Argonne Data Testing for ENDF/B-VII.1

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Overview

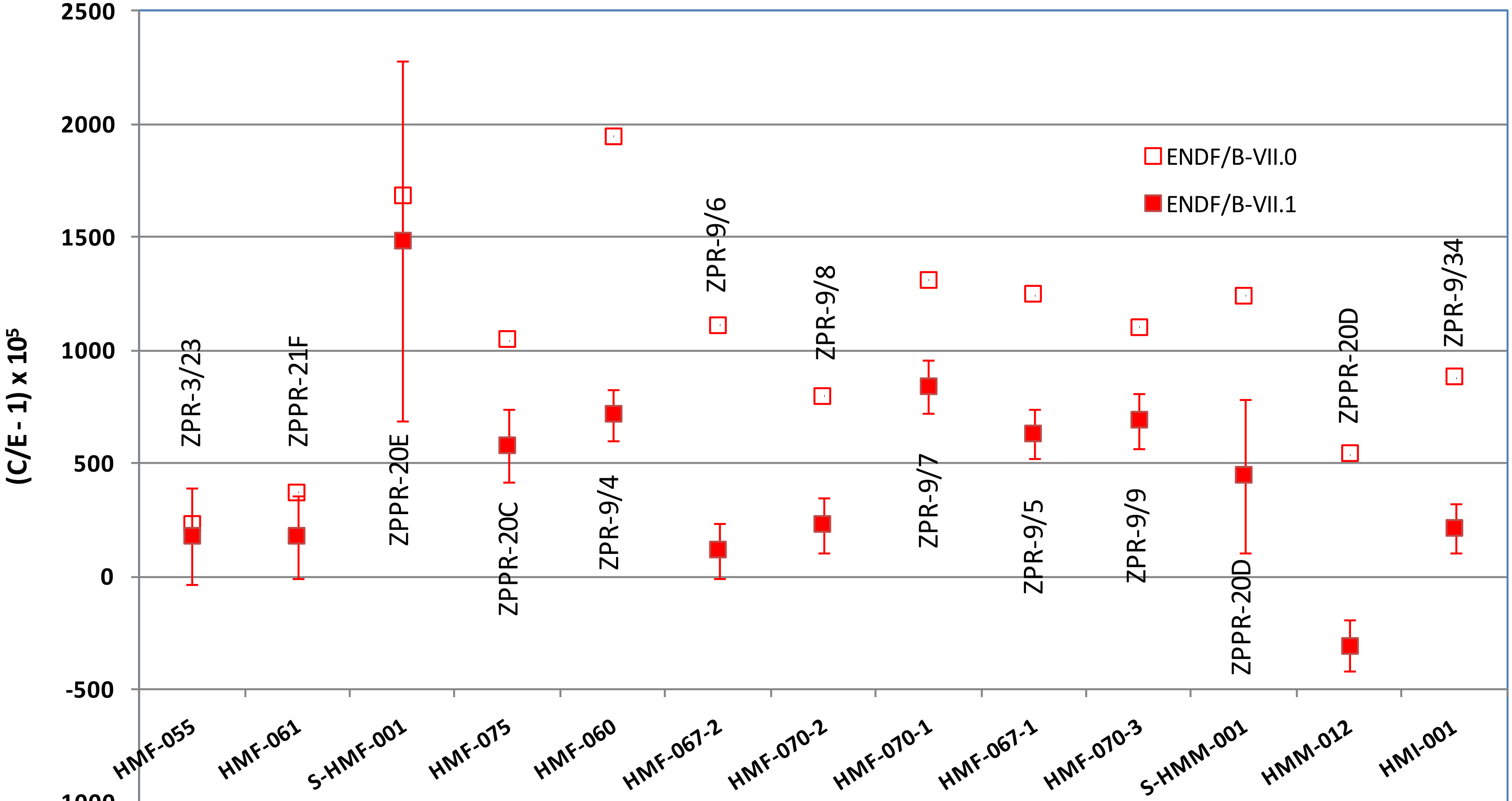
- A set of benchmark calculations have been selected primarily to complement analyses being done by others .
- Detailed as-built models, now available for a series of 38 Argonne ZPR/ZPPR critical assemblies, have been used.
  - These models represent the physical dimensions and masses of each and every plate, can, drawer and matrix tube and the interstitial gaps among these materials for the as-built material loadings for each of these assemblies, i.e., no significant approximations or biases are introduced in these models.
  - 13 high enriched uranium (HEU) configurations, 9 intermediate enriched uranium (IEU) configurations, 14 mixed-(Pu,U) configurations, and 2 Pu metal configurations were analyzed.

