Current Status of the IRPhEP and ICSBEP (August 2014)

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The Benchmark Evaluation Process





International Handbook of Evaluated Reactor Physics Benchmark Experiments

March 2014 Edition

- 20 Contributing Countries
- Data from 136 Experimental Series performed at 48 Reactor Facilities
- Data from 3 are published in DRAFT form
- Handbook available to OECD member countries, all contributing countries, and to others on a case-by-case basis



<u>http://irphep.inl.gov/</u> <u>http://www.oecd-nea.org/science/wprs/irphe/</u>



New/Revised Benchmarks in 2014 Handbook

- Gas-Cooled Reactor (GCR)
 - HTR-PROTEUS Cores 4, 9+10
 - Absorber Rod Worth Measurements
- Light Water Reactor (LWR)
 - IPEN/MB-01 Research Reactor
 - Subcritical measurements
- Space Reactor (SPACE)
 - SCCA 3
 - Cadmium-Ratio and Reaction-Rate Distributions

Pressurized Water Reactor (PWR)

- VENUS 7
 - Criticality, Reactivity Effects Measurements, and Reaction Rate Distributions
- B&W Spectral Shift Reactor Lattice Experiment
 - Criticality
- Fundamental Physics Reactor (FUND)
 - ORSphere
 - Reactivity Effects and Coefficient and β_{eff}
 - NRAD Reactor 64-Element Core Upgrade
 - Criticality, Absorber Rod Worth Measurements

HTR-PROTEUS Absorber Rod Worths



Coated particles imbedded in graphite matrix, 4.7 cm \varnothing

Coated Particles

PyC, 0.00400 cm thick
 SiC, 0.00353 cm thick
 PyC, 0.00399 cm thick
 Buffer C, 0.00915 cm thick

<u>Kernel</u> UO₂, 0.05020 cm ∅

11-GA50002-85

Air

Radial reflector





Rod Positions





Pefi

 ± 34

685

Core 10 Results (MCNP5 + ENDF/B-VII.0)

	Calculated			Ben	ark				
Absorber Rod	Worth		l	Experiment			C/E	±	1σ
	ρ\$	±	1σ	ρ\$	±	1σ			
Control Rod 1	-0.29	±	0.02	-0.30	±	0.02	0.97	±	0.09
Control Rod 2	-0.28	±	0.02	-0.29	\pm	0.02	0.97	\pm	0.10
Control Rod 3	-0.25	\pm	0.02	-0.29	\pm	0.02	0.86	\pm	0.09
Control Rod 4	-0.28	\pm	0.02	-0.30	\pm	0.02	0.93	\pm	0.09
Control Rod Bank	-1.11	±	0.06	-1.15	\pm	0.07	0.97	\pm	0.08
Autorod	-0.08	±	0.01	-0.073	±	0.004	1.14	±	0.14
Autorod Rest Worth	-0.09	±	0.01	-0.081	±	0.005	1.13	±	0.19
Shutdown Rod 5	-2.73	±	0.14	-2.81	±	0.10	0.97	±	0.06
Shutdown Rod 6	-2.75	±	0.14	-2.82	\pm	0.09	0.98	±	0.06
Shutdown Rod 7	-2.73	±	0.14	-2.80	\pm	0.16	0.98	±	0.07
Shutdown Rod 8	-2.66	\pm	0.13	-2.72	\pm	0.15	0.98	\pm	0.07
Shutdown Rods 5+6	-5.70	\pm	0.29	-5.93	\pm	0.16	0.96	\pm	0.06
Shutdown Rods 5+7	-5.54	±	0.28	-5.73	\pm	0.32	0.97	±	0.07
Shutdown Rods 5+8	-5.49	\pm	0.27	-5.75	\pm	0.33	0.95	\pm	0.07
Shutdown Rods 5+6+7	-8.65	\pm	0.43	-9.29	\pm	0.20	0.93	±	0.05
Shutdown Rods 5+6+7+8	-11 81	+	0 59	-12.64	+	0.29	0.93	+	0.05

7



IPEN/MB-01 Reactor

- Measurement of reactivity levels of subcritical systems
- Gandini and Salvatores subcritical kinetics model
 - Based on APSD
- Performed at critical with all control rods out and then inserted control rods in steps





