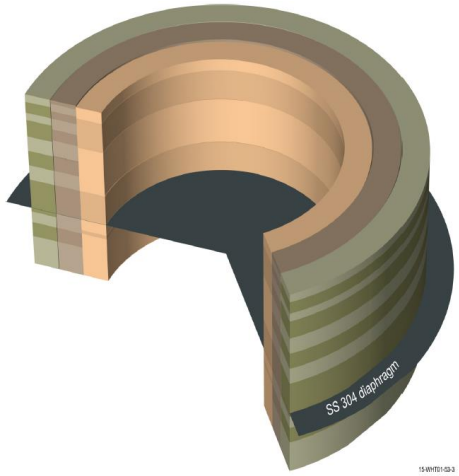
Case[a]	MORET 5 Continuous Energy JEF2.2 Library[b] (σ_{MC}= 0.00033)		MORET 5 Continuous Energy JEFF3.1 Library [b] (σ_{MC}= 0.00033)		MORET 5 Continuous Energy ENDF/VII.0 Library[b] (σ_{MC}= 0.00033)	
	k_{eff}	$(k_{eff(cal)} - k_{eff(exp)})/k_{eff(exp)}$ (%)	k_{eff}	$(k_{eff(cal)} - k_{eff(exp)})/k_{eff(exp)}$ (%)	k_{eff}	$(k_{eff(cal)} - k_{eff(exp)})/k_{eff(exp)}$ (%)
1	1.01284	1.51	1.00768	0.99	1.00770	0.99
2	1.01333	1.49	1.00874	1.03	1.00869	1.02
3	**1.01472**	**1.59**	**1.00942**	**1.06**	**1.01023**	**1.14**
4	**1.01411**	**1.53**	**1.00906**	**1.03**	**1.00919**	**1.04**
5	**1.01410**	**1.46**	**1.01082**	**1.13**	**1.01048**	**1.10**
6	**1.01494**	**1.57**	**1.01150**	**1.22**	**1.01191**	**1.26**
7	**1.01098**	**1.20**	**1.00735**	**0.84**	**1.00699**	**0.80**
8	**1.01146**	**1.25**	**1.00743**	**0.84**	**1.00847**	**0.95**
9	**1.01100**	**1.30**	**1.00648**	**0.85**	**1.00607**	**0.81**
10	**1.01040**	**1.17**	**1.00646**	**0.78**	**1.00633**	**0.76**
11	1.01071	1.26	1.00539	0.73	1.00607	0.80
12	1.00951	1.15	1.00434	0.64	1.00402	0.60
13	1.01799	1.92	1.01323	1.44	1.01330	1.45
14	1.01866	2.05	1.01220	1.40	1.01251	1.43
15	1.01357	1.56	1.00939	1.14	1.00912	1.11
16	1.01446	1.47	1.00982	1.00	1.01078	1.10
17	1.01482	1.40	1.01043	0.96	1.01062	0.98
18	1.01325	1.40	1.00895	0.97	1.00933	1.00
19	1.01139	1.22	1.00712	0.79	1.00716	0.80
20	1.01183	1.08	1.00788	0.69	1.00868	0.77
21	**1.01172**	**0.99**	**1.00886**	**0.70**	**1.00952**	**0.77**
22	**1.01164**	**1.04**	**1.00783**	**0.66**	**1.00793**	**0.67**
23	**1.01204**	**1.08**	**1.01075**	**0.95**	**1.01040**	**0.92**
24	**1.01438**	**1.29**	**1.00996**	**0.84**	**1.01045**	**0.89**

(a) In bold characters cases with PHENIX pins.
(b) Results provided by the evaluator Nicolas Leclaire (IRSN, France).

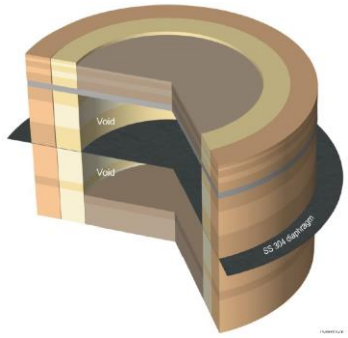
Oralloy (93.2 ^{235}U) Bare Metal Annuli
[HEU-MET-FAST-074]



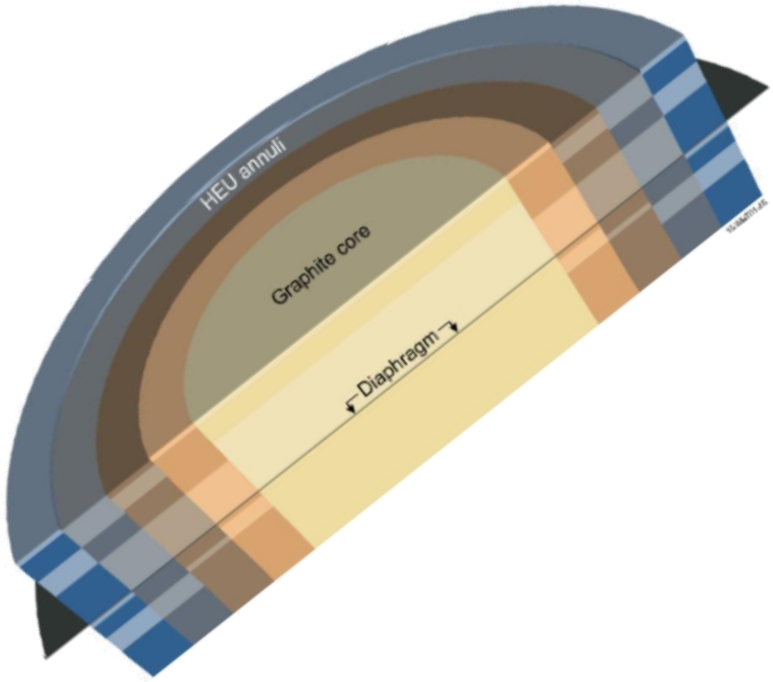




Case	Calculated			Benchmark Experiment			$\frac{C-E}{E}$%		
	k_{eff}	±	σ	k_{eff}	±	σ			
1	0.99640	±	0.00002	0.9988	±	0.0005	-0.24	±	0.05
2	0.99629	±	0.00002	0.9979	±	0.0005	-0.16	±	0.05
3	0.99471	±	0.00002	0.9970	±	0.0005	-0.23	±	0.05
4	0.99593	±	0.00002	0.9975	±	0.0005	-0.16	±	0.05



Experiments with HEU (93.14 wt.%) Metal Annuli with Internal Graphite Cylinder [HEU-MET-FAST-077]



(Case 1).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99723 ± 0.00004	0.9981 ± 0.0006	-0.08 ± 0.06
	ENDF/B-VII.0	0.99735 ± 0.00004		-0.07 ± 0.06
	JEFF-3.1[(a)]	0.99408 ± 0.00004		-0.40 ± 0.06
	JENDL-3.3[(a)]	1.00077 ± 0.00004		0.27 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

(Case 2).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99628 ± 0.00004	0.9971 ± 0.0006	-0.08 ± 0.06
	ENDF/B-VII.0	0.99640 ± 0.00004		-0.07 ± 0.06
	JEFF-3.1[(a)]	0.99312 ± 0.00004		-0.40 ± 0.06
	JENDL-3.3[(a)]	1.00005 ± 0.00004		0.29 ± 0.06

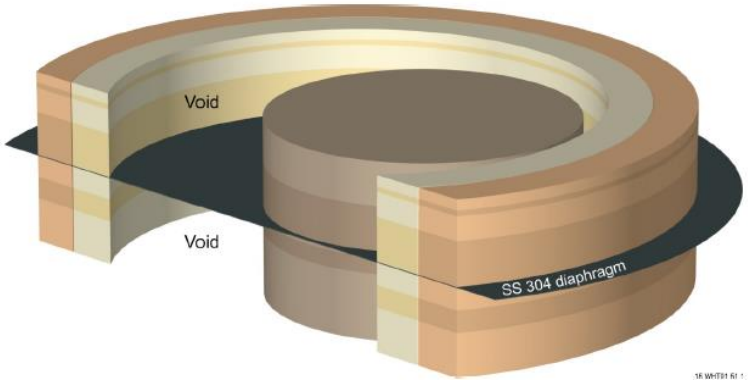
(a) Results provided by John D. Bess from Idaho National Laboratory.

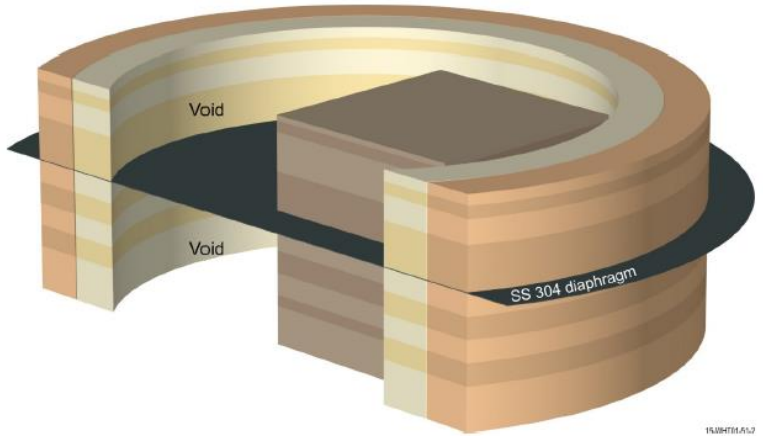
(Case 3).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99886 ± 0.00004	1.0001 ± 0.0006	-0.12 ± 0.06
	ENDF/B-VII.0	0.99893 ± 0.00004		-0.12 ± 0.06
	JEFF-3.1[(a)]	0.99568 ± 0.00004		-0.44 ± 0.06
	JENDL-3.3[(a)]	1.00218 ± 0.00004		0.21 ± 0.06

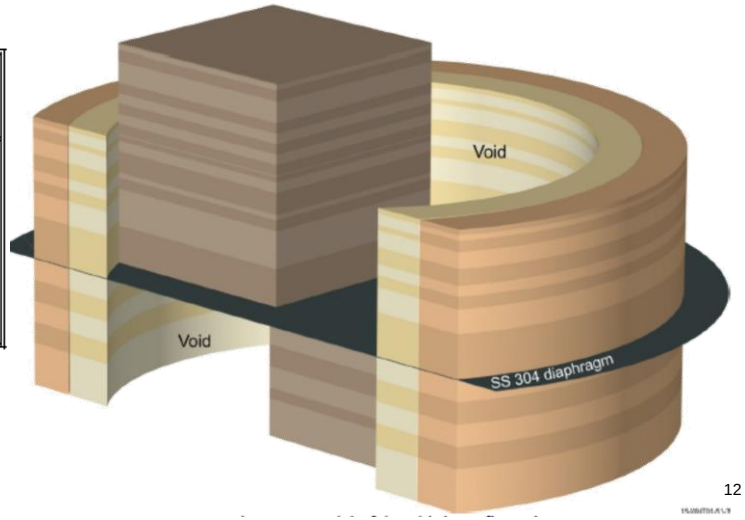
(a) Results provided by John D. Bess from Idaho National Laboratory.

Complex Geometry Bare Oralloy (93.15 ^{235}U) Metal Annuli Experiments
[HEU-MET-FAST-083]

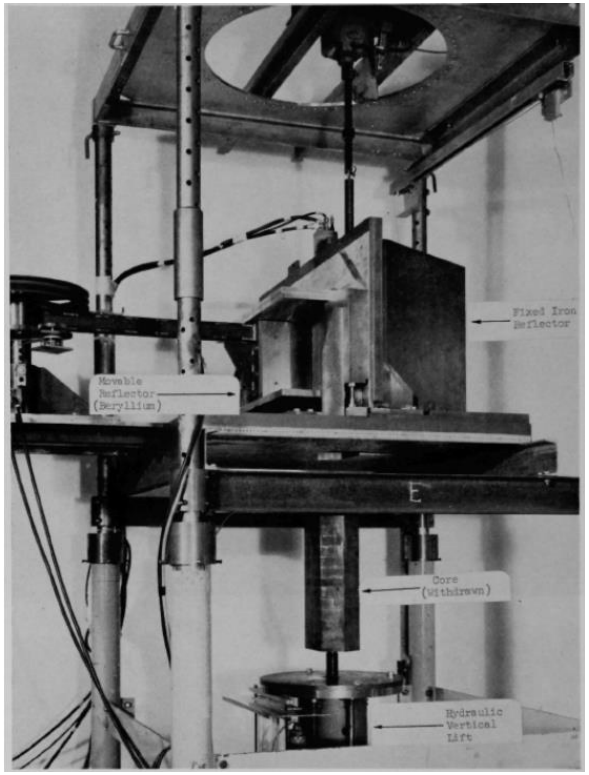


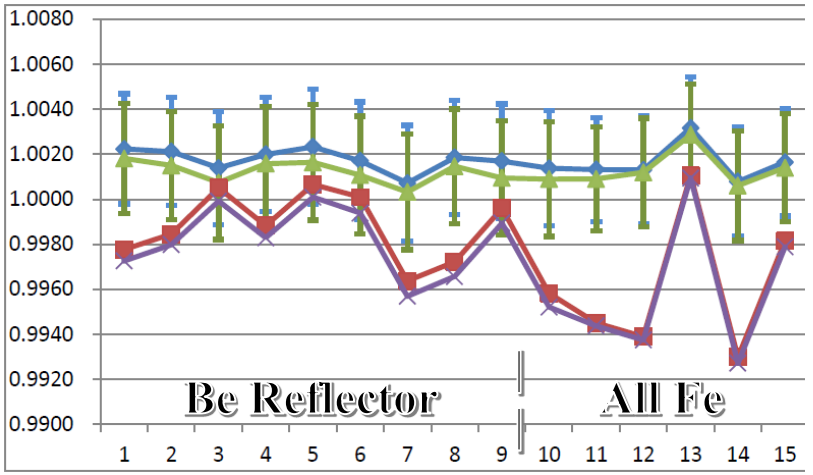


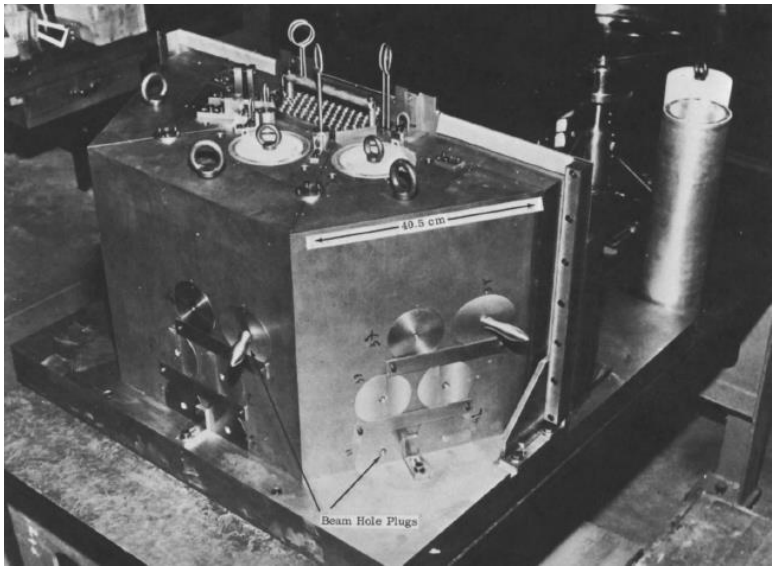
Case	Calculated			Benchmark Experiment			$\frac{C-E}{E}(\%)$
	k_{eff}	±	σ	k_{eff}	±	σ	
1 – Annulus with Cylinder	0.99693	±	0.00002	1.0001	±	0.0006	-0.31
2 – Annulus with Parallelepiped	0.99842	±	0.00002	0.9993	±	0.0012	-0.09
3 – Annulus with Split Parallelepiped	0.99616	±	0.00002	0.9984	±	0.0009	-0.22



