Adjacent Meetings of the JEF and EFF Projects

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"A MCNP Analysis of PWR/BWR Critical Benchmarks by using JEF-2.2 and ENDF/B-VI"

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"A MCNP Analysis of PWR/BWR Critical Benchmarks by using JEF-2.2 and ENDF/B-VI"

- The purpose of this summary is to present a preliminary benchmark result of JEF-2.2 and ENDF/B-VI data.

- The validation of data libraries has been done by using the MCNP code to simulate critical experiments with core configurations typical of those of PWR and BWR.

- The NJOY system has been used to process the JEF-2.2 and ENDF/B-VI into continuous-energy ACE-format.

- In addition, calculated values of k_{eff} and pin power density distribution are compared with corresponding results from ENDF/B-V data.

◎ Benchmark Problems

o Thermal reactor benchmark problems
(PNL-series)

o VENUS PWR engineering mockup experiment
(Reference : ORNL/TM-9238,1984)

o General Electric BWR critical benchmarks
(Reference : Nucl. Sci. Eng., 113, 239-250, 1993)

◎ Data Processing

o NJOY91.91 system

<Figure 1>

o Generation of ACE-format continuous energy data

- ENDF/B-VI (Cyber 960-31)
- JEF-2.2 (HP-710 workstation)

o Interpolation and thinning tolerance : 0.5%

o Temperature : 300° K

o Scattering Law Data : ENDF/B-VI

Table 1. The Results of MCNP Calculation in PNL-series

Problems	JEF-2.2	ENDF/B-VI	ENDF/B-V
PNL-6B	1.0106(0.0024)	0.9984(0.0026)	1.0030(0.0028)
PNL-7B	1.0078(0.0019)	1.0024(0.0018)	1.0112(0.0020)
PNL-8B	1.0138(0.0022)	1.0036(0.0021)	1.0121(0.0023)
PNL-12B	1.0089(0.0018)	1.0024(0.0015)	1.0120(0.0017)