Calculation and Benchmark k_{eff} and $\Sigma \rho$

Code (Cross Section Set) → Case Number	MCNP5 (Continuous Energy ENDF/B-VII.0)	Benchmark Valu k _{eff} ±σ	(C-E)/E ^(a) ± σ %
1	1.0007 ± 0.0002	1.0004 ± 0.0005	0.02 ± 0.02
2	0.9990 ± 0.0002	0.9992 ± 0.0005	-0.02 ± 0.02
3	0.9984 ± 0.0002	0.9984 ± 0.0006	0.00 ± 0.03
4	0.9977 ± 0.0002	0.9975 ± 0.0006	0.02 ± 0.03
5	0.9963 ± 0.0002	0.9964 ± 0.0006	-0.01 ± 0.03
6	0.9952 ± 0.0002	0.9955 ± 0.0006	-0.03 ± 0.03
7	0.9942 ± 0.0002	0.9942 ± 0.0006	0.01 ± 0.04
8	0.9923 ± 0.0002	0.9933 ± 0.0007	-0.11 ± 0.05
9	0.9910 ± 0.0002	0.9919 ± 0.0007	-0.09 ± 0.06
10	0.9896 ± 0.0002	0.9901 ± 0.0008	-0.07 ± 0.07
11	0.9875 ± 0.0002	0.9884 ± 0.0008	-0.09 ± 0.07
12	0.9860 ± 0.0002	0.9868 ± 0.0008	-0.09 ± 0.07
13	0.9836 ± 0.0002	0.9848 ± 0.0009	-0.13 ± 0.08
14	0.9814 ± 0.0002	0.9814 ± 0.0009	0.00 ± 0.08
15	0.9790 ± 0.0002	0.9786 ± 0.0010	0.04 ± 0.09
16	0.9764 ± 0.0002	0.9750 ± 0.0010	0.14 ± 0.10
17	0.9741 ± 0.0002	0.9717 ± 0.0011	0.25 ± 0.11
18	0.9711 ± 0.0002	0.9687 ± 0.0012	0.25 ± 0.12
19	0.9681 ± 0.0002	0.9651 ± 0.0013	0.31 ± 0.13
20	0.9653 ± 0.0002	0.9624 ± 0.0014	0.30 ± 0.15
21	0.9625 ± 0.0002	0.9597 ± 0.0016	0.29 ± 0.17
22	0.9592 ± 0.0002	0.9565 ± 0.0017	0.29 ± 0.19
23	0.9563 ± 0.0002	0.9542 ± 0.0020	0.23 ± 0.22

Code (Cross Section Set) → Case Number ↓	MCNP5 (Continuous Energy ENDF/B-VII.0)	Benchmark Value Σρ±σ	(C-E)/E ± σ %
1	68 ± 24	10 ± 4	580.00 ± 313.67
2	-168 ± 24	-117 ± 12	43.59 ± 25.35
3	-226 ± 24	-196 ± 15	15.63 ± 15.23
4	-299 ± 24	-288 ± 18	3.67 ± 10.60
5	-440 ± 24	-397 ± 22	10.81 ± 8.59
6	-550 ± 24	-484 ± 26	13.67 ± 7.92
7	-649 ± 24	-621 ± 33	4.53 ± 6.71
8	-849 ± 24	-708 ± 41	19.91 ± 7.67
9	-974 ± 24	-851 ± 52	14.44 ± 7.51
10	-1,121 ± 24	-1,020 ± 65	9.86 ± 7.33
11	-1,335 ± 24	-1,210 ± 67	10.33 ± 6.38
12	-1,493 ± 24	-1,372 ± 69	8.82 ± 5.76
13	-1,735 ± 24	-1,573 ± 73	10.28 ± 5.33
14	-1,964 ± 24	-1,928 ± 78	1.89 ± 4.30
15	-2,216 ± 24	-2,226 ± 84	-0.46 ± 3.91
16	-2,488 ± 24	-2,595 ± 92	-4.12 ± 3.52
17	-2,723 ± 24	-2,951 ± 101	-7.73 ± 3.27
18	-3,041 ± 24	-3,267 ± 113	-6.92 ± 3.30
19	-3,368 ± 24	-3,653 ± 126	-7.80 ± 3.26
20	-3,660 ± 24	-3,940 ± 143	-7.10 ± 3.42
21	-3,966 ± 24	-4,239 ± 162	-6.45 ± 3.61
22	-4,322 ± 24	-4,588 ± 182	-5.80 ± 3.78
23	-4.633 ± 24	-4.838 ± 206	-4.24 ± 4.11