Static Critical Experiments for the Sorgente Rapida (SORA) Reactor Mockup [HEU-MET-FAST-096]

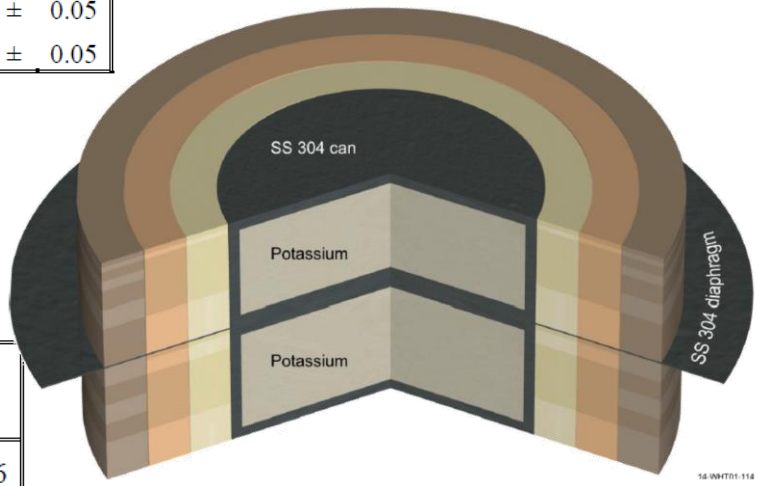






Fast Neutron Spectrum Potassium Worth for Space Power Reactor Design Validation
[HEU-MET-FAST-099 : ORCEF-SPACE-EXP-001]

Analysis Code	Neutron Cross Section Library	Calculated k_{eff}	±	σ	Benchmark Experiment k_{eff}	±	σ	$\frac{C-E}{E}$%	±	
MCNP6	ENDF/B-VII.1	0.99579	±	0.00002	0.9989	±	0.0005	-0.31	±	0.05
	ENDF/B-VII.0	0.99592	±	0.00002				-0.30	±	0.05
	JEFF-3.1	0.99258	±	0.00002				-0.63	±	0.05
	JENDL-3.3	1.00015	±	0.00002				0.13	±	0.05



Analysis Code	Neutron Cross Section Library	Calculated ρ(¢)	±	σ	Benchmark Experiment ρ(¢)	±	σ	$\frac{C-E}{E}$%	±	
MCNP6	ENDF/B-VII.1	3.8	±	0.4	11.4	±	1.7	-67	±	6
	ENDF/B-VII.0	3.1	±	0.4				-73	±	5
	JEFF-3.1	2.3	±	0.4				-80	±	4
	JENDL-3.3	2.4	±	0.4				-79	±	4

IEU, Mixed U, LEU, and Nat-U Benchmarks

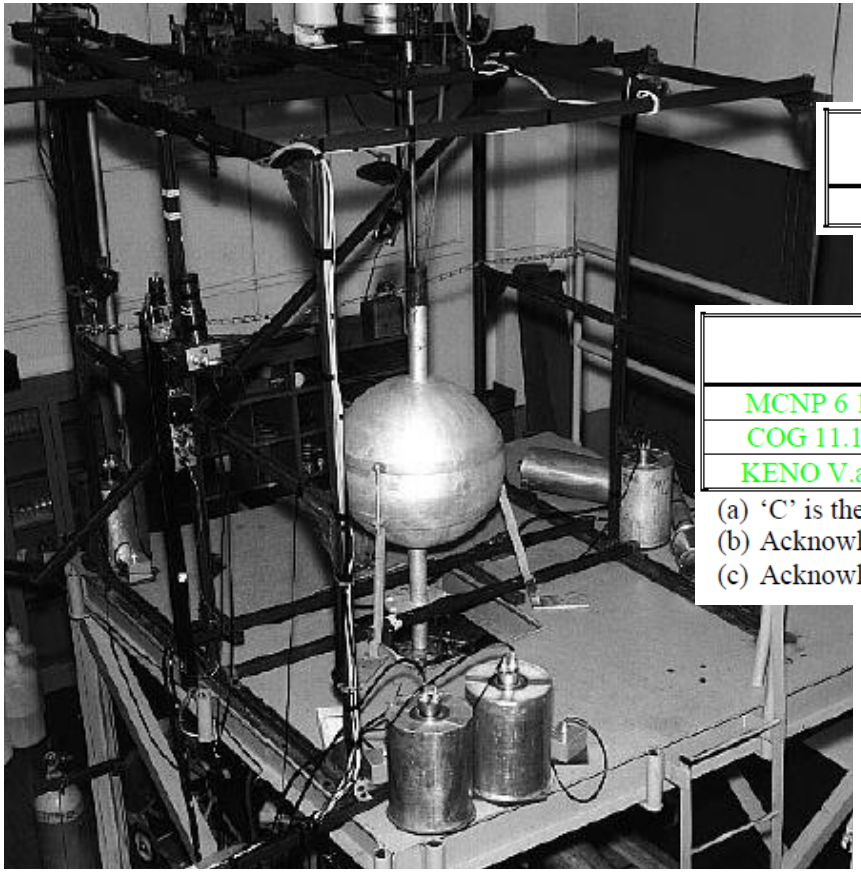
1 Intermediate-Enriched Uranium Benchmark:

- Oak Ridge National Laboratory (ORNL) in the United States

4 Low-Enriched or Natural Uranium Benchmarks:

- Institute de Pesquisas Energeticas e Nuclearesthe (IPEN) in Brazil
- Sandia National Laboratories (SNL) in the United States

Critical Dimension of Unreflected Aqueous Solution of $U(37\ \%)O_2F_2$ in Spherical Geometry *[IEU-SOL-THERM-005]*



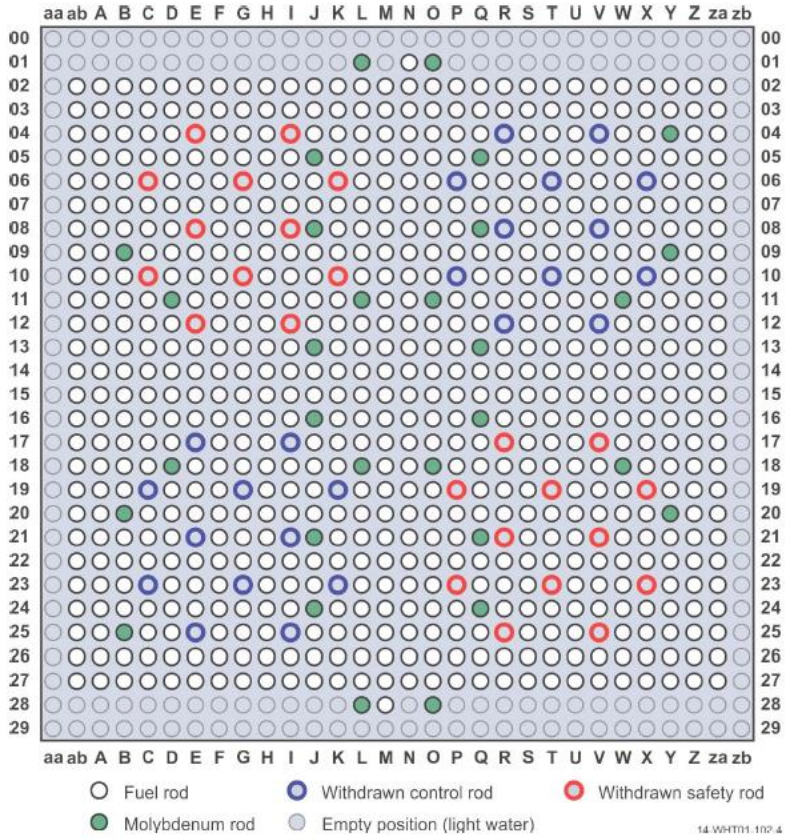
Model	Benchmark model k_{eff}	Uncertainty
Simplified	1.0041	0.0065

	k_{eff}	$\pm \sigma_{MCNP}$	Calculation Bias (Δk_{eff})	Relative deviation (C-E)/E[(a)]
MCNP 6 1.0	0.99940	± 0.00006	-0.00470	-0.5 %
COG 11.1 [(b)]	0.99943	± 0.00013	-0.00467	-0.5 %
KENO V.a [(c)]	0.99934	± 0.00008	-0.00476	-0.5 %

(a) 'C' is the calculate value. 'E' is the expected or benchmark value.
(b) Acknowledgement to Dr. Soon Sam Kim, Lawrence Livermore National Laboratory.
(c) Acknowledgement to Dr. Soon Sam Kim, Lawrence Livermore National Laboratory.

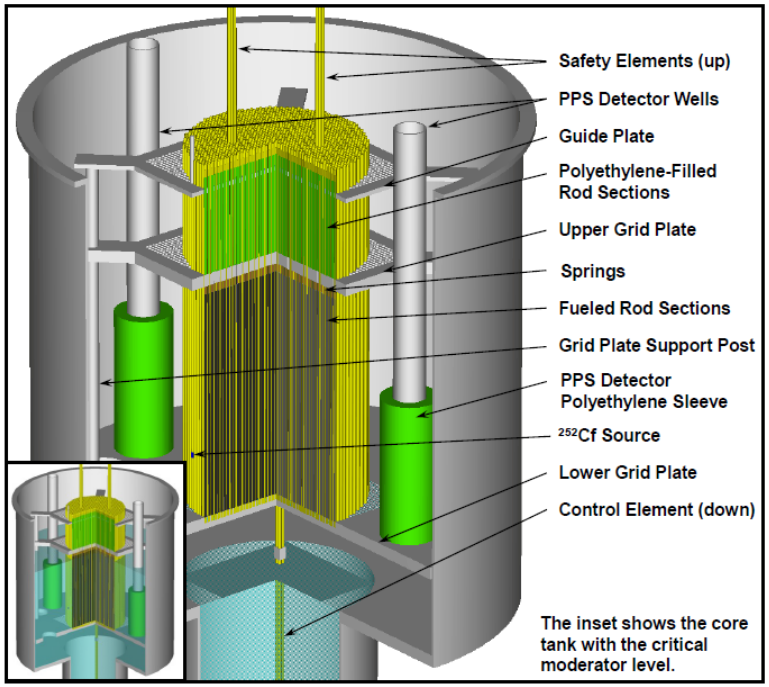
Critical Loading Configurations of the IPEN/MB-01 Reactor Composed of Fuel and Molybdenum Rods

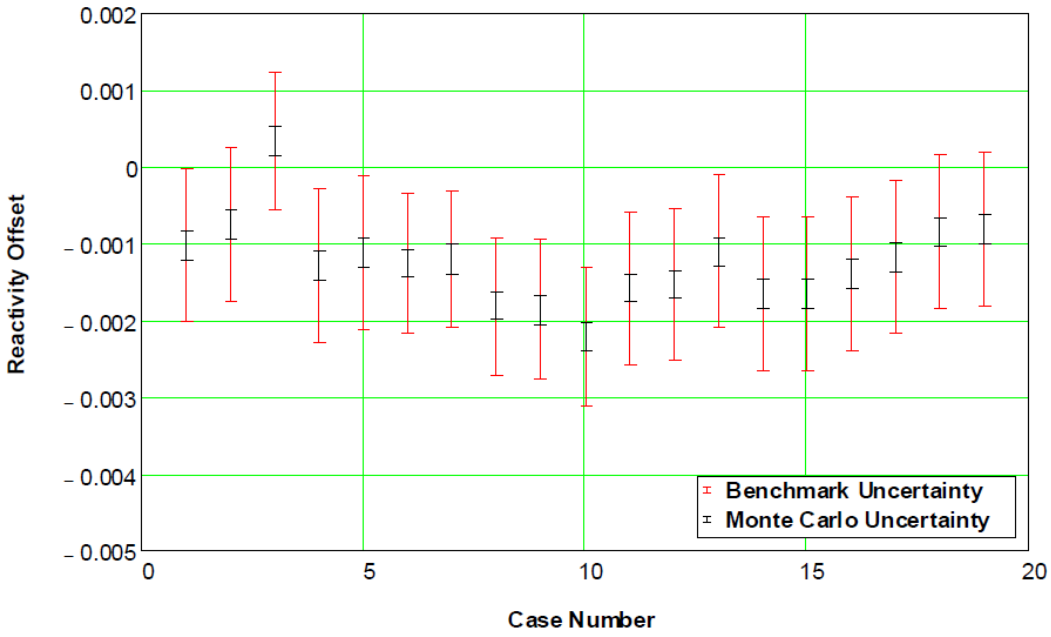
[LEU-COMP-THERM-067 : IPEN(MB-01)-LWR-RESR-018]