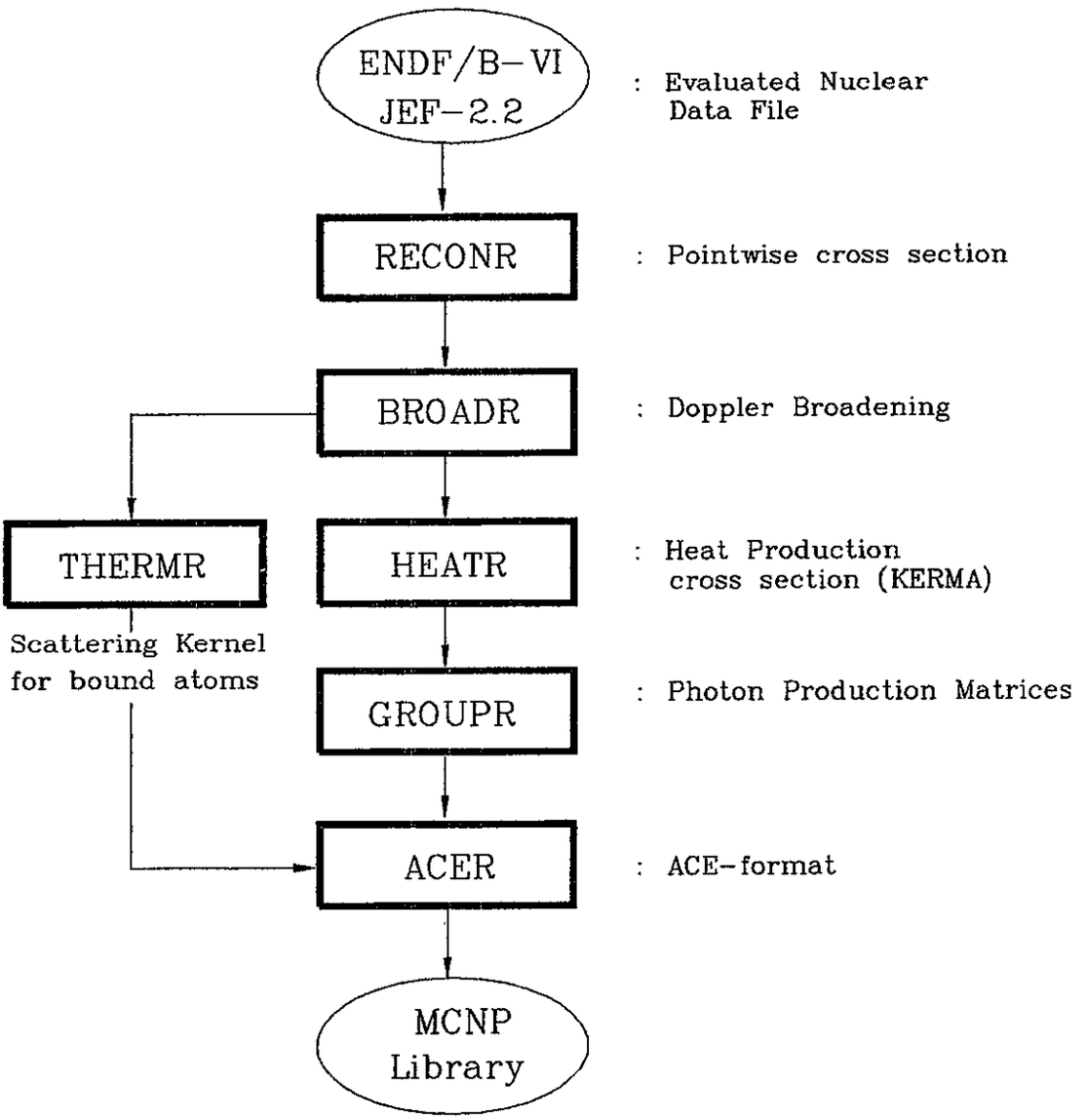


Fig. 1. Flow Diagram for Processing MCNP Library

◎ MCNP-4A Calculations

o Thermal reactor benchmark problems

° PNL-6B, PNL-7B, PNL-8B, PNL-12B

° Table 1 shows effective multiplication factors with different data library

o VENUS PWR engineering mockup experiment

° Figure 2 shows the MCNP calculational model of VENUS critical facility

° 752 fuel rods with zircaloy clad of 3.3% U-235 enrichment

° 1,800 fuel rods with steel clad of 4% U-235 enrichment

° 42 pyrex rods are distributed

° The k-effective and (C/E - 1) x 100 of relative power distribution is shown in Table 2

° relative power distribution

- about 1.5% uncertainty in the measurements
- about 1.5% fractional standard deviation in MCNP results

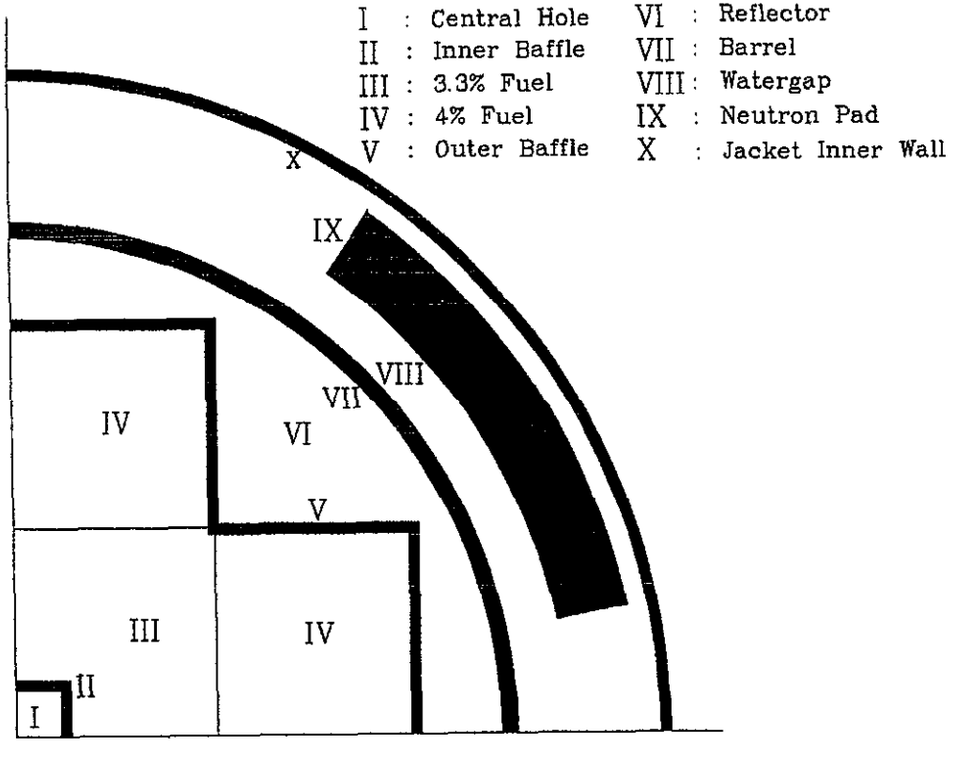


Fig. 2. MCNP Calculational Model of VENUS Core

TABLE 2. Power Distributions in the VENUS Core

(JEF-2.2)
rms = 2.012
max. err. = 4.723
(k-eff.) = 1.002946(0.0005)