Small Compact Critical Assembly – III



- Critical assemblies to support space reactor power plant design
- HEU-O₂ fuel, SS-clad
- Beryllium reflected
- 1.506-cm pitch







VENUS-7



- PWR with MOX and UO₂ fuel
- Part of VENUS-PRP (Plutonium Recycle Physics) Program
 - Main purpose was to improve/develop calculation methods for MOX power plants comparable with standard UO₂ fuel assemblies



VENUS-7 Results

Configuration no.	Benchmark case	k _{eff} (Benchmark model)	k _{eff} (MCNP5, ENDF/B-VII.0)	k _{eff} (MCNP5, JEFF-3.1.1)
7a	1	1.00075 ± 0.00163	0.99469	0.99449
7b	2	1.00117 ± 0.00163	0.99623	0.99595
7b subst. 3/1	3	1.00059 ± 0.00163	0.99535	0.99514
7b subst. 4/0	4	1.00211 ± 0.00163	0.99743	0.99727
7c	5	1.00067 ± 0.00163	0.99578	0.99557
7d	6	1.00105 ± 0.00163	0.99593	0.99577
7d subst. 2/2.7	7	1.00013 ± 0.00163	0.99527	0.99515
7/1a	8	0.99959 ± 0.00163	0.99576	0.99558
7/1b	9	1.00089 ± 0.00163	0.99699	0.99694
7/1c	10	1.00024 ± 0.00163	0.99637	0.99630
7/3	11	0.99830 ± 0.00163	0.99630	0.99621



Figure 4-1. Fission Rate Distribution in Configuration 7/1b along the X Axis: Benchmark Model and Calculated Values (Benchmark Case 9).



Figure 4-2. Fission Rate Distribution in Configuration 7/1b along the Diagonal: Benchmark Model and Calculated Values (Benchmark Case 9).



B&W Spectral Shift Control Reactor

- Study nuclear properties of rod lattices moderated by D₂O-H₂O mixtures
- PWR design experiments
- UO_2 -Th O_2 fuel rods - 93% ²³⁵U enrichment - N_{Th}/N₂₅ = 15
- 60.40 % (by mole) D₂O





B&W SSCR Criticality Results

Cross Section Library	Calculated Results	Benchmark Value	$\frac{C-E}{E} $ (%)
MCNP5 ENDF/B-VI.6	0.99270 ± 0.00009		-0.72
MCNP5 ENDF/B-VII.0	1.00382 ± 0.00009	0.0000 + 0.0014	+0.39
MCNP6 ENDF/B-VII.1	1.00315 ± 0.00008	0.9999 ± 0.0014	+0.32
MCNP5 JEFF 3.1.1	0.99152 ± 0.00009		-0.84



Oak Ridge Sphere (ORSphere)



- Recreation of GODIVA sphere in 1970s @ ONRL
- More accurate measurement of critical mass
- Additional measurements of higher quality than those from 1950s



ORSphere Results

	MCNP5 ENDF/B-VII.0	Calculated System Reactivity	Mass
8.80491-cm-Average- Radius Sphere	1.00411 ± 0.00002	62.301 ± 0.357	53,475.983 ± 1.017 g
8.74268-cm-Average- Radius Sphere	0.99821 ± 0.00002	-27.294 ± 0.317	$52,350.943 \pm 0.210 \text{ g}$
	Change	89.59 ± 0.477	$1,125.04 \pm 1.038 \text{ g}$
Benchma	ark Worth per Gram of Su	rface Material 0.086	\pm 0.003 ¢ per gram
Sample Calculation	of Worth per Gram of Su	rface Material 0.0796	± 0.0004 ¢ per gram