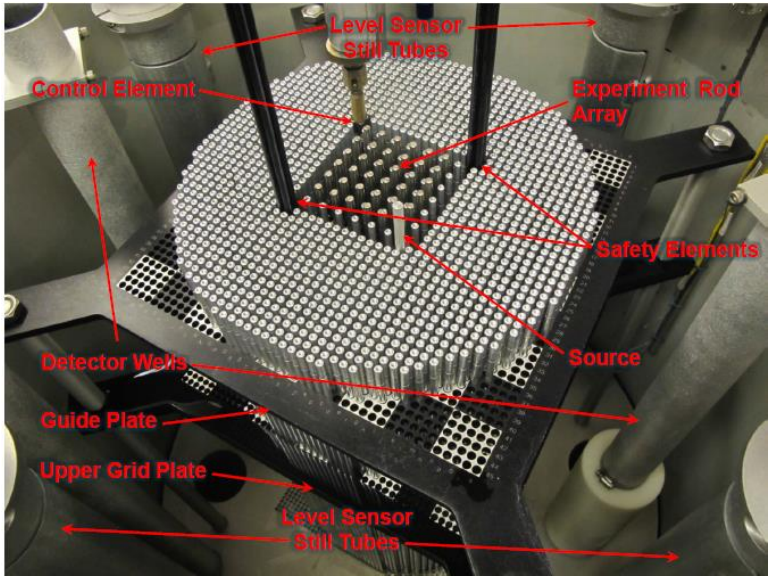
Code (Cross Section Set) → Case Number ↓	MCNP5 (Continuous Energy ENDF/B-VII.0)	Benchmark Value $k_{eff} \pm \sigma$	(C-E)/E %
1	1.00086 ± 0.00004	1.0005 ± 0.0005	0.036 ± 0.048
2	1.00068 ± 0.00004	1.0004 ± 0.0005	0.028 ± 0.048
3	1.00082 ± 0.00004	1.0004 ± 0.0005	0.042 ± 0.048
4	1.00094 ± 0.00004	1.0005 ± 0.0005	0.044 ± 0.048

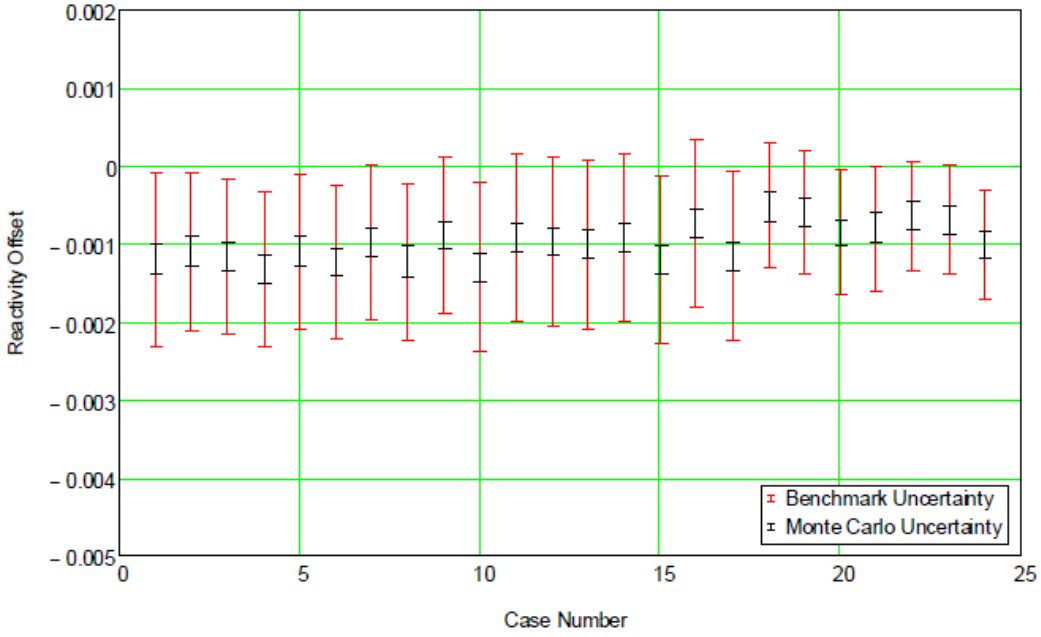
Partially-Reflected Water-Moderated Square-Pitched $U(6.90)O_2$ Fuel Rod Lattices with 0.67 Fuel to Water Volume Ratio (0.800 cm Pitch) *[LEU-COMP-THERM-096]*





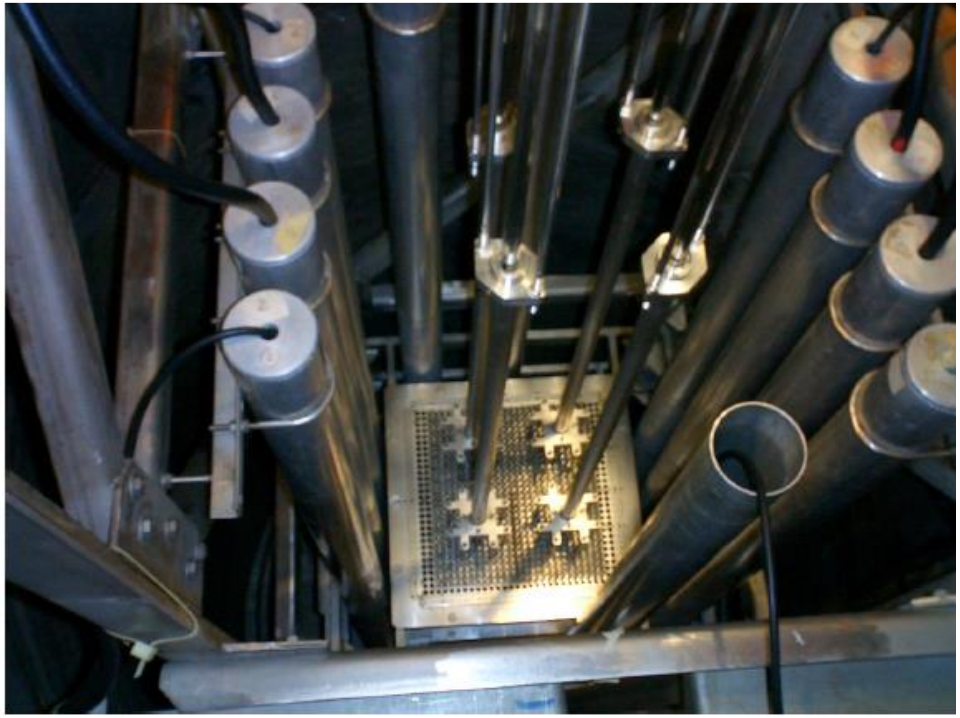
Titanium and/or Aluminum Rod-Replacement Experiments in Fully-Reflected Water-Moderated Square-Pitched U(6.90)O_2 Fuel Rod Lattices with 0.67 Fuel to Water Volume Ratio (0.800 cm Pitch) [LEU-COMP-THERM-097]





Subcritical Configurations of the IPEN/MB-01 Reactor

[SUB-LEU-COMP-THERM-002 : IPEN(MB-01)-LWR-RESR-016]



Case	$\Sigma\rho_{gen}$ Experimental (pcm)	$\Sigma\rho_{gen}$ Calculated (pcm)	(C-E)/E[(a)] ± 1σ (pcm) %
1	10 ± 3	72 ± 16	619 ± 269
2	-159 ± 17	-161 ± 23	1 ± 18
3	-239 ± 19	-246 ± 23	3 ± 12
4	-309 ± 20	-310 ± 23	0 ± 10
5	-432 ± 21	-430 ± 23	0 ± 7
6	-545 ± 23	-550 ± 23	1 ± 6
7	-657 ± 24	-656 ± 23	0 ± 5
8	-780 ± 26	-836 ± 23	7 ± 5
9	-918 ± 29	-960 ± 23	5 ± 5
10	-1047 ± 33	-1108 ± 23	6 ± 4
11	-1270 ± 37	-1325 ± 23	4 ± 4
12	-1468 ± 43	-1497 ± 23	2 ± 3
13	-1654 ± 47	-1730 ± 23	5 ± 3
14	-1939 ± 53	-1970 ± 23	2 ± 3
15	-2181 ± 59	-2214 ± 23	2 ± 3
16	-2480 ± 61	-2507 ± 23	1 ± 3
17	-2650 ± 66	-2746 ± 23	4 ± 3
18	-3052 ± 68	-3042 ± 23	0 ± 2
19	-3579 ± 72	-3502 ± 23	-2 ± 2
20	-3960 ± 75	-3974 ± 24	0 ± 2
21	-4399 ± 81	-4478 ± 24	2 ± 2
22	-4782 ± 86	-5017 ± 24	5 ± 2
23	-5072 ± 93	-5618 ± 24	11 ± 2

(a) C and E are, respectively, the calculated and benchmark experiment values.

Mixed Pu/U, Criticality Alarm/Shielding and Fundamental Physics Benchmarks

1 Mixed Uranium/Plutonium Benchmark:

- Valduc Nuclear Center in France

3 Criticality Alarm/Shielding Benchmarks:

- Valduc Nuclear Center in France

2 Fundamental Physics Benchmarks:

- National Criticality Experiments Research Center (NCERC) in the United States

Pulse 1/Air: Neutron Activation and Thermoluminescent Detector Response to a Bare Pulse of the CEA Valduc SILENE Critical Assembly

[ALARM-TRAN-AIR-SHIELD-001]

Position	Reaction	Activity (Bq/g)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 Collimator A	$^{59}Co(n,\gamma)^{60}Co$	7.498E+01	0.0016	1.1343	0.0665
	$^{115}In(n,\gamma)^{116}In$	9.932E+06	0.0019	1.0902	0.0708
	$^{115}In(n,n'\gamma)^{115m}In$	7.687E+03	0.0023	0.9573	0.0631
	$^{54}Fe(n,p)^{54}Mn$	2.095E-01	0.0020	1.0158	0.0641
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	2.411E+03	0.0022	1.0435	0.0643
	$^{24}Mg(n,p)^{24}Na$	6.717E+01	0.0046	1.0993	0.0641
	$^{58}Ni(n,p)^{58}Co$	1.376E+01	0.0019	0.9581	0.0629
Case 2 Collimator B	$^{59}Co(n,\gamma)^{60}Co$	2.848E+01	0.0013	1.2701	0.0820
	$^{197}Au(n,\gamma)^{198}Au$	3.008E+04	0.0019	1.2400	0.0837
	$^{115}In(n,\gamma)^{116}In$	3.642E+06	0.0015	1.2141	0.0847
	$^{115}In(n,n'\gamma)^{115m}In$	1.308E+03	0.0020	1.0936	0.1139
	$^{54}Fe(n,p)^{54}Mn$	3.515E-02	0.0021	1.1304	0.1214
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	9.160E+02	0.0017	1.1759	0.0782
	$^{24}Mg(n,p)^{24}Na$	1.196E+01	0.0061	1.1957	0.1338
	$^{58}Ni(n,p)^{58}Co$	2.330E+00	0.0020	1.0991	0.1169
Case 3 Free field	$^{59}Co(n,\gamma)^{60}Co$	7.782E+01	0.0022	1.1755	0.0665
	$^{197}Au(n,\gamma)^{198}Au$	7.858E+04	0.0037	1.1307	0.0650
	$^{115}In(n,\gamma)^{116}In$	9.442E+06	0.0029	1.0754	0.0711
	$^{115}In(n,n'\gamma)^{115m}In$	6.609E+03	0.0020	0.9635	0.0628
	$^{54}Fe(n,p)^{54}Mn$	1.949E-01	0.0016	0.9941	0.0643
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	2.662E+03	0.0029	1.1080	0.0636
	$^{24}Mg(n,p)^{24}Na$	6.549E+01	0.0043	1.1081	0.0644
	$^{58}Ni(n,p)^{58}Co$	1.271E+01	0.0016	0.9786	0.0629
Case 4 Scattering box 1	$^{59}Co(n,\gamma)^{60}Co$	2.947E+01	0.0014	1.3233	0.0771
	$^{197}Au(n,\gamma)^{198}Au$	2.939E+04	0.0017	1.2174	0.0811
	$^{115}In(n,\gamma)^{116}In$	3.357E+06	0.0014	1.2386	0.0761
	$^{115}In(n,n'\gamma)^{115m}In$	5.321E+02	0.0040	1.0135	0.1015
	$^{54}Fe(n,p)^{54}Mn$	1.155E-02	0.0034	1.0919	0.1214
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	1.033E+03	0.0018	1.2183	0.0670
	$^{58}Ni(n,p)^{58}Co$	7.888E-01	0.0033	1.1173	0.1147
Case 5 Scattering box 2	$^{59}Co(n,\gamma)^{60}Co$	3.396E+01	0.0010	1.3269	0.0712
	$^{197}Au(n,\gamma)^{198}Au$	3.261E+04	0.0015	1.2845	0.0693
	$^{58}Ni(n,p)^{58}Co$	4.244E-01	0.0049	1.4636	0.1232
Case 6 Scattering box 3	$^{59}Co(n,\gamma)^{60}Co$	5.373E+01	0.0010	1.2201	0.0695
	$^{197}Au(n,\gamma)^{198}Au$	5.310E+04	0.0014	1.1906	0.0680
	$^{58}Ni(n,p)^{58}Co$	3.277E+00	0.0024	1.0115	0.0661
Case 7 Scattering box 4	$^{59}Co(n,\gamma)^{60}Co$	4.881E+01	0.0010	1.2224	0.0702
	$^{197}Au(n,\gamma)^{198}Au$	4.790E+04	0.0014	1.2376	0.0685
	$^{58}Ni(n,p)^{58}Co$	3.451E+00	0.0031	1.0362	0.0658

Position	TLD type	Dose (Gy)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 Collimator A	Al_2O_3	4.811E+00	0.0047	0.7279	0.0786
Case 2 Collimator B	Al_2O_3	6.732E-01	0.0066	0.8209	0.0982
Case 3 Free field	Al_2O_3	4.172E+00	0.0034	1.1215	0.0788
Case 4 Scattering box 1	Al_2O_3	4.292E-01	0.0090	0.7400	0.0851
Case 5 Scattering box 2	Al_2O_3	3.018E-01	0.0078	0.6859	0.0821
Case 6 Scattering box 3	Al_2O_3	1.194E+00	0.0063	0.6785	0.0784
Case 7 Scattering box 4	Al_2O_3	1.281E+00	0.0042	0.6848	0.0908

Pulse 2/Pb: Neutron Activation Foil and Thermoluminescent Dosimeter Responses to a Lead Reflected Pulse of the CEA Valduc SILENE Critical Assembly

[ALARM-TRAN-PB-SHIELD-001]