Overview

- Four types of experiments analyzed.
  - Criticality
  - β_{eff}
  - Sodium-Void Worths
  - Control Rod and Control Rod Position Worths

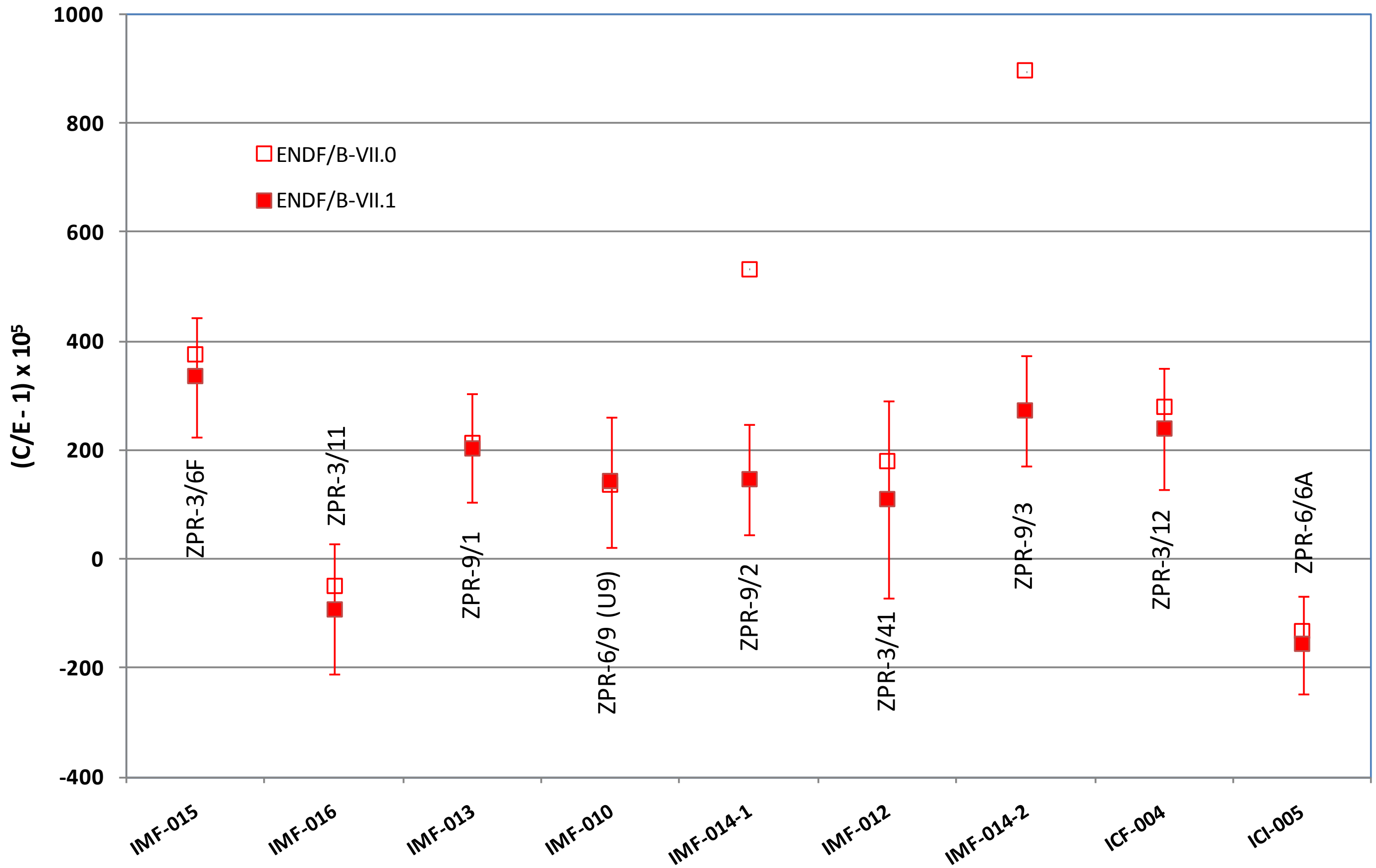
- Analyses of these detailed models were performed using MCNP5 and NJOY with both ENDF/B-VII.0 and -VII.1 data.
  - Typically, 250 million neutron histories with 1-sigma uncertainties on k_{eff}'s and δk's of ~3 pcm and ~4 pcm, respectively.

