Appendix I
VERIFICATION OF CODES AND CROSS-SECTIONS

The biases and uncertainties in the calculation methods can be determined from calculation of benchmarks. The bias β_{kc} in each calculated k_{eff} (k_c) is related to the best-estimate k_{eff} (k_e) as

$$k_c = k_e + \beta_{kc}$$

The k_{eff} calculation bias is thus the difference between kc and k_e. A statistical evaluation of many benchmark calculations may give a reasonably correct bias for the calculation method. A combination of different uncertainties should be associated with the bias determination. Ideally, each benchmark calculation should be weighted individually according to the accuracy of the benchmark specifications and to the similarity to the application. The study demonstrates some of the complexities of validation, methods to deal with them and includes examples.

A calculated reference value V_c is related to the best-estimate reference value Ve through the reference value calculation bias β_{rc} as

$$V_c = V_e + \beta_{rc}$$

The sensitivities (S_{vk}) of reference values (V_e) to small variations of k_{eff} are given in Appendix D. The real sensitivity is not linear, which means that a real change, different from the k_{eff} change used to determine the sensitivity, leads to an error. It is also important to understand that a bias in the k_{eff} calculation result for a minimum critical value leads to a bias with reversed sign (positive/negative) in the calculated reference value (V_c). E.g., an over-estimation of k_{eff} leads to an under-estimation of the best-estimate critical mass. For a maximum critical value (like H/X) the opposite is true.

The best-estimate reference value V_e can be expressed as

$$V_e = V_c - \beta_{rc} = V_c + S_{vk} * \beta_{kc}$$

The product $S_{vk} * \beta_{kc}$ is a bias correction of the calculated reference value.

Verification of the calculation of reference values for nuclear criticality safety involves consideration of many potential error sources. The Expert Group selected reference values for 110 applications (concentration and moderation ratio are identical applications). With at least 13 methods, the number of evaluations should be at least 1 400. At this time, individual evaluation of each bias and uncertainty is not possible, due to a lack of time and other resources.

Verification of calculation methods using the same benchmarks is the primary objective of this Appendix I. Discrepancies are identified and explained when possible. Further, the focus has been to determine biases, while uncertainties are left for a later phase of the study.

Table I1. EALF values for all applications

EALF values for applications (eV)						
Material	Isotopes	Mass	Volume	Cylinder	Slab	Concentration
UO_2	100	0.0413	11153	4599	385	0.0305
	20	0.0434	0.1289	0.1325	0.1624	0.0312
	5	0.0514	0.0965	0.0974	0.1089	0.0344
	4	0.0531	0.0981	0.0858	0.1049	0.0357
	3	0.0617	0.1011	0.1031	0.1092	0.0380
UNH	100	0.0416	0.1708	0.1633	0.1953	0.0306
	20	0.0436	0.0770	0.0807	0.0859	0.0316
	5	0.0534	0.0709	0.0713	0.0735	0.0361
	4	0.0572	0.0730	0.0727	0.0753	0.0384
	3	0.0689	0.0809	0.0808	0.0804	0.0438
PuO_2	100/0/0/0	0.0547	26164	8785	252	0.0193
	95/5/0/0	0.0550	29639	10364	405	0.0194
	80/10/10/0	0.0543	27949	10118	396	0.0193
	90/10/0/0	0.0552	31053	11354	510	0.0196
	80/15/5/0	0.0551	30557	11465	551	0.0196
	71/17/11/1	0.0547	29755	11234	542	0.0195
PuNH	100/0/0/0	0.0548	0.3097	0.3562	0.5620	0.0194
	95/5/0/0	0.0551	0.1443	0.1525	0.1811	0.0195
	80/10/10/0	0.0544	0.1371	0.1470	0.2012	0.0193
	90/10/0/0	0.0552	0.1292	0.1342	0.1537	0.0196
	80/15/5/0	0.0553	0.1246	0.1304	0.1635	0.0196
	71/17/11/1	0.0547	0.1247	0.1298	0.1473	0.0195

Table I1 shows the calculated EALF values for all the requested reference values.

In the following tables in this Appendix I, the bias (B) refers to the bias in k_{eff}. The bias correction (BC) refers to the corresponding correction of the reference value. Uncertainty (U) is used for both k_{eff} and reference values.

The identification of calculation methods in the tables is shortened. S or S5 stands for SCALE 5 while M or M5 stands for MCNP5. After S, the numbers 8, 7 and 4 refer to the 238-group, the 27-group and the 44-group cross-section libraries. After M, the numbers 50, 5F, 62, 66, 68, 7P refer to ENDF/B releases, 22 and 30 refer to JEFF releases while 32 and 33 refer to JENDL releases.

Fast high-enriched uranium systems

The three applications in this group are $U(100)O_2$ systems for which critical volume, cylinder diameter and slab thickness are minimized. The EALF values are 11 000, 4 600 and 385.