Position	Reaction	Activity (Bq/g)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 collimator A	$^{59}Co(n,\gamma)^{60}Co$	7.448E+01	0.0012	1.22	0.0706
	$^{197}Au(n,\gamma)^{198}Au$	8.606E+04	0.0015	1.25	0.0681
	$^{115}In(n,\gamma)^{116}In$	9.884E+06	0.0013	1.24	0.0744
	$^{115}In(n,n'\gamma)^{115m}In$	5.774E+03	0.0016	0.95	0.0633
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	2.358E+03	0.0016	1.17	0.0690
	$^{24}Mg(n,p)^{24}Na$	2.953E+01	0.0067	1.19	0.0650
	$^{58}Ni(n,p)^{58}Co$	7.600E+00	0.0018	1.11	0.0636
Case 2 collimator B	$^{59}Co(n,\gamma)^{60}Co$	3.841E+01	0.0011	1.19	0.0783
	$^{197}Au(n,\gamma)^{198}Au$	3.941E+04	0.0013	1.27	0.0830
	$^{115}In(n,\gamma)^{116}In$	4.740E+06	0.0014	1.23	0.0841
	$^{115}In(n,n'\gamma)^{115m}In$	9.642E+02	0.0019	1.03	0.1074
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	1.225E+03	0.0013	1.18	0.0740
	$^{24}Mg(n,p)^{24}Na$	6.450E+00	0.0079	1.17	0.1189
	$^{58}Ni(n,p)^{58}Co$	1.429E+00	0.0018	1.12	0.1118
Case 3 free field	$^{59}Co(n,\gamma)^{60}Co$	7.700E+01	0.0017	1.23	0.0702
	$^{197}Au(n,\gamma)^{198}Au$	7.865E+04	0.0027	1.22	0.0659
	$^{115}In(n,\gamma)^{116}In$	9.503E+06	0.0020	1.21	0.0711
	$^{115}In(n,n'\gamma)^{115m}In$	4.949E+03	0.0017	0.95	0.0632
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	2.615E+03	0.0025	1.25	0.0644
	$^{24}Mg(n,p)^{24}Na$	2.884E+01	0.0065	1.09	0.0711
	$^{58}Ni(n,p)^{58}Co$	6.908E+00	0.0017	1.09	0.0634
Case 4 scattering box 1	$^{59}Co(n,\gamma)^{60}Co$	3.174E+01	0.0013	1.30	0.0738
	$^{197}Au(n,\gamma)^{198}Au$	3.184E+04	0.0015	1.32	0.0709
	$^{115}In(n,\gamma)^{116}In$	3.777E+06	0.0013	1.30	0.0780
	$^{115}In(n,n'\gamma)^{115m}In$	3.380E+02	0.0031	1.05	0.1051
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	1.110E+03	0.0016	1.26	0.0672
	$^{24}Mg(n,p)^{24}Na$	1.344E+00	0.0073	1.11	0.1353
	$^{58}Ni(n,p)^{58}Co$	4.020E-01	0.0029	1.24	0.1315
Case 5 scattering box 2	$^{59}Co(n,\gamma)^{60}Co$	3.648E+01	0.0008	1.30	0.0732
	$^{197}Au(n,\gamma)^{198}Au$	3.488E+04	0.0011	1.35	0.0698
	$^{58}Ni(n,p)^{58}Co$	2.155E-01	0.0057	1.14	0.1127
Case 6 scattering box 3	$^{59}Co(n,\gamma)^{60}Co$	5.598E+01	0.0008	1.22	0.0719
	$^{197}Au(n,\gamma)^{198}Au$	5.572E+04	0.0011	1.28	0.0686
	$^{58}Ni(n,p)^{58}Co$	1.755E+00	0.0022	1.00	0.0716
Case 7 scattering box 4	$^{59}Co(n,\gamma)^{60}Co$	5.111E+01	0.0008	1.24	0.0727
	$^{197}Au(n,\gamma)^{198}Au$	5.040E+04	0.0011	1.29	0.0693
	$^{58}Ni(n,p)^{58}Co$	1.865E+00	0.0032	1.02	0.0724

Position	TLD type	Dose (Gy)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 collimator A	Al_2O_3	6.832E-01	0.0051	0.83	0.0811
Case 2 collimator B	Al_2O_3	4.271E-01	0.0055	0.78	0.1188
Case 3 free field	Al_2O_3	3.152E-01	0.0044	0.56	0.0786
Case 6 scattering box 3	Al_2O_3	3.149E-01	0.0037	0.75	0.0716

Pulse 3/CH_2: Neutron Activation Foil and Thermoluminescent Dosimeter Responses to a Polyethylene Reflected Pulse of the CEA Valduc SILENE Critical Assembly

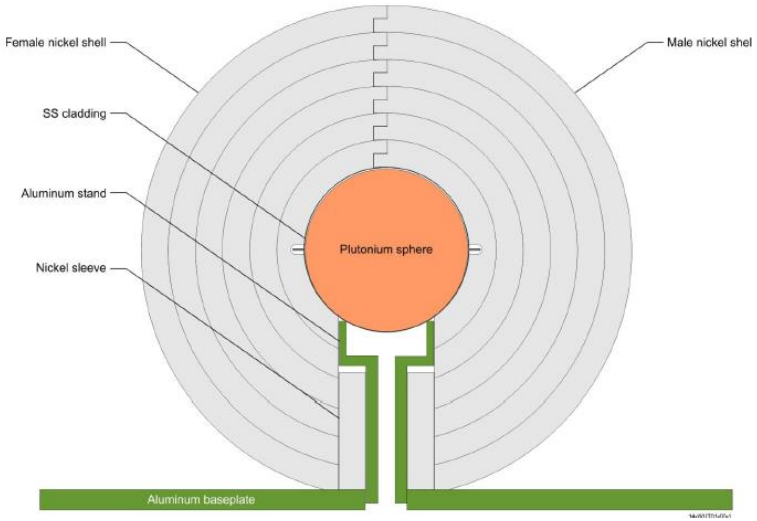
[ALARM-TRAN-CH2-SHIELD-001]

Position	Reaction	Activity (Bq/g)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 collimator A	$^{59}Co(n,\gamma)^{60}Co$	4.644E+00	0.0024	1.0206	0.0683
	$^{197}Au(n,\gamma)^{198}Au$	5.801E+03	0.0030	0.8911	0.0716
	$^{115}In(n,\gamma)^{116}In$	6.407E+05	0.0032	0.9591	0.0691
	$^{115}In(n,n'\gamma)^{115m}In$	8.269E+02	0.0020	0.8327	0.0630
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	1.722E+02	0.0029	0.9165	0.0638
	$^{24}Mg(n,p)^{24}Na$	1.608E+01	0.0036	0.9928	0.0747
	$^{58}Ni(n,p)^{58}Co$	1.939E+00	0.0018	0.9005	0.0654
Case 2 collimator B	$^{59}Co(n,\gamma)^{60}Co$	7.427E-01	0.0024	1.1253	0.0855
	$^{197}Au(n,\gamma)^{198}Au$	1.091E+03	0.0033	0.9314	0.0798
	$^{115}In(n,\gamma)^{116}In$	9.983E+04	0.0033	0.9092	0.0825
	$^{115}In(n,n'\gamma)^{115m}In$	3.595E+02	0.0019	0.8746	0.0722
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	3.775E+01	0.0022	0.9075	0.0749
	$^{24}Mg(n,p)^{24}Na$	8.019E+00	0.0034	1.0428	0.0774
Case 3 free field	$^{59}Co(n,\gamma)^{60}Co$	5.448E+00	0.0033	1.0896	0.0692
	$^{197}Au(n,\gamma)^{198}Au$	5.860E+03	0.0043	1.0559	0.0648
	$^{115}In(n,\gamma)^{116}In$	6.648E+05	0.0035	1.1326	0.0725
	$^{115}In(n,n'\gamma)^{115m}In$	7.067E+02	0.0021	0.8403	0.0683
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	2.110E+02	0.0037	0.9859	0.0671
	$^{24}Mg(n,p)^{24}Na$	1.575E+01	0.0044	1.0712	0.0801
	$^{58}Ni(n,p)^{58}Co$	1.800E+00	0.0025	1.0033	0.0634
Case 4 scattering box 1	$^{59}Co(n,\gamma)^{60}Co$	2.577E+00	0.0016	1.1894	0.0729
	$^{197}Au(n,\gamma)^{198}Au$	2.548E+03	0.0020	1.0798	0.0739
	$^{115}In(n,\gamma)^{116}In$	3.034E+05	0.0019	1.1448	0.0743
	$^{115}In(n,n'\gamma)^{115m}In$	5.681E+01	0.0034	0.9661	0.0994
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	9.111E+01	0.0021	1.1636	0.0685
Case 5 scattering box 2	$^{59}Co(n,\gamma)^{60}Co$	3.040E+00	0.0013	1.2078	0.0709
	$^{197}Au(n,\gamma)^{198}Au$	2.951E+03	0.0018	1.1763	0.0688
Case 6 scattering box 3	$^{59}Co(n,\gamma)^{60}Co$	4.327E+00	0.0014	1.1065	0.0717
	$^{197}Au(n,\gamma)^{198}Au$	4.336E+03	0.0018	1.1089	0.0681
Case 7 scattering box 4	$^{59}Co(n,\gamma)^{60}Co$	3.953E+00	0.0013	1.1388	0.0696
	$^{197}Au(n,\gamma)^{198}Au$	3.888E+03	0.0017	1.0595	0.0730

Position	TLD Type	Dose (Gy)	Monte Carlo relative uncertainty	C/E	C/E relative uncertainty
Case 1 collimator A	Al_2O_3	3.314E+00	0.0071	0.6265	0.0787
Case 2 collimator B	Al_2O_3	1.902E+00	0.0044	0.6040	0.0832
Case 3 free field	Al_2O_3	3.130E+00	0.0041	0.6535	0.0917
Case 6 scattering box 3	Al_2O_3	6.628E-01	0.0034	0.6563	0.0846
Case 7 scattering box 4	Al_2O_3	7.478E-01	0.0058	0.6560	0.0784

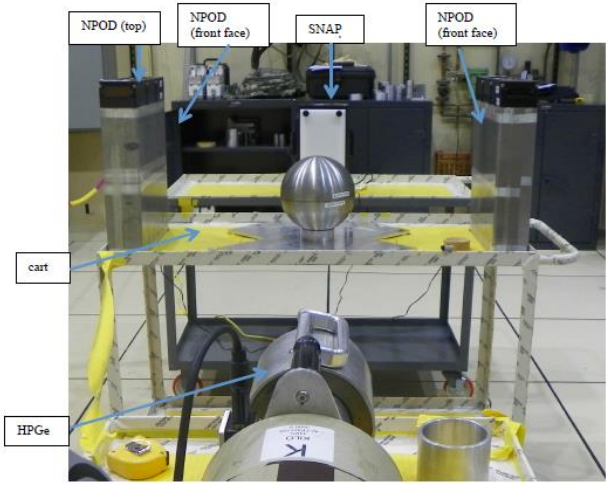
Nickel-Reflected Plutonium-Metal-Sphere Subcritical Measurements
[FUND-NCERC-PU-HE3-MULT-001]

Case	Nickel Thickness (in.)	R_1 (cts/s)	σ	(C-E)/E (%)	R_2 (cts/s)	σ	(C-E)/E (%)	M_L	σ	(C-E)/E (%)
1	0.0	9155.80	3.08	2.6	1627.81	9.43	1.8	3.56	0.02	5.3
2	0.5	12260.80	3.84	3.4	3984.60	15.57	5.3	4.55	0.02	4.7
3	1.0	15095.05	4.59	3.6	7447.52	23.77	6.6	5.41	0.02	3.1
4	1.5	17843.94	5.36	4.2	12156.59	33.81	8.3	6.20	0.03	2.1
5	2.0	20499.00	6.15	5.2	18242.34	46.82	11.5	6.95	0.03	2.4
6	2.5	23065.95	6.96	5.6	25638.07	62.25	13.0	7.65	0.03	2.2
7	3.0	25489.73	7.75	6.8	34138.54	79.17	16.3	8.30	0.03	2.5



Tungsten-Reflected Plutonium-Metal-Sphere Subcritical Measurements
[FUND-NCERC-PU-HE3-MULT-002]

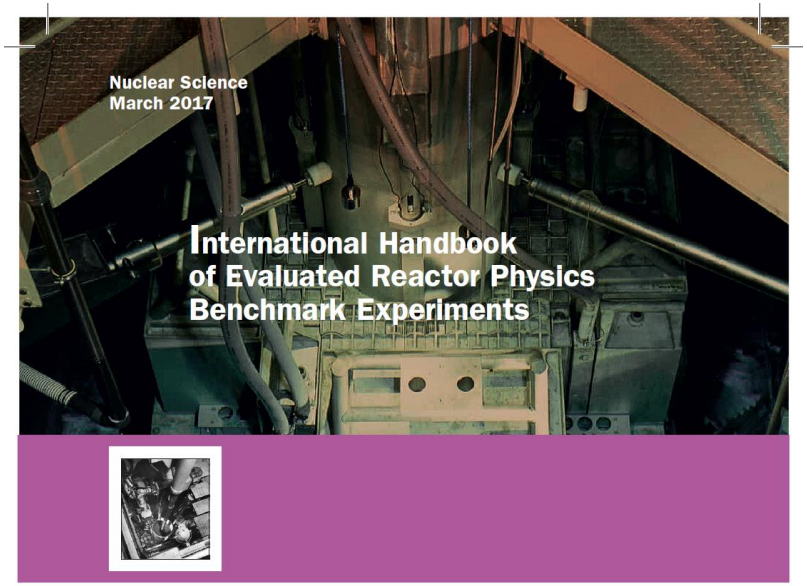
Case	Tungsten Thickness (in.)	R_1 (cts/s)	σ	(C-E)/E (%)	R_2 (cts/s)	σ	(C-E)/E (%)	M_L	σ	(C-E)/E (%)
1	0.0	9387.38	3.14	4.06	1752.88	9.65	6.64	3.545	0.023	5.16
2	0.5	13402.94	4.10	1.83	4810.58	17.46	0.38	4.473	0.022	-0.71
3	1.0	17273.83	5.12	0.84	10174.02	29.20	-2.40	5.514	0.024	-4.43
4	1.5	21518.23	6.36	0.04	19521.57	49.74	-3.38	6.644	0.026	-5.66
5	2.0	26082.81	7.81	-0.15	34258.82	79.50	-4.05	7.865	0.029	-6.28
6	2.5	30718.62	9.44	-0.46	55664.39	122.18	-4.33	9.137	0.029	-7.08
7	2.75	32958.73	10.29	-0.57	68657.54	146.86	-4.49	9.834	0.035	-6.20
8	3.0	35236.45	11.16	-1.00	83636.32	175.06	-5.42	10.442	0.032	-7.29