- Benchmark βeff = 0.00657 ± 0.00009
- Most cross section libraries calculate high using Keepin-Inhour Point-Kinetics methods and low using MCNP analyses



Neutron Radiography (NRAD) Reactor



- 250 kW TRIGA Mark II
- Conversion-type
- Located at INL
- 64 U(30/20)ErZrH rods
- 12 graphite reflector blocks
- 4 graphite rods
- 3 B₄C control rods
- 2 beam lines
- Empty positions for incore experimentation



NRAD Reactor Calculations

						().	
Analysis	Neutron Cross	Calculated		ted	Benchmark			$\frac{C-E}{E}(\%)$
Coue	Section Library	k _{eff}	±	σ	\mathbf{k}_{eff}	±	σ	E $$
	ENDF/B-VII.0	1.01479	±	0.00007				1.36
MONDS	JEFF-3.1	1.01281	±	0.00007				1.16
MCNP3	JENDL-3.3 ^(a)	1.01191	±	0.00007				1.07
	ENDF/B-VI.8 ^(b)	1.01022	±	0.00007				0.90
	ENDF/B-VII.0 (238-group)	1.01528	±	0.00007	1.0012	±	0.0015	1.41
KENO-VI	ENDF/B-VII.0 (continuous energy) ^(c)	1.010205	±	0.0007				0.90
	ENDF/B-VII.0 (v. 1.1.17)	1.01490	±	0.00008				1.37
SERPENT	ENDF/B-VII.0 (v. 2.1.13)	1.01332	±	0.00008				1.21

(a) $S(\alpha,\beta)$ data from the ENDF/B-VII.0 library were used with the JENDL-3.3 cross section data..

(b) ENDF/B-VII.0 cross section data for erbium isotopes were used.

(c) This value is calculated to be 1.01385 ± 0.00008 using updated thermal scattering data and treatments currently in the SCALE 6.2 software package (prerelease). Personal communication with B. J. Marshall at ORNL (July 3, 2013).

Rod Worth Calculations in Good Agreement



International Handbook of Evaluated Criticality Safety Benchmark Experiments

September 2014 Edition

- 20 Contributing Countries
- Spans nearly 67,000 Pages
- Evaluation of 561 Experimental Series
- 4,839 Critical, Near Critical, Subcritical, or k_∞ Configurations
- 24 Criticality-Alarm/Shielding Benchmark Configuration
- 207 Fundamental Physics Measurements



<u>http://icsbep.inel.gov/</u> <u>http://www.oecd-nea.org/science/wpncs/icsbep/</u>



New/Revised Benchmarks in 2014 Handbook

MIX-MISC-THERM-007

Assemblies of UO₂-PuO₂
 PHENIX Pins in Pu Nitrate
 Solution

• PU-MET-INTER-003

 ZPR-3 Assembly 58: Pu Metal and Graphite with Thick DU Reflector

• PU-MET-INTER-004

 ZPR-3 Assembly 59: Pu Metal and Graphite with Thick Pb Reflector

• SUB-LEU-COMP-THERM-002

 IPEN/MB-01 Research Reactor Subcritical Configurations

• FUND-NCERC-PU-HE3-MULT-001

 Ni-Reflected Pu-Metal-Sphere Subcritical Measurements



MIX-MISC-THERM-007



- UO₂-PuO₂ PHENIX pins in various arrays

 26 wt.% Pu
 ²⁴⁰Pu/Pu = 16 wt.%
- Pu-nitrate solution

 ²⁴⁰Pu/Pu = 19 wt.%
- Apparatus B @ French Valduc facility – 1974-1976



Results from PHENIX Pins in Pu-Nitrate Solution

	MORET	5 Continuous	MORET 5 Continuous		MORET 5 Continuous		
	Energy JE	F2.2 Library ^(b)	Energy JEFF3.1 Library ⁽⁶⁾		Energy END	F/VII.0 Library ^(b)	
Case ^(a)	(σ _{MC} =	= 0.00033)	$(\sigma_{\rm MC}=0.$	00033)	(σ _{MC} =	= 0.00033)	
Case		$(\mathbf{k}_{eff(cal)} -$		(k _{eff(cal)} -		$(\mathbf{k}_{eff(cal)} -$	
	$\mathbf{k}_{\mathbf{eff}}$	$k_{eff(exp)})/k_{eff(exp)}$	$\mathbf{k}_{\mathbf{eff}}$	$k_{eff(exp)})/k_{eff(exp)}$	\mathbf{k}_{eff}	$k_{eff(exp)})/k_{eff(exp)}$	
		(%)		(%)		(%)	
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	<mark>0.6</mark> 9	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).