MCNP5 Calculations with “As-built” Models for HEU FAST and INTER ZPR/ZPPR Assemblies



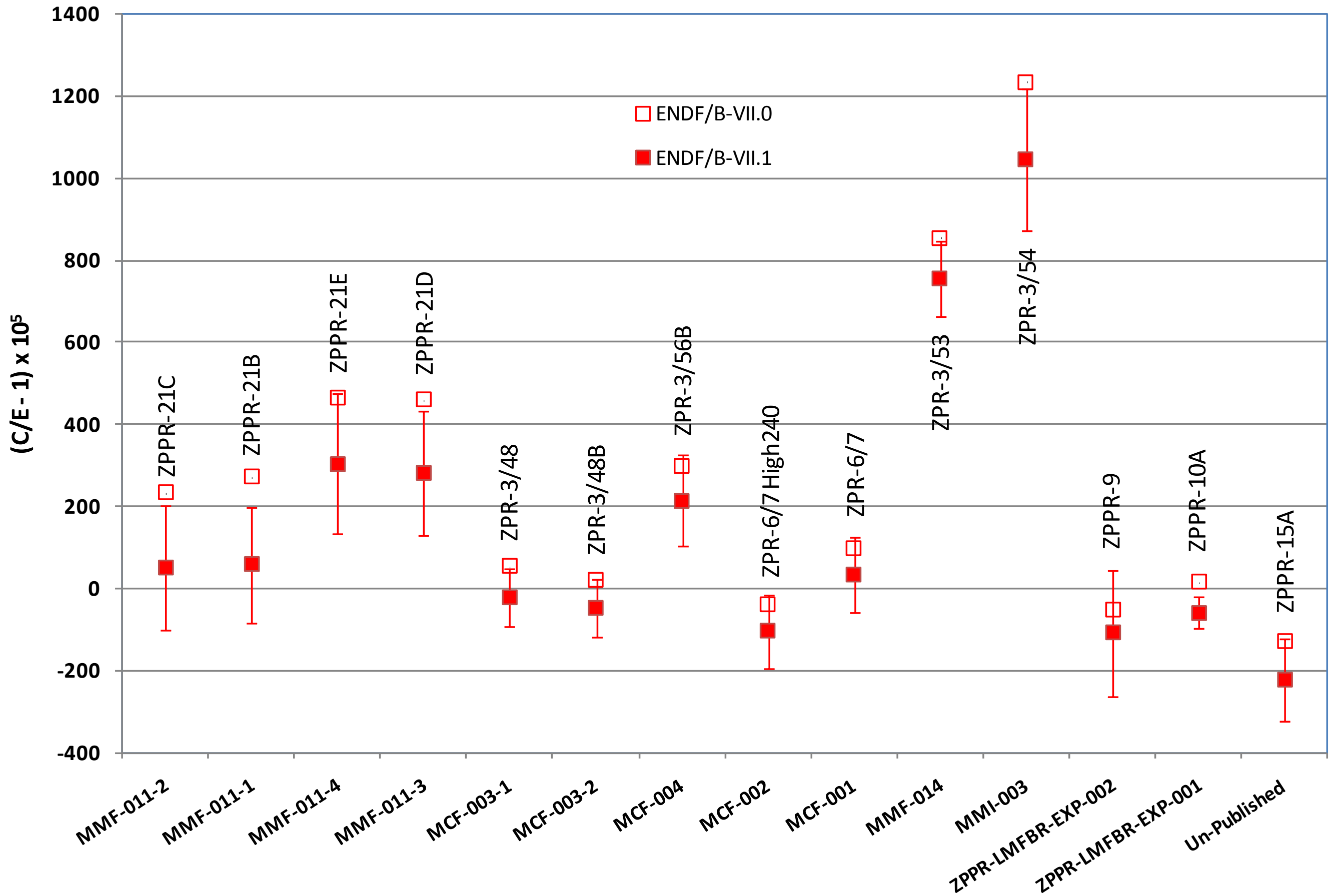
The average bias of the values obtained with ENDF/B-VII.0 data was over 1% δk/k (1042 pcm); the largest bias (ZPR-9/4) was almost 2% δk/k (1948 pcm). All 13 k_{eff}’s were reduced with the ENDF/B-VII.1 data and the average bias of the values obtained with these data was <0.5% δk/k (463 pcm). The bias for ZPR-9/4 was reduced by >1.2% δk/k to ~0.7% δk/k with the ENDF/B-VII.1 data.