International Handbook of Evaluated Reactor Physics Benchmark Experiments

March 2017 Edition

- 21 Contributing Countries
- 50 Reactor Facilities
- Data from 151 Experimental Series
  - 147 Approved Benchmarks
  - 4 DRAFT Benchmarks



NEA
NUCLEAR ENERGY AGENCY

http://irphep.inl.gov/

http://www.oecd-nea.org/science/wprs/irphe/

Breakdown of Current Reactor Facilities on IRPhEP Handbook

- 6 Pressurized Water Reactor (PWR)
  - DIMPLE, DUKE, EOLE, OTTOHAHN, SSCR, VENUS
- 3 Vodo-Vodynaoi Energetichesky Reactor (VVER)
  - LR-0, P-Facility, ZR-6
- 0 Boiling Water Reactor (BWR)
- 9 Liquid Metal Fast Reactor (LMFR)
  - BFS-1, BFS-2, BR2, FFTF, JOYO, SNEAK, ZEBRA, ZPPR, ZPR
- 5 Gas Cooled (Thermal) Reactor (GCR)
  - ASTRA, HTR10, HTTR, PROTEUS, VHTRC
- 1 Gas Cooled Fast Reactor (GCFR)
  - PROTEUS
- 5 Light Water Reactor (LWR)
  - CROCUS, DIMPLE, IPEN(MB01), KRITZ, TCA
- 3 Heavy Water Reactor (HWR)
  - DCA, ETA, ZED2
- 0 Molten Salt Reactor (MSR)
- 1 Reaktor Bolshoy Moshchnosti Kanalniy (RBMK)
  - RBMK(CF)
- 6 Space Reactor (SPACE)
  - ORCEF, SCCA, TOPAZ, UKS1M, ZPPR, ZPR
- 19 Fundamental Physics Reactor Measurements (FUND)
  - ATR, BFS-1, BFS-2, CORAL(1), FR0, HECTOR, IGR, KUCA, LAMPRE, MINERVE, NRAD, ORSPHERE, PBF, RA-6, RB, RHF, TRIGA, ZEBRA, ZPR

PWR and VVER Benchmarks

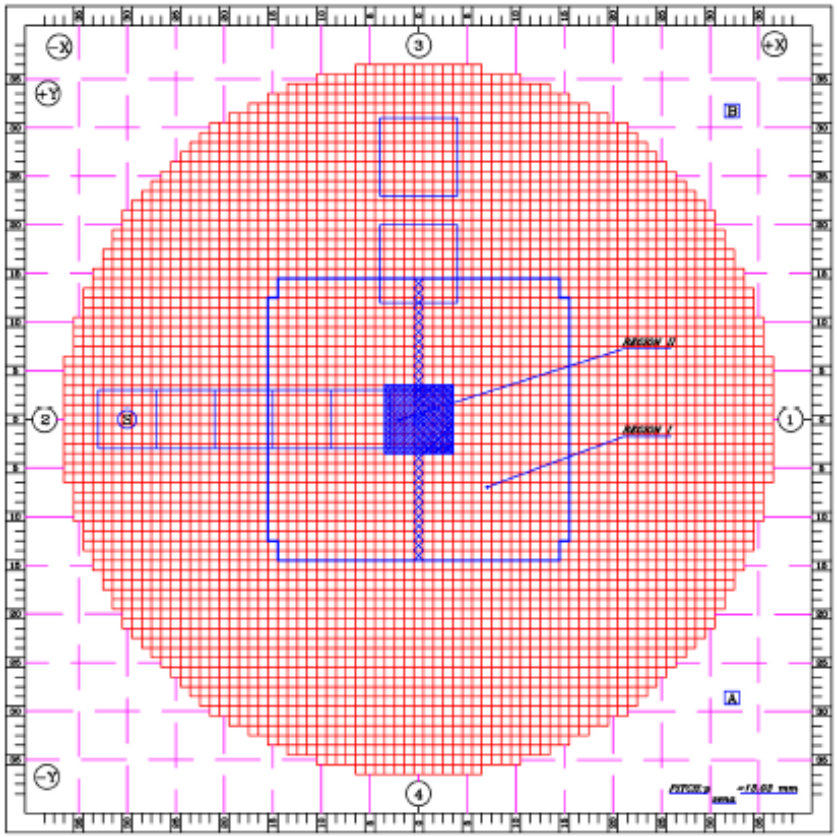
1 PWR Benchmark:

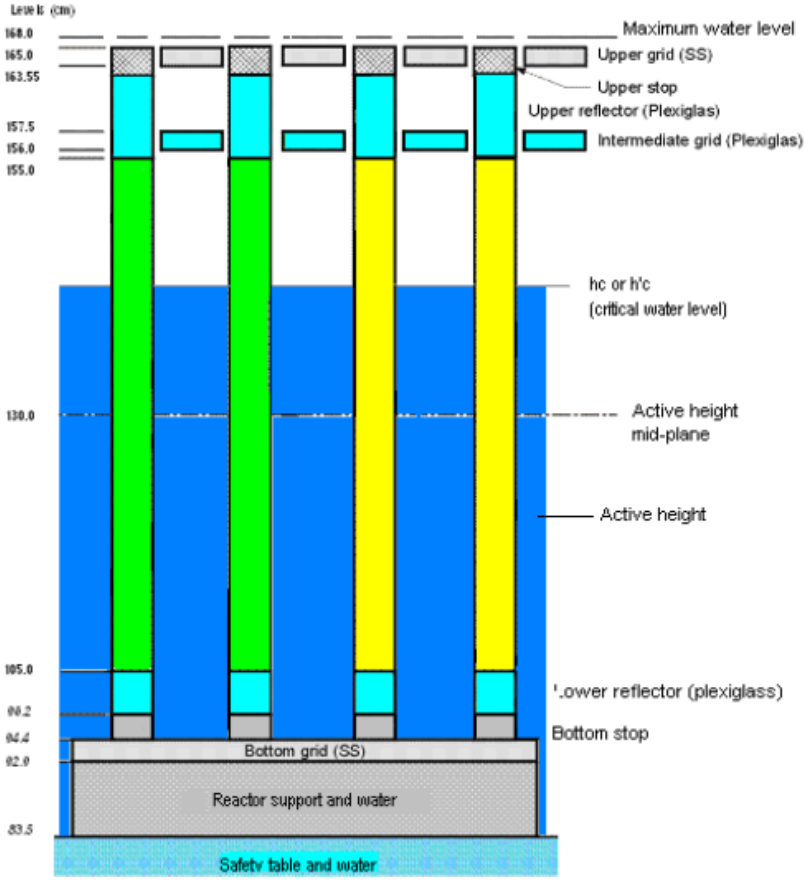
- Centre d'étude de l'Energie Nucléaire / Studiecentrum voor Kernenergie (CEN/SCK) in Belgium

2 VVER Benchmarks:

- Nuclear Research Institute, Řež plc (NRI) facility in the Czech Republic

Experimental Study of the VENUS Configuration No. 17 (DRAFT)
[VENUS-PWR-EXP-006]



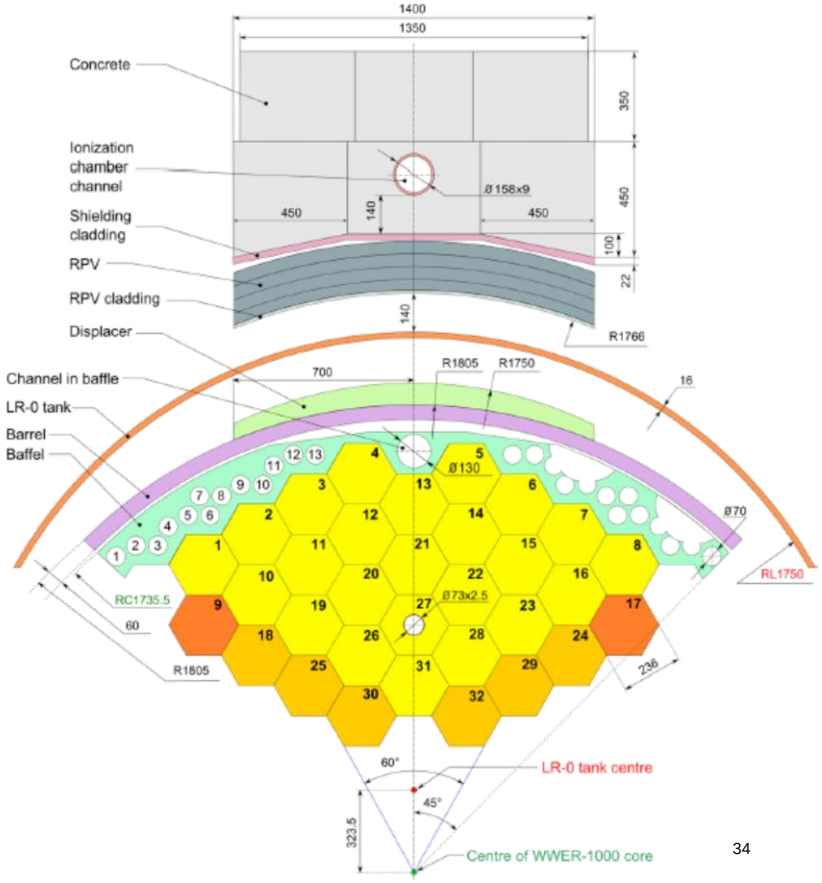


VVER-1000 Mock Up Physics Experiments Hexagonal Lattices (1.275 cm Pitch) of Low Enriched U(2.0, 3.0, 3.3 wt.% $^{235}U)O_2$ Fuel Assemblies in Light Water with H_3BO_3 [LR(0)-VVER-RESR-002]

Case	k_{eff}	Uncertainty	Bias[(a)]
1	1.00000	0.00152	0.00074
2	1.00000	0.00139	0.00083
3	1.00000	0.00156	0.00084
4	1.00000	0.00164	0.00080
5	1.00000	0.00167	0.00077
6	1.00000	0.00173	0.00068

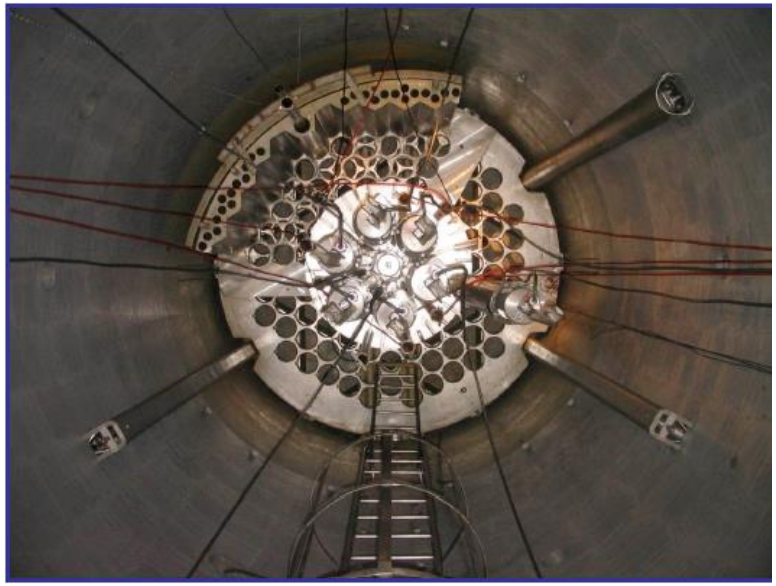
(a) The effect of omitting ^{234}U content.

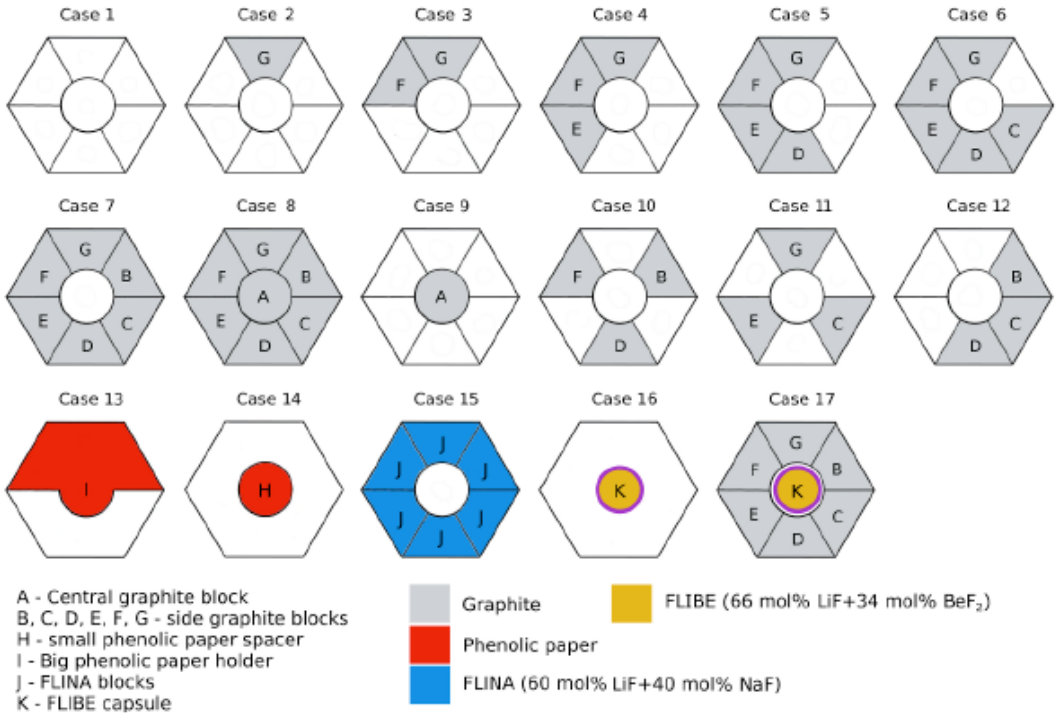
Case	1	2	3	4	5	6
ENDF VII.1	1.00217 ±0.00183	1.00355 ±0.00166	1.00457 ±0.00189	1.00501 ±0.00199	1.00510 ±0.00202	1.00446 ±0.00212
CENDL 3.1	0.99996 ±0.00183	1.00123 ±0.00166	1.00212 ±0.00189	1.00259 ±0.00199	1.00279 ±0.00202	1.00227 ±0.00212
JENDL 4.0	1.00201 ±0.00183	1.00340 ±0.00166	1.00417 ±0.00189	1.00479 ±0.00199	1.00473 ±0.00202	1.00418 ±0.00212
ROSFOND 2009	1.00188 ±0.00183	1.00352 ±0.00166	1.00431 ±0.00189	1.00478 ±0.00199	1.00487 ±0.00202	1.00470 ±0.00212
TENDL 2013	1.00148 ±0.00183	1.00273 ±0.00166	1.00392 ±0.00189	1.00433 ±0.00199	1.00458 ±0.00202	1.00405 ±0.00212
JENDL 3.3	1.00004 ±0.00183	1.00133 ±0.00166	1.00228 ±0.00189	1.00270 ±0.00199	1.00293 ±0.00202	1.00216 ±0.00212
JEFF 3.1	1.00127 ±0.00183	1.00241 ±0.00166	1.00372 ±0.00189	1.00402 ±0.00199	1.00410 ±0.00202	1.00368 ±0.00212
JEFF 3.2	1.00136 ±0.00183	1.00284 ±0.00166	1.00370 ±0.00189	1.00412 ±0.00199	1.00417 ±0.00202	1.00373 ±0.00212