PU-MET-INTER-003 and -004







All dimensions in cm 13-WHT03-68 24



ZPR-3 Results

DU Reflected

	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	-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

Pb Reflected

	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	-0.0221 ± 0.0001
Benchmark Model k _{eff}	0.9723 ± 0.0023

	MCNP5
	(Continuous Energy
	ENDF/B-VII.1)
Case 1	0.97472 ± 0.0009



SUB-LEU-COMP-THERM-002

02
15 000000000000000000000000000000000000
18 000000000000000000000000000000000000
aa ab A B C D E F G H I J K L M N O P Q R S T U V W X Y Z za zb
O Fuel rod O Withdrawn control rod O Withdrawn safety rod
• • • • • • • • • • • • • • • • • • • •
Light water Remark: Fully reflected by light water 14/WHT01-05-23
aa ab A B C D E F G H I J K L M N O P Q R S T U V W X Y Z za zb
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 $\Sigma
ho_{
m gen}$

Case	$\Sigma ho_{_{gen}}$	Σho_{gen}	$(C-E)/E \pm 1\sigma$
	Experimental	Calculated	(pcm)
	(pcm)	(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



FUND-NSERC-PU-HE3-MULT-001

- National Criticality Experiments Research Center
- BERP ball
 - α-phase Pu sphere
 - Steel clad
- Ni reflectors up to 3" thick
- Subcritical multiplication measurements





Ni-Reflected BERP Ball Measurements

	R1		(C-E)/E	R2		(C-E)/E			(C-E)/E
Configuration	(cts/s)	σ	(%)	(cts/s)	σ	(%)	Ml	σ	(%)
Bare	9165.22	3.08	2.7	1643.94	8.93	2.8	3.46	0.01	0.6
Threshold/0.5"	12279.05	3.84	3.5	3970.47	15.48	4.9	4.47	0.01	2.8
5"/1.0"	15108.29	4.59	3.7	7399.47	23.80	5.9	5.38	0.01	2.5
6"/1.5"	17874.68	5.36	4.4	12107.45	33.38	7.8	6.19	0.01	1.8
7"/2.0"	20515.21	6.14	5.3	18092.06	46.38	10.5	6.95	0.01	2.4
8"/2.5"	23062.18	6.94	5.6	25379.04	61.44	11.9	7.66	0.01	2.3
9"/3.0"	25538.92	7.74	7.0	33952.73	78.13	15.6	8.31	0.01	2.7

• R₁ = Singles Counting Rate

- Neutron count rate in a single detector
- R₂ = Doubles Counting Rate
 - Rate at which two neutrons from a single fission chain are detected in a single detector
- M_L = Leakage Multiplication
 - Number of neutrons that escape the outer-most reflector per starter neutron



Database International Criticality Experiments (est. 2001)

Relational Database

 Made available online 2013

 Search using sensitivity data 2013

M DICE				
File Database=NEA Window Help				
Critical / Subcritical Alarm / Shielding Fundamental Physics	Correlation Matrix	Keff trends plots		
Themes Identification General items Identification E Valuator E valuator E Valuator E valuator E Valuator E valuator E Valuator E valuator Varying parameter(s) across cases Laboratory Varying parameter(s) across cases Laboratory Wain purpose Title Keywords Dates (evaluation and experiment) References Fuel oregion V U/U+Pu) ratio Moderator/coolant material Cladding material Reflector material Reflector material Renergy, spectra, sensitivities Penergy of Average Resulton Lethargy causing Fission Average Fission Group Energy Fission distribution (3-g) Fission distribution (3-g) Return balance Neutron absorbed in the c<	Identification code Fissile material None selected (PU) - Plutonium (HEU) - Highly Enriched U (U233) - Uranium-233 (MIX) - Mixed Plutonium (SPEC) - Special Isotope Subcritical © Critical and subcritica Acceptable	Jranium iched Uranium anium - Uranium al O Critical O Sul	Physical form None selected (MET) - Metal (SOL) - Solution (COMP) - Compound (MISC) - Miscellaneous	Spectrum None selected (FAST) - Fast (INTER) - Intermediate-Energy (THERM) - Thermal (MIXED) - Mixed
Ouery	,			
Spectrum = Fast		^ Title	Number of cases Case label	C/E Clear
and Acceptable = Acceptable		-		
History :				Search !
199 Evaluations, 665 Cases				