MCNP5 Calculations with "As-built" Models for IEU FAST and INTER ZPR/ZPPR Assemblies



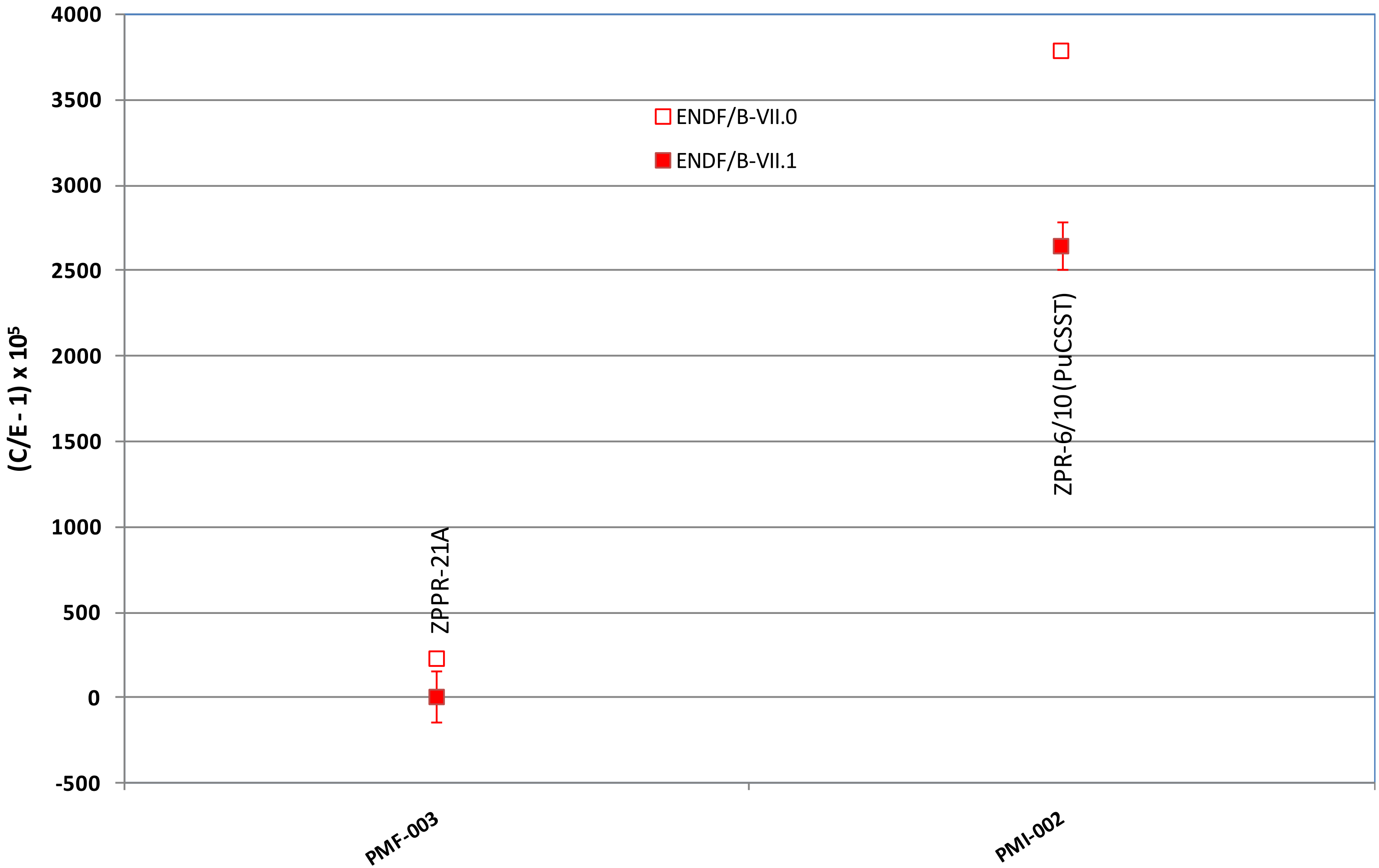
7 of the 9 IEU assemblies were over-predicted with the ENDF/B-VII.0 data. The average bias of the values obtained with ENDF/B-VII.0 data was ~0.25% δk/k (270 pcm). Eight of the 9 k_{eff}'s were reduced and 1 unchanged with the ENDF/B-VII.1 data and the average bias of the values obtained with these data was reduced by one-half (134 ± 115 pcm).