VVER-1000 Physics Experiments Hexagonal Lattices (1.275 cm Pitch) of Low Enriched U(3.3 wt.% $^{235}U)O_2$ Fuel Assemblies in Light Water with Graphite and Fluoride Salt Insertions in Central Assembly

[LR(0)-VVER-RESR-003]





Case	Benchmark Value	Estimated Uncertainties	ENDF-VII.0	JEFF-3.1	JENDL- 3.3	JENDL- 4	ROSFOND-2010	CENDL-3.1
1	0.99919	0.00192	1.00041	1.00009	0.99780	1.00000	0.99939	0.99906
2	0.99819	0.00188	0.99939	0.99900	0.99673	0.99889	0.99823	0.99789
3	0.99830	0.00178	0.99940	0.99912	0.99665	0.99889	0.99835	0.99805
4	0.99691	0.00179	0.99805	0.99764	0.99530	0.99748	0.99694	0.99672
5	0.99856	0.00173	0.99966	0.99929	0.99685	0.99901	0.99851	0.99827
6	0.99858	0.00179	0.99976	0.99926	0.99686	0.99903	0.99863	0.99836
7	0.99893	0.00180	1.00013	0.99966	0.99718	0.99941	0.99889	0.99871
8	0.99865	0.00178	0.99987	0.99935	0.99688	0.9991	0.99861	0.99859
9	0.99931	0.00180	1.00043	1.00014	0.99761	0.99992	0.99945	0.99902
10	0.99802	0.00191	0.99931	0.99894	0.99652	0.99881	0.9982	0.99789
11	0.99833	0.00172	0.99936	0.99902	0.99656	0.99884	0.99837	0.99803
12	0.99786	0.00183	0.99904	0.99869	0.99624	0.99843	0.99789	0.99759
13	0.99816	0.00194	0.99938	0.99918	0.99665	0.99883	0.99836	0.99795
14	0.99837	0.00183	0.99947	0.99903	0.99686	0.99898	0.99847	0.99798
15	0.99733	0.00153	0.99839	0.99791	0.99552	0.99789	0.99732	0.99685
16	1.00071	0.00170	1.00174	1.00133	0.99914	1.00135	1.00073	1.00030
17	1.00211	0.00167	1.00320	1.00284	1.00034	1.00259	1.00206	1.00197

GCFR and LWR Benchmarks

1 GCFR Benchmark:

- Paul Scherrer Institute's (PSI) PROTEUS facility in Switzerland

4 LWR Benchmarks:

- Winfrith in the United Kingdom
- Institute de Pesquisas Energeticas e Nucleares (IPEN) in Brazil

GCFR-PROTEUS Experimental Program Core 11: Nominal Core Configuration [PROTEUS-GCFR-RESR-001]

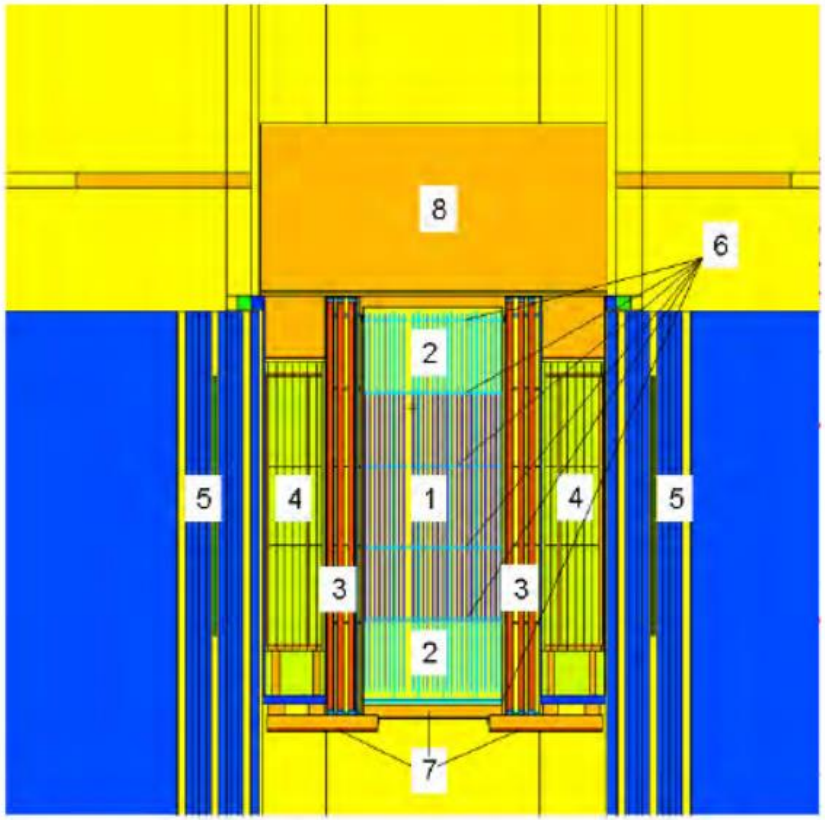
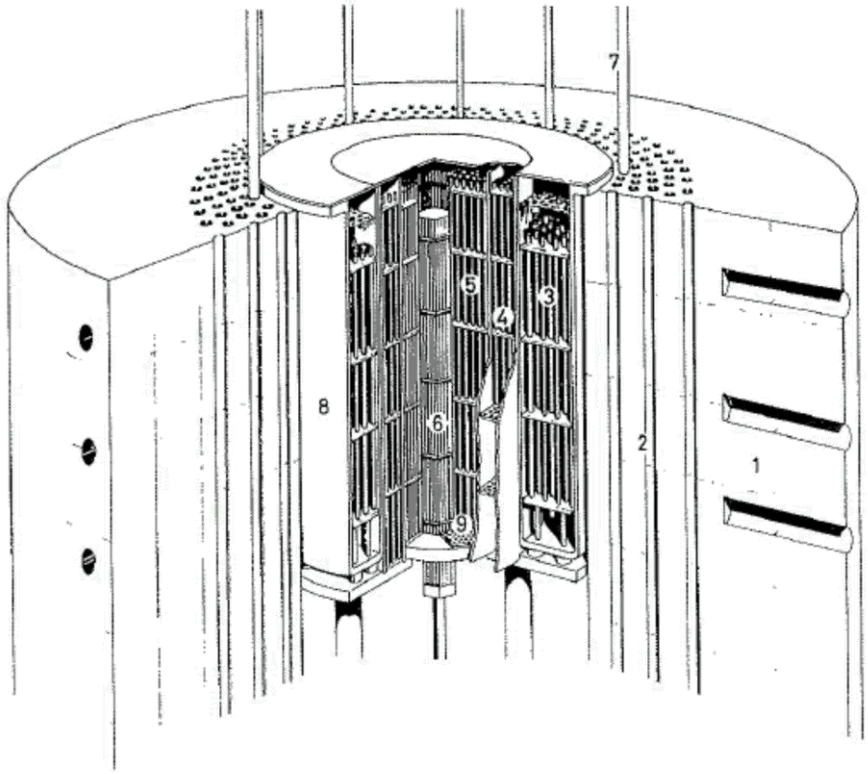
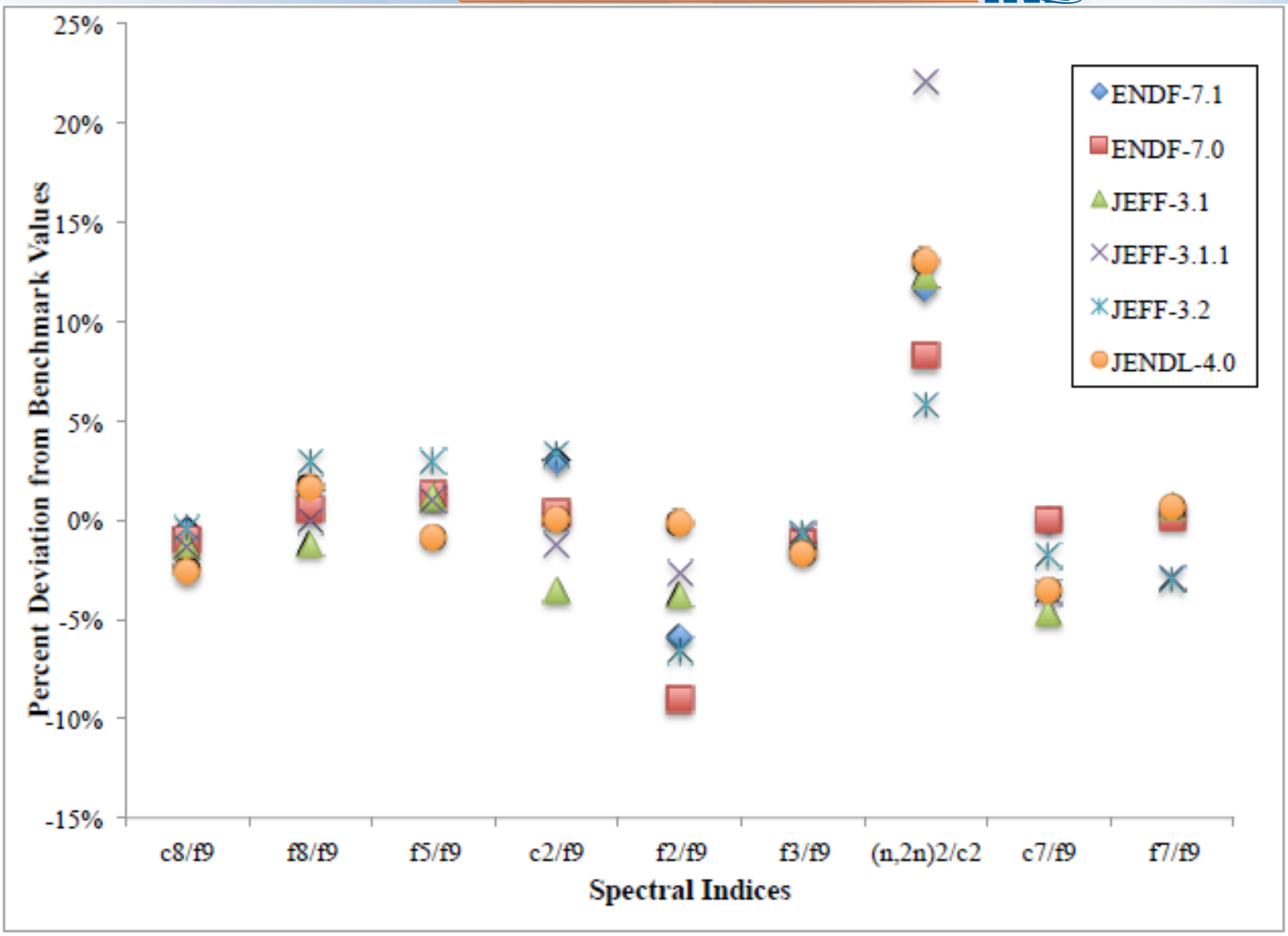


Figure 24. Vertical View of Core 11 3D Benchmark Model.
1) test zone (MOX lattice), 2) blanket zone (UO2 lattice), 3) buffer zone, 4) D_2O zone, 5) graphite driver zone, 6) grid plates, 7) reactor support plates, 8) steel shielding/ plates.