* calculated value
** measured value
# (C/E -1) x 100

									* .864 **.907 # -4.7	.943 .961 -1.9	.824	.754 .735 2.6	.696	.662 .659 .4	.629	.589 .590 -.1	.544	.503 .496 1.4	.460	.410 .417 -1.6	.375	.326 .320 1.9	.285 .277 2.9	.235 .228 3.2
								1.134 1.111 2.1	1.005	1.144	.980	.901	.875	.809	.755	.721	.656	.586	.541	.516	.451	.406	.348 .341 2.0	.284 .274 3.7
							1.269	1.176	1.075	1.215	1.092	1.005	.958	.899	.841	.778	.726	.680	.615	.567	.523	.469	.403	.307 .312 -1.7
						1.307 1.318 -.9	1.282	1.234	1.128	1.311	1.163	1.082	1.016	.972	.915	.857	.789	.747	.678	.624	.562	.505	.430	.335
					1.327	1.320	1.308	1.224	1.143	1.340	1.201	1.120	1.077	1.024	.990	.908	.848	.788	.712	.669 .680 -1.7	.622	.557 .550 1.3	.473 .000 .0	.357 .365 -2.1
				1.317 1.350 -2.4	1.355	1.336	1.291	1.230	1.147	1.348	1.243	1.179	1.140	1.093	1.037	.988	.899	.857	.784	.713	.655	.589	.501	.400
			1.333	1.294	1.250	1.280	1.259	1.157	1.137	1.370	1.274	1.213	1.186	1.114	1.070	1.023	.970	.910 .892 2.0	.832	.769	.684	.620	.534	.412 .416 -.9
		1.331 1.361 -2.2	1.329	1.218		1.194	1.191		1.103	1.363	1.314	1.233	1.213	1.150	1.100	1.051	1.007	.961	.864	.788	.719	.651	.553	.443
	1.321	1.333	1.317	1.263	1.198	1.244	1.250	1.172	1.150 1.165 -1.2	1.390 1.391 -.1	1.303	1.263 1.265 -.1	1.222	1.193 1.168 2.1	1.136	1.107	1.022	.962	.870	.840	.752	.669	.579	.458 .450 1.8
1.206 1.197 .8	1.284	1.301	1.280	1.217	1.258	1.295	1.266	1.149	1.148	1.420	1.376	1.302	1.263	1.222	1.173	1.121	1.055	.985	.907	.832	.755	.686	.605	.474
1.053	1.224	1.279 1.292 -1.0	1.225		1.201 1.242 -3.3	1.281 1.303 -1.7	1.216 1.226 -.8		1.112 1.118 -.6	1.440	1.360	1.313	1.278	1.235	1.176	1.128	1.088	1.016	.953	.879	.801	.703	.605	.475 .478 -.6
.991	1.194	1.241	1.242	1.186 1.202 -1.3	1.242	1.293	1.265	1.163	1.185	1.474	1.382	1.336	1.300	1.233	1.213	1.158	1.110	1.046	.978	.889	.807	.723	.628	.504
.997 .963 3.5	1.181	1.218 1.274 -4.4	1.221	1.198 1.206 -.7	1.265 1.258 .6	1.294	1.256	1.153	1.190	1.478	1.405	1.339	1.312	1.262	1.218	1.175	1.119	1.037	.974	.905	.815	.750	.641	.517 .499 3.6
1.004	1.182	1.236	1.178		1.218	1.285	1.205		1.120	1.471	1.394	1.335	1.320	1.289	1.230	1.174	1.109	1.070	.996	.922	.827	.755	.658	.515
.993 .955 4.0	1.178	1.202 1.241 -3.2	1.211	1.165 1.191 -2.2	1.249	1.323 1.298 1.9	1.265	1.179 1.181 -.2	1.161 1.170 -.7	1.482 1.473 .6	1.391	1.373 1.331 3.2	1.324	1.275 1.270 .4	1.251	1.199 1.180 1.6	1.133	1.047 1.051 -.4	.975	.908 .910 -.3	.842	.738 .737 .1	.645	.519 .496 4.7

TABLE 2. (Continued)

(ENDF/B-VI)
rms ≈ 2.322
max.err. ≈ 5.558
(k-eff.)≈ 1.00008(0.0005)