MCNP5 Calculations with "As-built" Models for MIXED (Pu,U) FAST and INTER ZPR/ZPPR Assemblies



For the mixed-(Pu,U) assemblies, 14 calculated k_{eff}'s were reduced with the ENDF/B-VII.1 data by approximately 60-215 pcm. The average bias for the 14 assemblies with ENDF/B-VII.0 data is 271 pcm; the average bias with ENDF/B-VII.1 data is 156 pcm. The biases for ZPR-3/53 and ZPR-3/54 with ENDF/B-VII.0 data are 855 and 1233 pcm, respectively; and with ENDF/B-VII.1 data are 755 and 1047 pcm, respectively. The average bias for the other 12 assemblies with ENDF/B-VII.0 data is 142 pcm; the average bias with ENDF/B-VII.1 data is 31 pcm.

MCNP5 Calculations with “As-built” Models for Pu Metal FAST and INTER ZPR/ZPPR Assemblies



Average Values of C/E - 1 (in pcm) for ENDF/B-VII.1 according to Fuel Type in ZPR/ZPPR Assemblies

Fuel Type	# of Expts	ENDF/B-VII.0 mean values, pcm			ENDF/B-VII.1 mean values, pcm			Δk Difference (VII.1 - VII.0)		
		C/E-1	±	σ	C/E-1	±	σ	Δk	±	σ
Pu-Metal [a]	2	2005	±	143	1327	±	143	-679	±	10
Mixed (Pu,U)	14	271	±	114	156	±	114	-120	±	9
HEU	13	1042	±	201	463	±	201	-576	±	9
IEU	9	270	±	115	134	±	115	-151	±	7

[a] Mean values are perhaps not meaningful for these assemblies because there were only 2 experiments with distinctly different energy spectra and performance

Measured and Calculated Values of Beta-effective obtained with ENDF/B-VII.1 Data`

ICSBEP Identifier	ZPR Assembly	Experiment $\beta_{eff} \pm \sigma$	ENDF/B Version	Calculated $\beta_{eff} \pm \sigma$	C/E ± σ
HMI-001	ZPR-9/34 (U/Fe)	0.00657 ± 0.00013	VII.0 VII.1	0.00681 ± 0.00006 0.00682 ± 0.00006	1.037 ± 0.023 1.038 ± 0.023
IMF-010	ZPR-6/9 (U9)	0.00706 ± 0.00009	VII.0 VII.1	0.00716 ± 0.00006 0.00707 ± 0.00006	1.014 ± 0.016 1.001 ± 0.016
PMI-002	ZPR-6/10 (PuC/SST)	0.00222 ± 0.00005	VII.0 VII.1	0.00224 ± 0.00003 0.00224 ± 0.00003	1.009 ± 0.029 1.009 ± 0.029

Sodium-Void Worth Measurements in ZPPR-9 and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Na} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Na} \pm \sigma$ (pcm)	C/E - 1 ± σ (%)
8-inch axial region in 97 drawers per half	104 ± 1.81	VII.0 VII.1	106 ± 4 100 ± 4	2.0 ± 4.4 -3.7 ± 4.4
20-inch axial region in 97 drawers per half	112 ± 1.88	VII.0 VII.1	109 ± 4 110 ± 4	-2.7 ± 4.1 -2.6 ± 4.1
27-inch axial region in 97 drawers per half	86 ± 1.46	VII.0 VII.1	85 ± 4 78 ± 4	-0.8 ± 5.2 -8.9 ± 5.2

Sodium-Void Worth Measurements in ZPPR-10A and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Na} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Na} \pm \sigma$ (pcm)	C/E - 1 $\pm$ σ (%)
8-inch axial region in 88 drawers per half	76 ± 0.88	VII.0 VII.1	88 ± 4 78 ± 4	15.9 ± 5.8 2.7 ± 5.8
8-inch axial region in 172 drawers per half	145 ± 1.56	VII.0 VII.1	153 ± 4 148 ± 4	5.6 ± 3.2 2.3 ± 3.2
16-inch axial region in 172 drawers per half	187 ± 2.07	VII.0 VII.1	194 ± 4 192 ± 4	3.7 ± 2.6 2.7 ± 2.5
16-inch axial region in 172 drawers per half	159 ± 1.76	VII.0 VII.1	160 ± 4 154 ± 4	0.8 ± 2.9 -2.9 ± 2.9