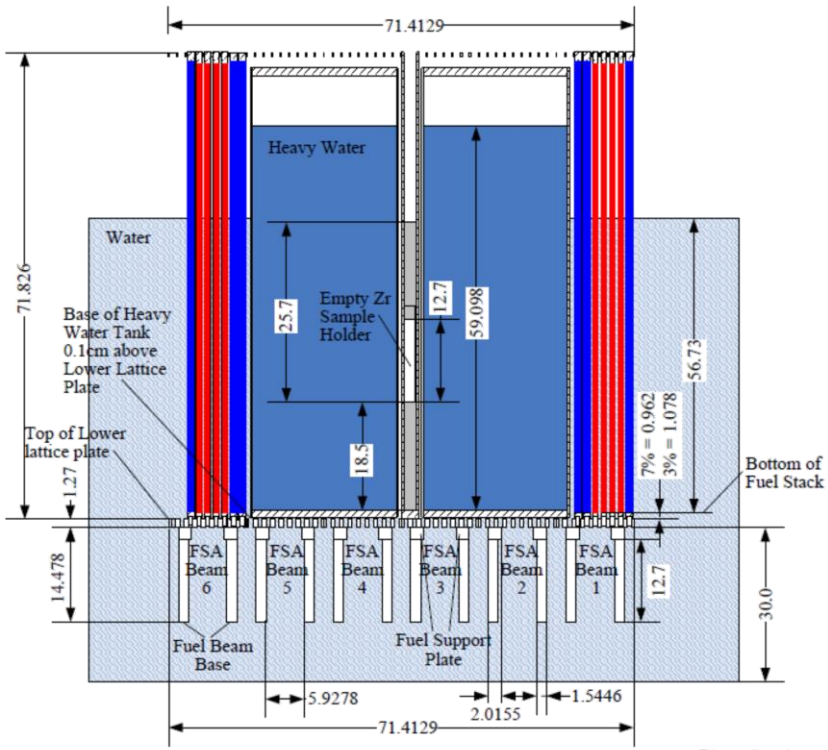


1 GRAPHITE REFLECTOR
2 GRAPHITE DRIVER
3 D_2O-DRIVER
4 BUFFER (U-METAL)
5 FAST ZONE ($Pu O_2/UO_2$)
6 TEST COLUMN
7 CONTROL ROD
8 MODERATOR TANK
9 REMOVABLE GRID PLATE


25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
Percent Deviation from Benchmark Values
ENDF-7.1
ENDF-7.0
JEFF-3.1
JEFF-3.1.1
JEFF-3.2
JENDL-4.0
c8/f9
f8/f9
f5/f9
c2/f9
f2/f9
f3/f9
(n,2n)2/c2
c7/f9
f7/f9
Spectral Indices

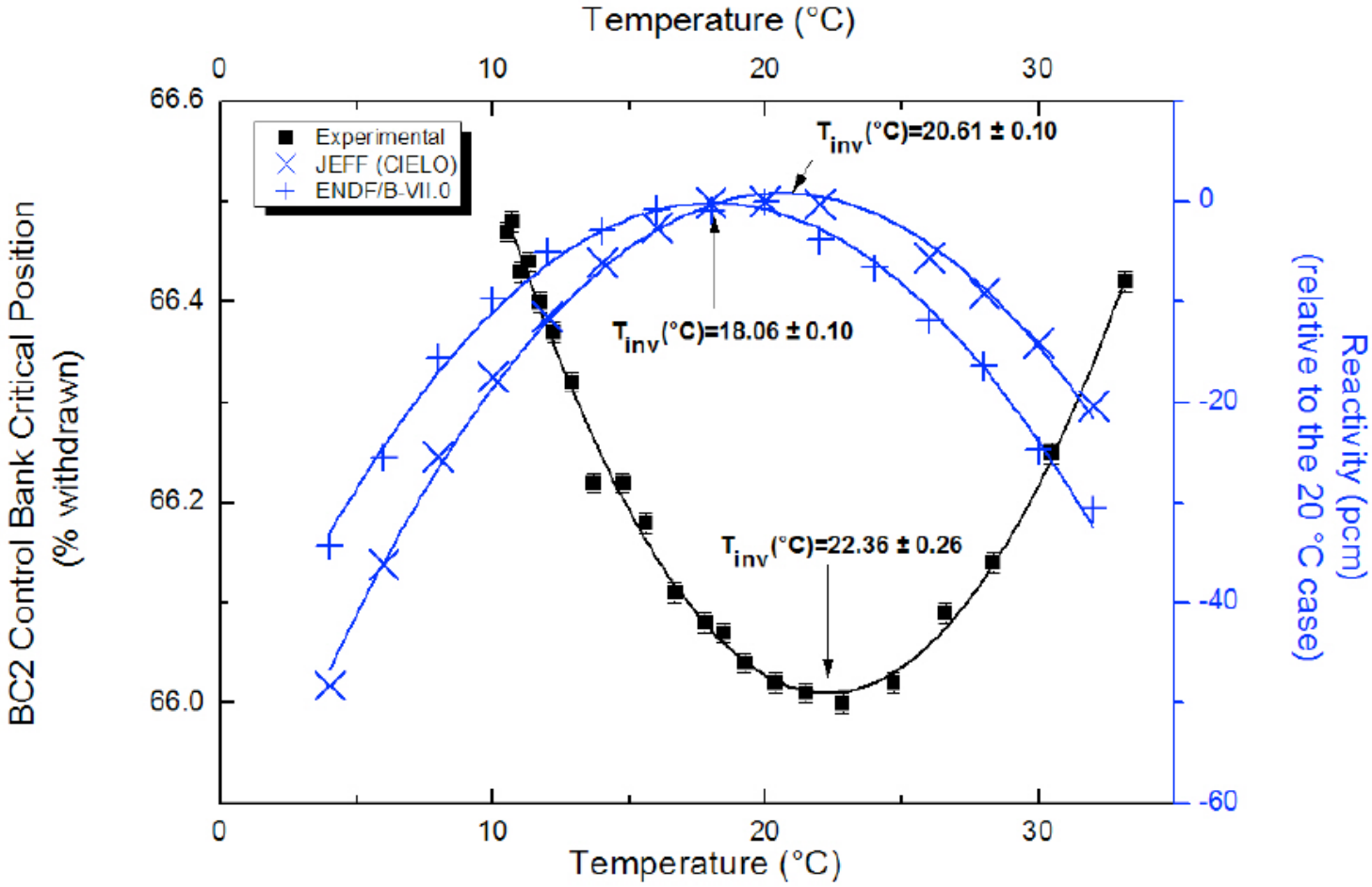
Light Water Moderated and Reflected Low Enriched Uranium (3 wt.% ^{235}U or 7 wt.% ^{235}U) Dioxide Rod Lattices, DIMPLE CERES Phase II (DRAFT)

[DIMPLE-LWR-EXP-003]



Code (Cross Section Set) → Sample ↓	Experimental Reactivity Worth (mNiles or pcm)	MCNP6 (Continuous Energy JEFF3.1.2)	C-M
Calibration Samples			
b900ppm	-15.18	-16.97	-1.79
b1800ppm	-31	-33.82	-2.82
b3600ppm	-58.01	-68.76	-10.75
CEA1CuC	-31.93	-11.06	20.87
CEA1CuD	-50.56	-29.21	21.36
CEA1StB	-26.88	-23.40	3.49
CEA1StD	-46.05	-51.01	-4.96
Fission Product Samples			
CEA2	-25.35	-27.40	-2.05
CEA3	-27.06	-29.84	-2.78
CEA4	-20.88	-31.25	-10.37
CEA5	-43.79	-48.84	-5.05
CEA6	-19.93	-22.85	-2.92
CEA7	-20.95	-22.24	-1.29
CEA8	-29.4	-35.18	-5.78
CEA9	-19.13	-21.71	-2.58
CEA10	-11.74	-8.41	3.33
CEA22	-9.15	-10.17	-1.02
CEA23	-14.96	-12.35	2.62
CEA25	-11.62	-12.98	-1.36

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor *[IPEN(MB-01)-LWR-RESR-017]*



Space Reactor and Fundamental Physics Experiment Benchmarks

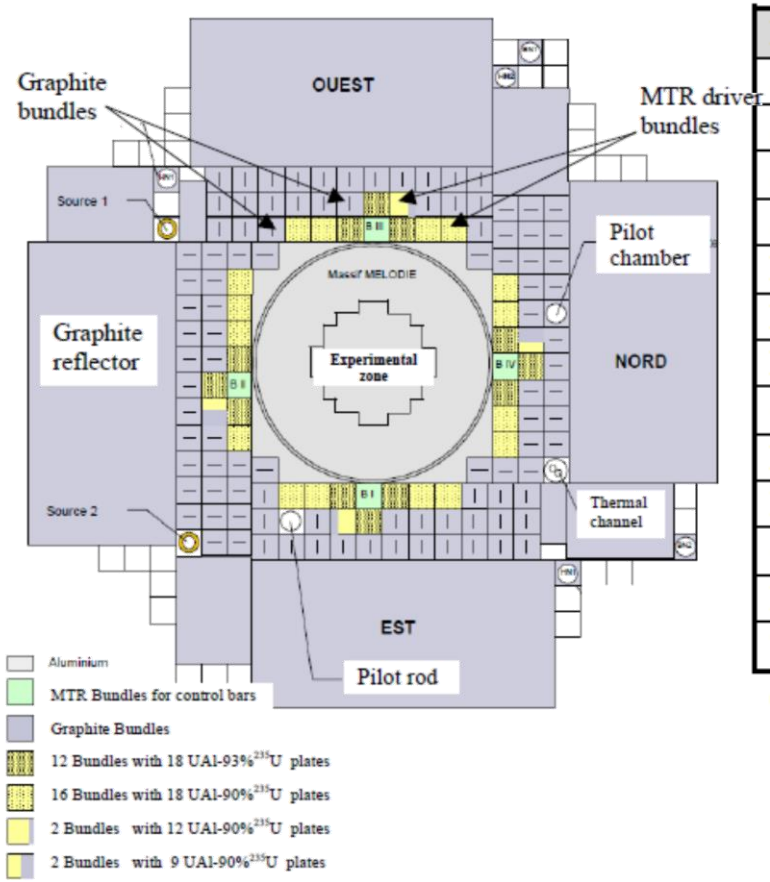
1 SPACE Benchmark:

- Oak Ridge Critical Experiment Facility (ORCEF) at ORNL

6 FUND Benchmarks:

- Cadarache research center of the French Commission of Atomic and Alternative Energies (CEA)
- Vinča's RB reactor in Serbia
- Jožef Stefan Institute (JSI) in Slovenia
- Argonne National Laboratory – West (ANL-W) in the United States

Reactivity Worth Measurement of Major Fission Products in MINERVE LWR-Lattice Experiments *[MINERVE-FUND-RESR-001]*



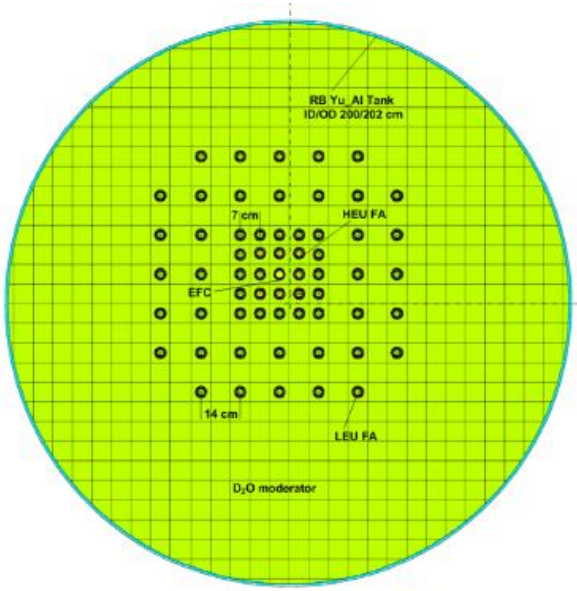
FP Sample	Measured Worth	Calculated Worth	(C-E)/E ± δE/E[(a)]
Sm	-509 ± 10.7	-513.2	0.8% ± 2.3%
Sm9	-543 ± 10.4	-538.0	-0.9% ± 2.2%
Sm2	-527 ± 11.0	-538.4	2.1% ± 2.3%
Sm7	-1009 ± 24.2	-1051.9	4.2% ± 2.6%
Nd	-390 ± 9.0	-383.8	-1.6% ± 2.5%
Nd3	-413 ± 8.3	-399.2	-3.3% ± 2.2%
Nd5	-356 ± 6.8	-364.7	2.4% ± 2.2%
Gd5	-463 ± 9.3	-460.9	-0.5% ± 2.2%
Eu3	-567 ± 18.1	-556.9	-1.8% ± 3.4%
Rh	-413 ± 13.2	-424.1	2.7% ± 3.4%
Cs	-363 ± 8.8	-403.5	11.1% ± 2.6%
Mo5	-219 ± 6.3	-216.8	-1.0% ± 3.1%
Tc99	-288.1 ± 10.1	-315.5	9.5% ± 3.7%

(a) δE/E includes both the experimental uncertainty and the systematic uncertainty due to the calibration factor.

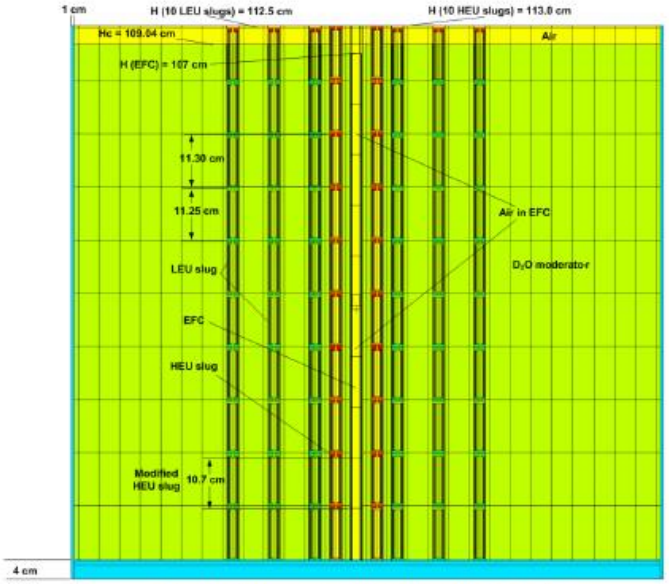
RB Reactor: VINET – Experimental Fuel Channel (EFC), Core RB 58/1982

[RB-FUND-EXP-007]

Code (Cross Section Set) → Core No./Year ↓:	MCNP6.1 (Continuous-energy ENDF/B-VII.1) [b] USA	(C-E)/E (%)
RB58/1982	1.00014 ± 0.00008	-0.33



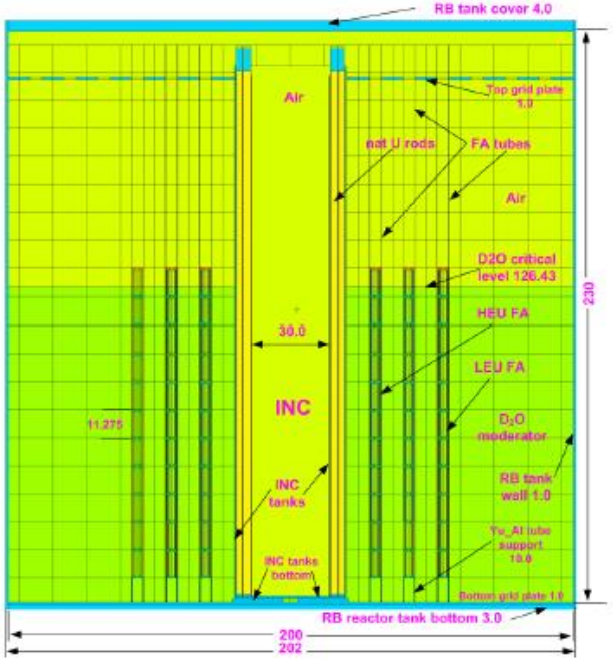
(a) Horizontal cross section
(tank centre is in intersection of dashed lines)