								.892 .907 -1.7	.963 .961 .2	.847	.769 .735 4.6	.719	.669 .659 1.6	.646	.585 .590 -.8	.559	.515 .496 3.8	.455	.423 .417 1.5	.375	.336 .320 5.1	.290 .277 4.8	.236 .228 3.4
							1.12 1.11 1.2	1.040	1.158	1.022	.935	.867	.811	.760	.732	.664	.617	.561	.506	.459	.409	.341 .341 .1	.280 .274 2.1
						1.248	1.193	1.102	1.238	1.099	1.026	.959	.906	.839	.809	.760	.705	.653	.569	.512	.471	.390	.315 .312 1.0
					1.273 1.318 -3.4	1.274	1.237	1.137	1.285	1.152	1.108	1.029	.996	.936	.879	.815	.762	.702	.623	.565	.516	.445	.351
				1.332	1.301	1.293	1.244	1.170	1.327	1.219	1.147	1.102	1.049	.992	.916	.868	.813	.736	.676 .680 -.5	.615	.532 .550 -3.3	.475	.380 .365 4.2
			1.311 1.350 -2.9	1.317	1.307	1.300	1.249	1.194	1.372	1.250	1.187	1.135	1.084	1.021	.952	.907	.856	.790	.723	.667	.591	.500	.406
		1.270	1.277	1.205	1.244	1.255	1.158	1.146	1.390	1.279	1.204	1.165	1.135	1.061	1.010	.964 .0	.904 .892 1.3	.842	.758	.683	.603	.521	.416 .416 -.1
	1.327 1.361 -2.5	1.280	1.201		1.195	1.169		1.077	1.394	1.309	1.263	1.211	1.145	1.119	1.063	1.013	.933	.866	.788	.712	.636	.560	.443
1.278	1.296	1.297	1.265	1.177	1.221	1.249	1.171	1.150 1.165 -1.3	1.401 1.391 .7	1.328	1.277 1.265 .9	1.228	1.207 1.168 3.3	1.141	1.082	1.037	.967	.897	.824	.752	.679	.571	.470 .450 4.5
1.166 1.197 -2.6	1.242	1.289	1.246	1.180	1.238	1.301	1.259	1.161	1.146	1.415	1.351	1.299	1.262	1.214	1.189	1.103	1.073	.993	.920	.861	.766	.692	.589	.482
1.035	1.198	1.268 1.292 -1.9	1.195		1.190 1.242 -4.2	1.277 1.303 -2.0	1.216 1.226 -.8		1.114 1.118 -.4	1.423	1 355	1.305	1.279	1.242	1.168	1.126	1.099	1.017	.946	.881	.795	.702	.611	.493 .478 3.1
.983	1.173	1.240	1.243	1.189 1.202 -1.0	1.255	1.296	1.249	1.174	1.136	1.439	1 363	1.328	1.287	1.272	1.194	1.154	1.087	1.041	.980	.875	.808	.727	.633	.505
.968 .963 .6	1.162	1.223 1.274 -4.0	1.234	1.170 1.206 -3.0	1.254 1.258 -.3	1.282	1.251	1.150	1.193	1.452	1 384	1.354	1.284	1.253	1.230	1.183	1.129	1.049	.977	.895	.842	.749	.652	.508 .499 1.8
.984	1.148	1.213	1.157		1.187	1.259	1.200		1.112	1.454	1 392	1.348	1.309	1.291	1.260	1.187	1.135	1.088	1.001	.920	.834	.753	.651	.522
1.008 .955 5.6	1.154	1.202 1.241 -3.2	1.215	1.168 1.191 -1.9	1.253	1.301 1.298 .2	1.264	1.152 1.181 -2.5	1.159 1.170 -.9	1.450 1.473 -1.6	1 393	1.331 1.331 .0	1.303	1.307 1.270 2.9	1.254	1.205 1.180 2.1	1.125 .000 .0	1.066 1.051 1.5	.990	.917 .910 .8	.826	.740 .737 .4	.646	.521 .496 5.1

TABLE 2. (Continued)

(ENDF/B-V)
rms = 1.857
max.err. = 5.885
(k-eff.)= 0.999756(0.0006)