Sodium-Void Worth Measurements in ZPPR-15A and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Na} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Na} \pm \sigma$ (pcm)	C/E - 1 $\pm \sigma$ (%)
8-inch axial region in 148 drawers per half	370 ± 3.14	VII.0 VII.1	352 ± 4 356 ± 4	-4.9 ± 1.4 -3.9 ± 1.4
14-inch axial region in 148 drawers per half	101 ± 0.90	VII.0 VII.1	89 ± 4 80 ± 4	-12.3 ± 4.3 -21.1 ± 4.3
18-inch axial region in 148 drawers per half	-35 ± 0.46	VII.0 VII.1	-39 ± 4 -30 ± 4	11.6 ± 12.2 -14.0 ± 12.2
31-inch axial region in 148 drawers per half	-76 ± 1.55	VII.0 VII.1	-75 ± 4 -84 ± 4	-1.5 ± 5.7 10.7 ± 5.8

Control Rod (CR) and Control Rod Position (CRP) Measurements in ZPPR-9 and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Cr} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Cr} \pm \sigma$ (pcm)	C/E - 1 ± σ (%)
6 CRPs in Row 7	-968.6 ± 11.7	VII.0 VII.1	-990.7 ± 4 -979.6 ± 4	2.3 ± 1.3 1.1 ± 1.3
6 CRs in Row 7 (outer ring)	-6244.5 ± 73.1	VII.0 VII.1	-6355.9 ± 5 -6379.3 ± 5	1.8 ± 1.2 2.2 ± 1.2
6 CRs 1-7 in center and middle ring	-6130.9 ± 74.2	VII.0 VII.1	-6170.3 ± 5 -6198.0 ± 5	0.6 ± 1.2 1.1 ± 1.2
CRs 4 and 7	-2315.1 ± 27.7	VII.0 VII.1	-2373.8 ± 4 -2372.3 ± 4	2.5 ± 1.2 2.5 ± 1.2
Central 3x3 CR	-1178.6 ± 14.2	VII.0 VII.1	-1208.9 ± 4 -1209.3 ± 4	2.6 ± 1.3 2.6 ± 1.3

Control Rod (CR) and Control Rod Position (CRP) Measurements in ZPPR-10A and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Cr} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Cr} \pm \sigma$ (pcm)	C/E - 1 $\pm \sigma$ (%)
Central Rod	-885.6 ± 10.2	VII.0 VII.1	-944.9 ± 9 -953.4 ± 4	6.7 ± 1.6 7.7 ± 1.3
6 CRs in Row 4 (6R4)	-4495.7 ± 47.5	VII.0 VII.1	-4832.9 ± 4 -4854.3 ± 4	7.5 ± 1.1 8.0 ± 1.1
12 CRs in Row 7 (6R7C + 6R7F)	-7155.8 ± 105.2	VII.0 VII.1	-7549.7 ± 5 -7573.6 ± 5	5.5 ± 1.6 5.8 ± 1.6
6 Row 7 corner rods (6R7C)	-3236.9 ± 37.3	VII.0 VII.1	-3446.6 ± 4 -3458.0 ± 4	6.5 ± 1.2 6.8 ± 1.2

Control Rod (CR) and Control Rod Position (CRP) Measurements in ZPPR-15A and Calculated Values obtained with ENDF/B-VII.1 Data

Void Region	Experiment $\rho_{Cr} \pm \sigma$ (pcm)	ENDF/B Version	Calculated $\rho_{Cr} \pm \sigma$ (pcm)	C/E - 1 ± σ (%)
Central 2x2 Na CRP	-160.8 ± 1.25	VII.0 VII.1	-160 ± 4 -156 ± 4	-0.6 ± 2.8 -2.9 ± 2.8
Central 2x2 CR - 100% natural B_4C	-1305.87 ± 8.88	VII.0 VII.1	-1265 ± 4 -1277 ± 4	-3.2 ± 0.7 -2.2 ± 0.7
Central 2x2 CR - 50% natural B_4C	-999.043 ± 6.89	VII.0 VII.1	-910 ± 4 -932 ± 4	-8.9 ± 0.8 -8.7 ± 0.8