IRPhEP Database and Analysis Tool (est.2013)

 Made available online 2014

 Visualize fluxes and reaction rates

Search by meas.
 type

✓ Trend C/ E's by

Themes	Identific
📲 General Items	
 Identification 	
Evaluator	
 Internal Reviewer 	Reactor
Independent Reviewer	Noneco
Organisation/Laboratory	None se
• Title	ASTRA
Keywords	ATR
 Dates (Evaluation and Experiment) 	DEC 1
 References 	0131
📲 Materials	BFS2
• Fuel	BR2
Fuel Composition	CORAL
Cladding	
Moderator/Coolant	CREOLE
Absorber	CROCUS
Measurements Type	DCA
CRIT - Criticality Measurements	
Benchmark and Calculated Values	Measure
Uncertainties	
🖃 퉬 BUCK - Buckling & Extrapolation Length	CRI
Benchmark and Calculated Values	
🖃 🌗 SPEC - Spectral Indices	KEA
 Detector 	POW
 Spectral Index 	
Benchmark and Calculated Values	Handbo
🖃 퉬 REAC - Reactivity Effects	
Materials / Method	🛛 🎱 Both
Benchmark and Calculated Values	FRESH-CORE RE
🖃 🌗 COEF - Reactivity Coefficients	Files
Coefficient Type / Method	A:
Benchmark and Calculated Values	Display
🖃 퉬 KIN - Kinetics Measurements	XForm A coord.
Kinetics Parameter	Collapse:
Benchmark and Calculated Values	Mesh Tally Number Mesh Tally Number
RRATE - Reaction-Rate Distributions	Mesh Tally Number Mesh Tally Number
Detector/Detection Details	Mesh Tally Number Mesh Tally Number
Device Input/Reaction	200x200x10
Benchmark and Calculated Values	Rel.Err. range = [0.0
POWDIS - Power Distributions	
Detector/Detection Details	
Device Input/Reaction	
Benchmark and Calculated Values	
Calculated Data (Over Entire System)	Data
 Flux Distribution (3-g) 	View
 Fission Distribution (3-g) 	PoV: TOP
 Capture Distribution (3-g) 	Zoom: Show Pel Fr
 Neutron Balance 	Show grid
Keff Sensitivities	Plot horiz, axis: E
	Color scale RAINBOW
	Per slice color so

			•	
Reactor Name	Reactor Type			Facility Type
None selected ASTRA ATR BFS1 BFS2 BR2 CORAL(I) CREOLE CROCUS DCA T	None selected (BWR) - Boiling Water Reactor (FUND) - Fundamental (GCFR) - Gas Cooled (Fast) Reactor (GCR) - Gas Cooled (Thermal) Reactor (HWR) - Heavy Water Moderated Reactor (LMFR) - Light Mater Moderated Reactor (LWR) - Light Water Moderated Reactor (MSR) - Molten Salt Reactor (PWR) - Pressurized Water Reactor			None selected (EXP) - Experimental Facility (POWER) - Power Reactor (RESR) - Research Reactor
Measurements Typ	es			
CRIT	SUB	BUCK		SPEC
REAC	COEF	KIN		RRATE
POWDIS	ISO	MISC		
Handbook Both Handbook	s 🔘 Only present in I	RPhEP 🔘 Only pres	ent i	n ICSBEP





Summary and Conclusions

- The ICSBEP and IRPhEP are collaborative efforts that involve numerous scientists, engineers, administrative support personnel and program sponsors from 24 different countries and the OECD NEA. The authors would like to acknowledge the efforts of all of these dedicated individuals without whom those two projects would not be possible.
- 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.