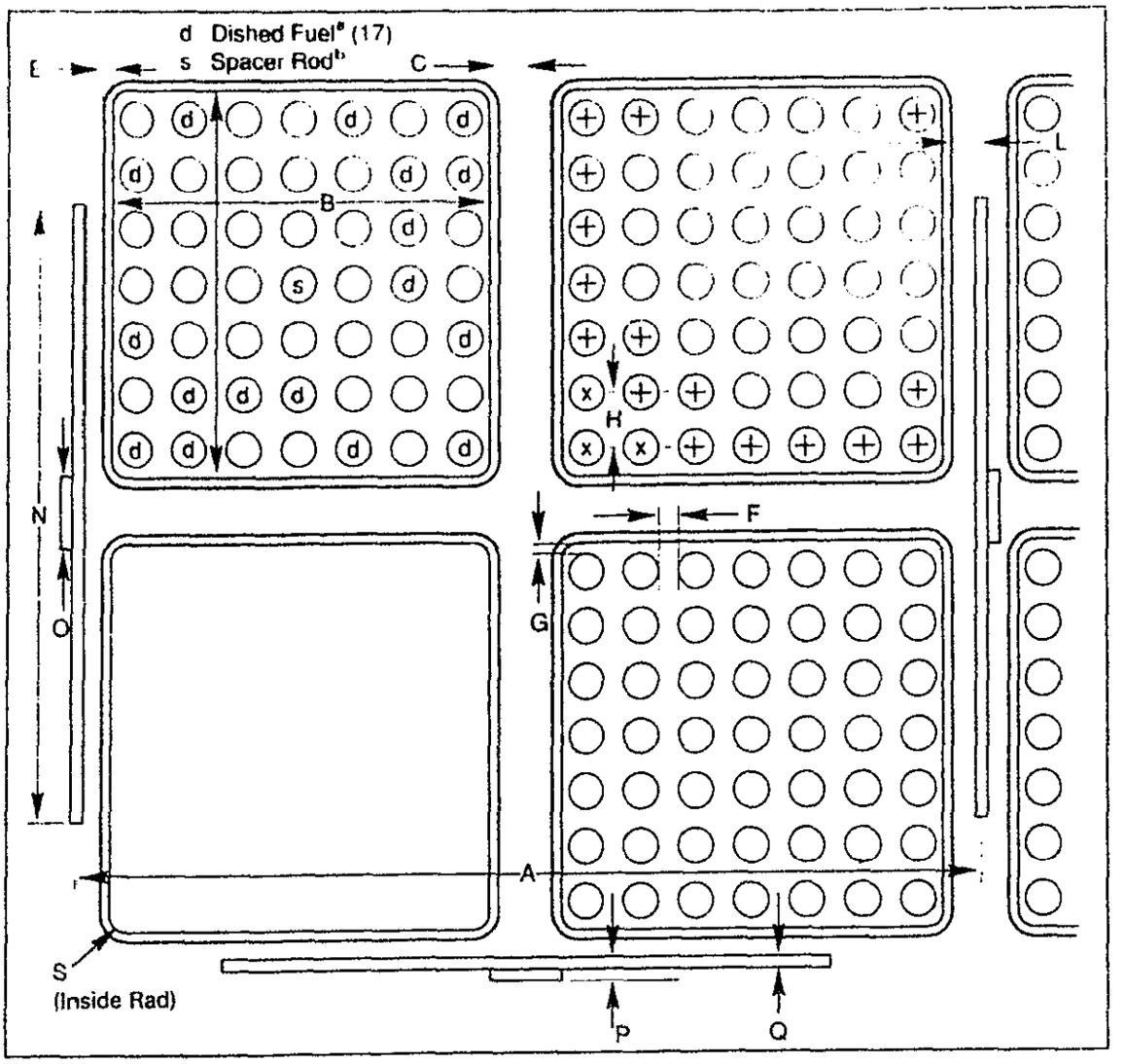
								.880 .907 -3.0	.941 .961 -2.1	.825	.763 .735 3.9	.717	.679 .659 3.0	.645	.596 .590 1.0	.546	.493 .496 -.6	.460	.419 .417 .6	.374	.329 .320 3.0	.290 .277 4.5	.234 .228 2.7
							1.140 1.111 2.6	1.007	1.139	.988	.929	.877	.819	.766	.713	.655	.606	.556	.503	.447	.403	.351 .341 3.0	.277 .274 1.1
						1.241	1.215	1.080	1.225	1.085	1.027	.960	.917	.850	.799	.745	.674	.619	.566	.517	.464	.383	.309 .312 -1.1
					1.331 1.318 1.0	1.296	1.223	1.123	1.313	1.169	1.086	1.027	.974	.903	.869	.797	.749	.693	.611	.556	.506	.423	.344
				1.338	1.309	1.304	1.273	1.146	1.357	1.221	1.154	1.072	1.015	.975	.900	.876	.801	.734	.665 .680 -2.3	.618	.551 .550 .2	.472	.386 .365 5.9
			1.338 1.350 -.9	1.328	1.330	1.296	1.242	1.144	1.356	1.250	1.181	1.130	1.065	1.020	.968	.930	.834	.776	.713	.660	.580	.503	.407
		1.358	1.325	1.245	1.289	1.262	1.163	1.135	1.376	1.268	1.237	1.183	1.123	1.066	1.012	.966	.891 .892 -.1	.832	.763	.690	.610	.530	.419 .416 .8
	1.358 1.361 -.3	1.343	1.242		1.196	1.162		1.086	1.366	1.283	1.255	1.191	1.151	1.100	1.045	.969	.940	.862	.778	.719	.646	.557	.464
1.314	1.337	1.331	1.272	1.220	1.261	1.247	1.169	1.138 1.165 -2.3	1.400 1.391 .6	1.325	1.267 1.265 .2	1.240	1.188 1.168 1.8	1.148	1.075	1.030	.974	.900	.821	.738	.666	.579	.461 .450 2.4
1.219 1.197 1.9	1.302	1.297	1.285	1.225	1.270	1.297	1.233	1.176	1.140	1.389	1.333	1.307	1.248	1.215	1.161	1.124	1.053	1.003	.934	.866	.768	.688	.593	.470
1.083	1.226	1.266 1.292 -2.0	1.207		1.202 1.242 -3.2	1.282 1.303 -1.6	1.204 1.226 -1.8		1.102 1.118 -1.4	1.409	1.355	1.325	1.282	1.235	1.186	1.151	1.076	1.013	.934	.866	.785	.707	.626	.487 .478 2.0
1.028	1.204	1.233	1.241	1.183 1.202 -1.6	1.253	1.330	1.279	1.167	1.170	1.458	1.364	1.365	1.287	1.238	1.198	1.162	1.098 .0	1.018 .0	.950 .0	.903 .0	.798 .0	.711 .0	.625 .0	.511 .0
.996 .963 3.5	1.196	1.235 1.274 -3.0	1.226	1.185 1.206 -1.7	1.275 1.258 1.3	1.311	1.255	1.190	1.170	1.445	1.404	1.340	1.302	1.253	1.231	1.161	1.095	1.045	.957	.893	.815	.726	.646	.507 .499 1.7
.999	1.167	1.235	1.174		1.213	1.295	1.193		1.130	1.451	1.386	1.352	1.284	1.260	1.211	1.166	1.108	1.046	.993	.902	.825	.741	.643	.512
1.001 .955 4.8	1.180	1.222 1.241 -1.5	1.243	1.178 1.191 -1.1	1.236	1.304 1.298 .4	1.282	1.187 1.181 .5	1.167 1.170 -.3	1.455 1.473 -1.2	1.385	1.334 1.331 .2	1.319	1.260 1.270 -.8	1.230	1.146 1.180 -2.9	1.122	1.065 1.051 1.3	.991	.905 .910 -.6	.829	.735 .737 -.3	.638	.514 .496 3.6