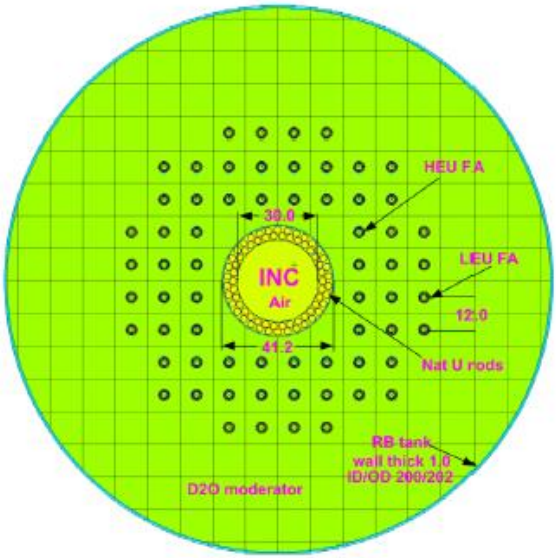
(b) Vertical cross section through the EFC

RB Reactor: Internal Neutron Converters (INC), Cores RB59/1983, RB60/1984 and RB61/1984 [RB-FUND-EXP-008]

Code (Cross Section Set) → Core No./Year ↓:	Experimental k_{eff} + bias (E)	Benchmark k_{eff}	MCNP6.1.1b (Continuous-energy ENDF/B-VII.1), [a] (C) [b]	(C-E)/E (%)
RB59/1983 (INC-0)	1.00083 ± 0.00015	1.00083 ± 0.00132	1.00071 ± 0.00003	-0.011 ± 0.015
RB60/1984 (INC-2)			1.00132 ± 0.00003	0.049 ± 0.015
RB61/1984 (INC-1)			1.00150 ± 0.00003	0.067 ± 0.015



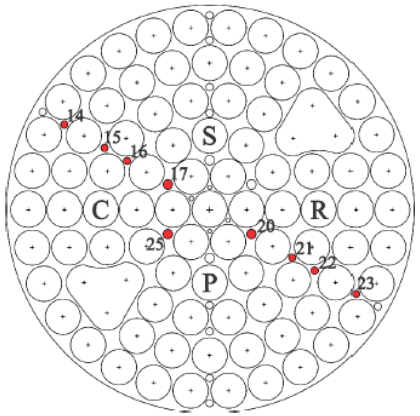
Vertical cross section

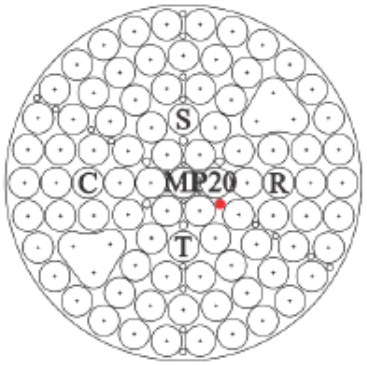


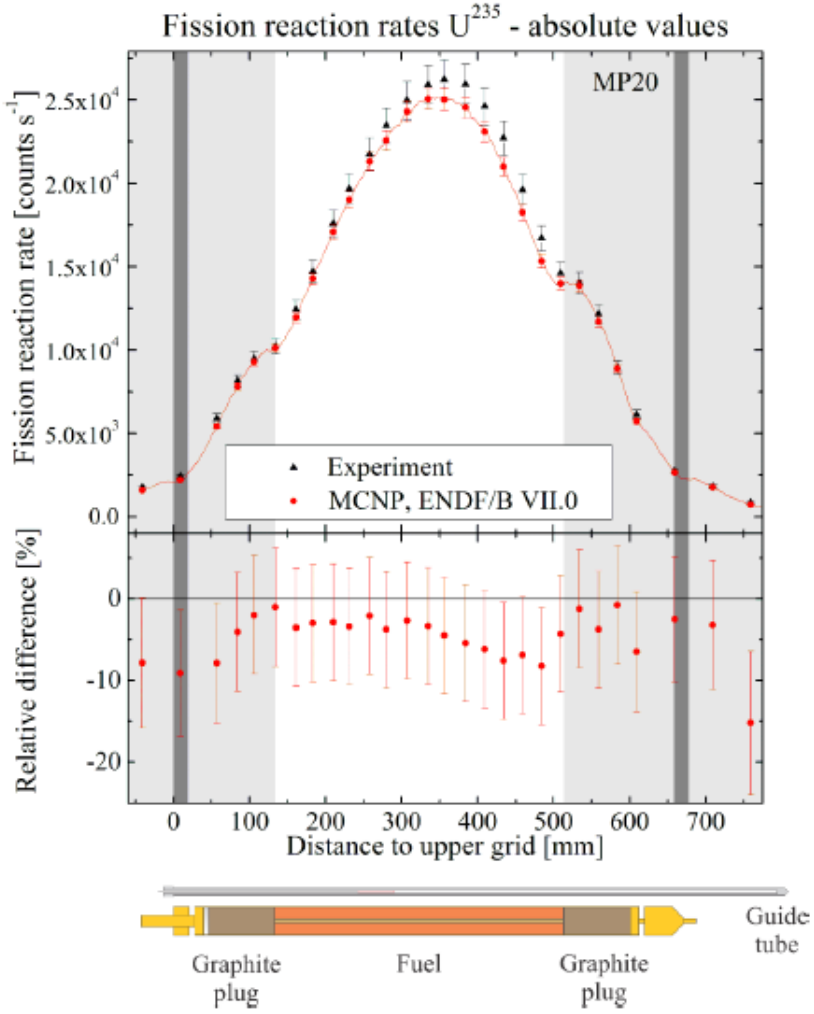
Horizontal cross section at elevation of 50 cm

Reaction Rate Distribution Experiments in the TRIGA Mark II Research Reactor

[TRIGA-FUND-RESR-002]







Summary and Conclusions

- ✓ Hundreds of scientists from 26 different countries have combined their efforts to produce the ICSBEP and IRPhEP Handbooks.
- ✓ Those two handbooks continue to grow and provide high-quality integral benchmark data that will be of use to the criticality safety, nuclear data, and reactor physics communities for future decades.

Questions?

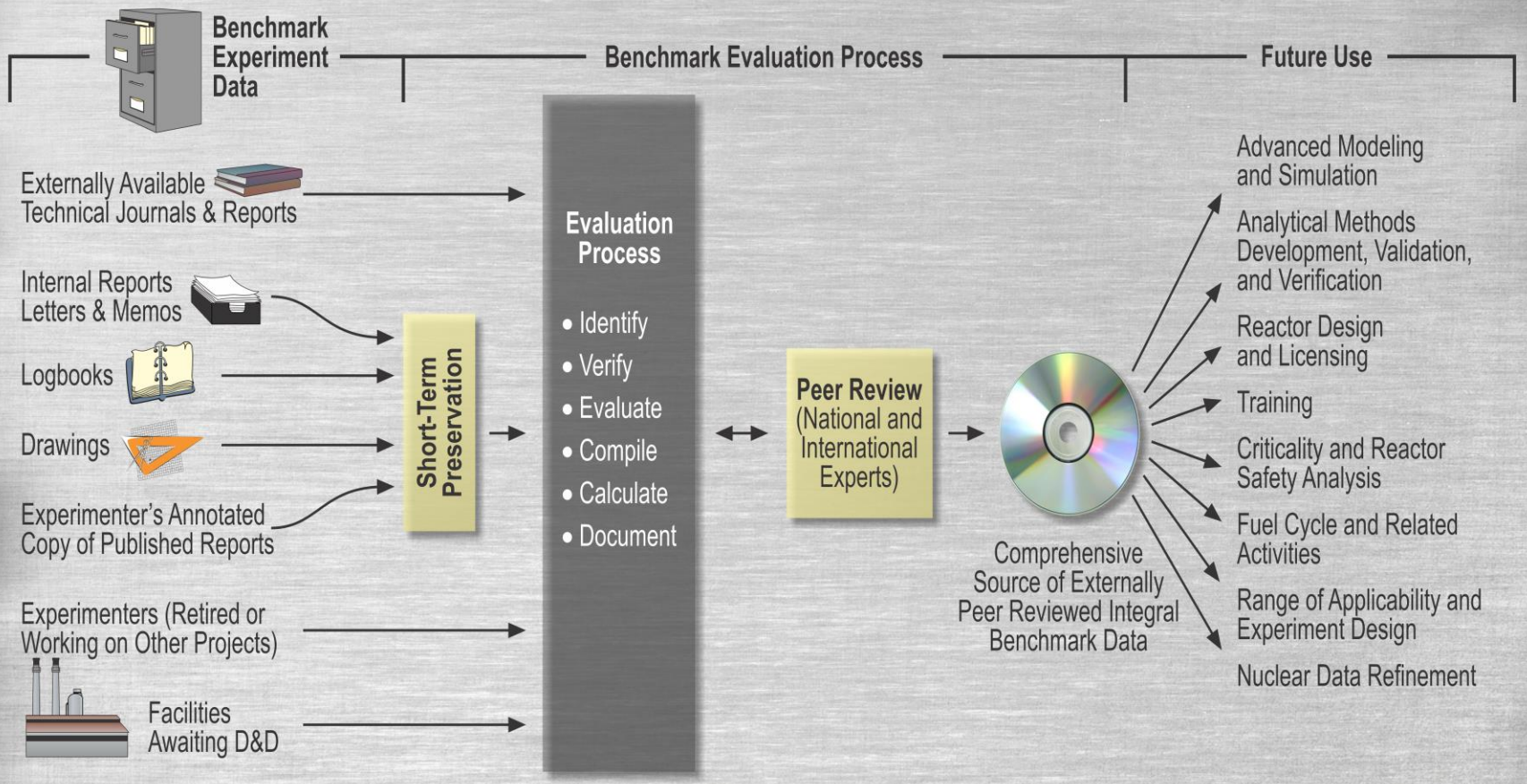
EXTRA SLIDES

INTERNATIONAL BENCHMARK PROGRAMS

NEA NUCLEAR ENERGY AGENCY

OECD BETTER POLICIES FOR BETTER LIVES

INL Idaho National Laboratory



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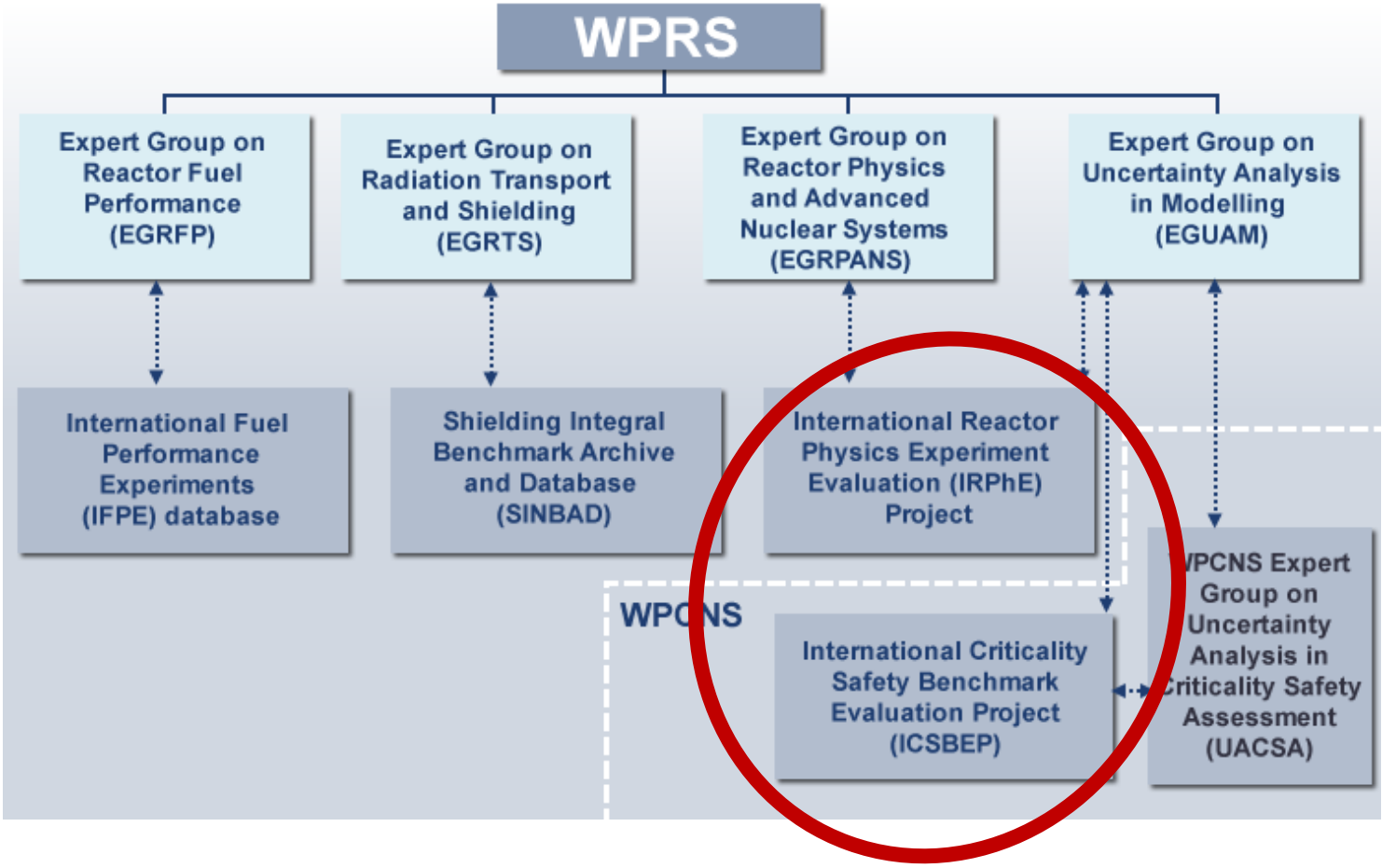

Managed by an Elected Chair

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Australia	France	Luxembourg	Slovak Republic
Austria	Germany	Mexico	Slovenia
Belgium	Greece	Netherlands	Spain
Canada	Hungary	New Zealand	Sweden
Chile	Iceland	Norway	Switzerland
Czech Republic	Ireland	Poland	Turkey
Denmark	Israel	Portugal	United Kingdom
Estonia	Italy	Republic of Korea	United States
Finland	Japan	Russian Federation	

Available to Member Countries and Active Participating Facilities

Countries Participating in the ICSBEP & IRPhEP

- Argentina
- Belgium
- Brazil
- Canada
- People's Republic of China
- Czech Republic
- France
- Germany
- Hungary
- India
- Israel
- Italy
- Japan

- Kazakhstan
- Poland
- Republic of Korea
- Russian Federation
- Serbia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States of America