o General Electric BWR critical benchmarks

- ° MCNP calculational model is shown in Fig. 3.
- ° fuel bundles arranged in a 4 x 4 matrix
- ° each fuel bundle contained(1.19, 1.67 and 2.42 wt%) U-235 enriched UO_2 fuel (7 x 7)
- ° with poison curtain
- ° without poison curtain
- ° The k-effective and (C/E - 1) x 100 of relative power distribution is shown in Table 3
- ° relative power distribution
  - average 0.5 % and locally 2% uncertainty in the measurements
  - about 1.5 % fractional standard deviation in MCNP calculations

◎ Results

- ° The calculated results of PNL-series with JEF-2.2 and ENDF/B-V show high tendency.
- ° The calculated results with JEF-2.2 of pin power distributions in the VENUS and BWR cores agree well with the measured values, compared with those of ENDF/B-VI.



Dimensions (cm)	
A = 30.48	L = 0.47498
B = 13.40612	N = 21.4376
C = 0.9525	O = 1.42748
E = 0.2032	P = 1.42748
F = 0.42672	Q = 0.19304
G = 0.3556	S = 1.016
H = 1.87452	

[a]Fuel Density: Dished = 10.15 g/cm^3
Regular = 10.34 g/cm^3

[b]Active Fuel Length: Regular Rod = 365.76 cm
Spacer Rod = 345.19 cm

Fig. Bundle Configuration for Experiment Set

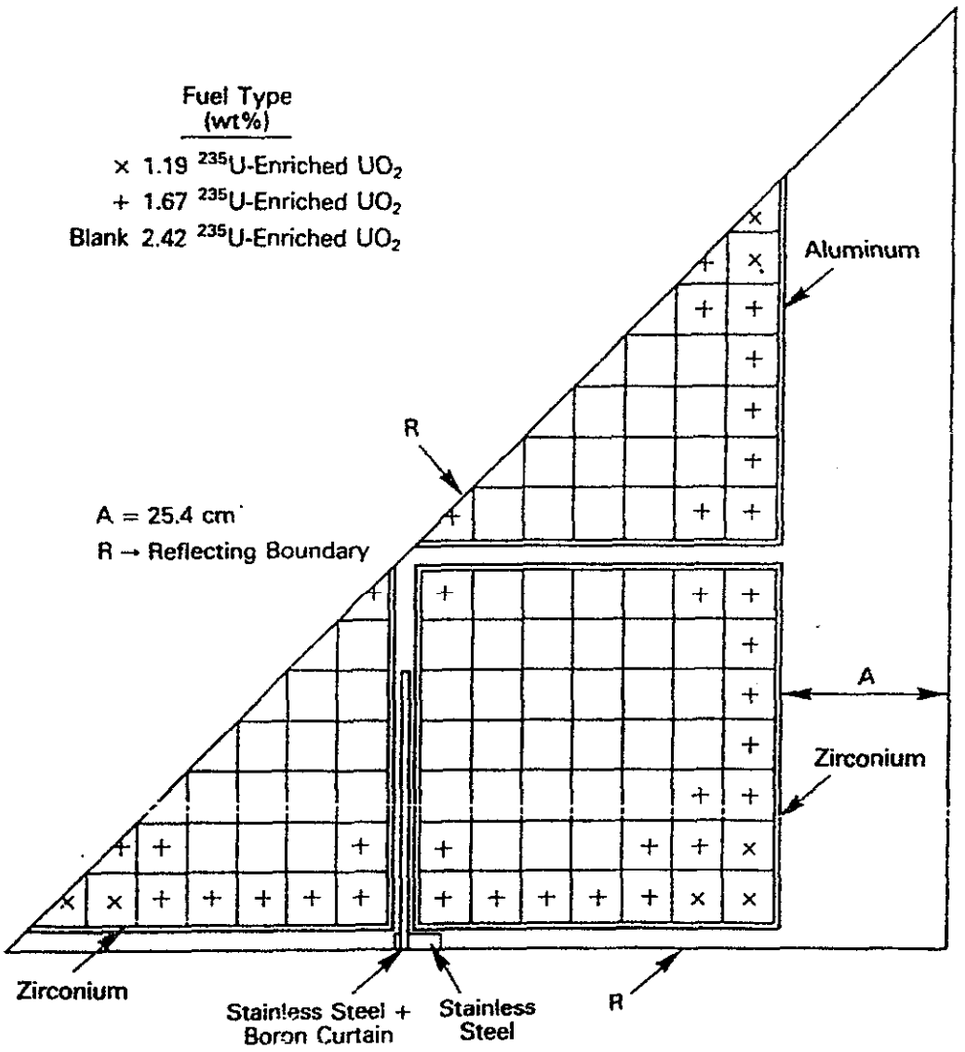


Fig 3. Calculational BWR Core Model : With Poison Curtain and Without Poison Curtain

Table 3. Comparison of calculation with measured results with different data in typical BWR with poison curtain

	k-effective	Fission Density Distribution	
		rms *	max. err.
JEF-2.2	1.0025 (0.0008)	1.93	3.79
ENDF/B-VI	0.9997 (0.0009)	2.09	3.94
ENDF/B-V	1.0007 (0.0008)	1.92	3.67

* root mean square of calculated and measured values

JEF-2.2

**							
	-1.67	-1.81	-2.41	-1.20		-.71	-1.60
	1.59	.01	-.30	-1.48	.26	-2.11	-2.19
		-.04	-1.99	-2.10	-1.18	.26	
	2.83	-.82	-1.76		-2.95	-.70	-1.76
	2.35	.64	-1.23	-1.17	-1.58	-.41	-1.76
	2.55	1.19	.85	-1.16			-.37
	3.79	2.93	2.68	2.74		1.69	2.79

ENDF/B-VI

-2.77	-1.03	-1.67	1.39		-.98	-.87
-.02	2.07	-.71	.42	-.67	-1.00	-2.45
	-.03	-2.95	-2.00	-2.11	-.67	
3.29	-.15	-3.71		-2.86	1.21	.81
2.23	-.55	-1.26	-3.13	-2.55	-.82	-1.02
2.88	.91	-.35	-.49			.43
3.94	3.26	2.56	3.20		.08	1.64

ENDF/B-V

-3.20	-.64	-2.02	-1.36		-.16	-.58
-.33	-.24	-1.79	-1.80	.43	1.30	-1.64
	-.84	-2.14	-2.72	-3.00	.43	
1.72	-.13	-.94		-3.57	-1.02	-1.92
3.34	1.35	2.03	-.35	-1.74	-1.90	-1.37
2.36	1.41	1.56	-.48			.82
2.81	2.74	3.67	1.63		-.23	1.19

** (C/E - 1) x 100

Table 4. Comparison of calculation with measured results with different data in typical BWR without poison curtain

	k-effective	Fission Density Distribution	
		rms *	max. err.
JEF-2.2	0.9985 (0.0009)	1.22	4.36
ENDF/B-VI	0.9965 (0.0008)	1.44	3.39
ENDF/B-V	0.9998 (0.0009)	1.29	4.29

* root mean square of calculated and measured values

JEF-2.2

**							
	-.55	1.18	-.01	.85		.92	1.68
	1.64	.03	1.75	.18	1.22	.92	-.77
		-.99	-.57	-4.36	-.16	.52	
	.50	-1.29	.12		-2.90	.18	.07
	.42	-.27	-2.46	.66	-1.23	1.86	-1.80
	1.81	-.68	-.73	-1.66	-.22	-.15	.86
	.93	-.15	.85	.50		.98	-.47

ENDF/B-VI

-.69	.66	.98	2.09		.13	-.44
2.91	-.63	-1.11	.22	1.95	-1.20	-1.55
	-.29	1.93	-2.66	-.09	1.24	
.07	-3.03	-1.32		-1.17	.22	1.30
.23	-.43	-2.25	-.78	1.25	-1.00	-.83
3.01	.79	-.89	-3.39	.49	-.81	.34
.88	1.02	.66	.07		2.24	-.61

ENDF/B-V

-.16	-.27	-2.54	.38		1.03	-1.67
1.12	-.63	-.10	-1.16	1.31	.58	-.66
	.45	.78	-2.98	-.88	.61	
.86	1.58	-.43		-1.50	-1.16	-.39
-.28	2.13	1.77	.11	.11	.01	-4.29
2.00	.19	1.66	1.20	1.23	-.81	-.59
-.24	.03	.15	.86		.46	-.08

** (C/E-1) x 100

Table Comparison of calculated results with measured values of pin power distributions in the VENUS and BWR core

	Venus Core		BWR Core with poison curt.		BWR core without poison curt.	
Data	rms	max.err.	rms	max.err.	rms	max.err.
JEF-2.2	2.01	-4.723	1.93	3.79	1.22	-4.36
ENDF/B-VI	2.32	5.558	2.09	3.94	1.44	-3.39
ENDF/B-V	1.86	5.885	1.92	3.67	1.29	-4.29

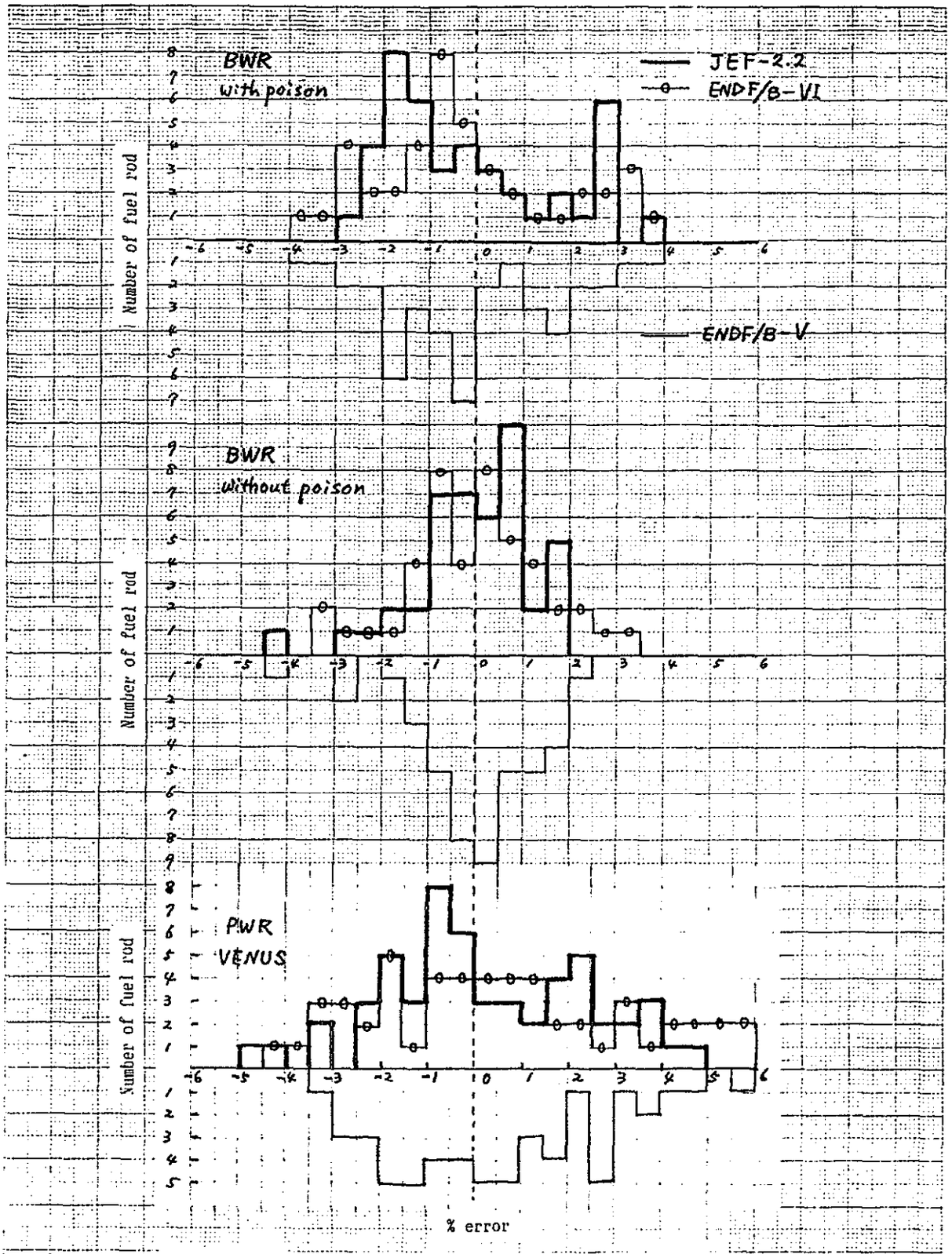


Fig. Distribution of percent error of calculations from measurement for fission density