The number of benchmarks is too low to get a high-quality determination of biases and uncertainties. Unfortunately, the degree of reflection seems to be a significant factor. Most of the selected systems are bare (unreflected) while the applications are reflected (or infinite). The uncertainty for benchmark HEU-MF-004 is very low. For demonstration only, this single benchmark is used to determine biases and uncertainties for fast, high-enriched systems; see Table 12.

If HEU-MF-004 is treated in SCALE 5 TSUNAMI-IP as an application, it can be evaluated against other benchmarks. As expected, the other HEU-MF benchmarks are the only ones with high similarities. Ck and Esum values are higher than 0.90 while G values are around 0.60. The completeness parameter is 0.36 and the penalty summary shows an uncertainty of 0.22% due to uncovered sensitivity coefficients. The R_{e2} values showing EALF similarities are low; 0.24 for HEU-MF-020 (some polyethylene reflection) and about 0.18 for the others (bare).

As can be seen in Table 12, the SCALE TSUNAMI parameters C_k and E_{sum} for similarity between the three applications and the HEU-MF-004 are above 0.90. The G parameter values are 0.84, 0.78 and 0.58 for volume, cylinder and slab. The EALF values for the three applications (11 000, 4 600, 385) are very different and this shows in the R_{e2} values 0.61, 0.40 and 0.11.

Evaluation of completeness parameters and penalties were made with all uranium benchmarks included. The completeness parameters for the three reference systems are 0.3258, 0.3831 and 0.5449. The penalties due to uncovered sensitivity coefficients in the form of relative standard deviations are 0.1588, 0.2112 and 1.1234% respectively.

The low benchmark uncertainty, the quality of the benchmark preparation, the results of similarity tests and the lack of other similar benchmarks together lead to the conclusion that HEU-MF-004 alone is adequate for determining biases for different methods (input data and codes).

The sensitivities of reference values to small k_{eff} variations, specified in APPENDIX D, are used to derive biases and uncertainties for the different reference parameters volume, cylinder diameter and slab thickness.

Table I2. B for fast $U(100)O_2$

Biases for $U(100)O_2$ volume (V), cylinder (Φ) and slab (S) geometry (mk)														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
V	B	0.0	9.0	3.5	-2.5	-1.0	-3.5	-3.0	-1.5	-2.5	-3.0	2.0	4.0	2.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Φ	B	0.0	9.0	3.5	-2.5	-1.0	-3.5	-3.0	-1.5	-2.5	-3.0	2.0	4.0	2.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
S	B	0.0	9.0	3.5	-2.5	-1.0	-3.5	-3.0	-1.5	-2.5	-3.0	2.0	4.0	2.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

[1] Uncertainties have not been evaluated. The example values are often too low.

Table I3. BC for fast $U(100)O_2$

Bias corrections for $U(100)O_2$ volume (V), cylinder (Φ) and slab (S) geometry (reference value units)														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
V (ml)	BC	0.0	169.2	65.8	-47.0	-18.8	-65.8	-56.4	-28.2	-47.0	-56.4	37.6	75.2	37.6
	U													
Φ (mm)	BC	0.00	2.00	0.78	-0.56	-0.22	-0.78	-0.67	-0.33	-0.56	-0.67	0.44	0.89	0.44
	U													
S (mm)	BC	0.00	1.23	0.48	-0.34	-0.14	-0.48	-0.41	-0.21	-0.34	-0.41	0.27	0.55	0.27
	U													

Thermal high-enriched uranium systems

The five $U(20)O_2$, the two remaining (mass and concentration) $U(100)O_2$, the five U(20)NH and the five U(100)NH applications are included in this group.

The primary selection basis for the verification is the uncertainty of each benchmark. Benchmarks with larger uncertainties (1 σ or about 67% confidence) than 3 mk are rejected in this demonstration. The included benchmarks are HEU-MT-011 (cases 1, 3, 5, 7, 35, 37, 39, 41 and 43), HEU-ST-010 (cases 1-4), HEU-ST-011 (cases 1, 2), HEU-ST-025 (case 1), HEU-ST-028 (case 1), HEU-ST-038 (case 1), HEU-ST-042 (case 3) and HEU-ST-043 (cases 1-3). No further weighting due to expected correlations between benchmarks was carried out.

The SCALE 5 TSUNAMI-IP similarity evaluations show good values (above 0.90) for C_k and E_{sum}. G values are more scattered but usually above 0.60 and in a few cases above 0.90. R_{e2} values were not used in the evaluation (shown in tables).

The TSUNAMI-IP results show that for high-enriched uranium (HEU) concentration applications, the benchmark model HEU-ST-042 case 3 is particularly good. All the four similarity parameters C_k, E_{sum}, G and R_{e2} are well above 0.90 and often close to 1.00. Other benchmarks with low uncertainties are not as good for these applications. This benchmark series is weighted higher due to the TSUNAMI results. All the HEU-ST-042 cases 1-8 in the evaluation were included, in spite of larger uncertainties, rather than only case 3.

The benchmarks HEU-MT-011 (cases 1, 3, 5, 7, 35, 37, 39, 41 and 43) are the only ones with very low uncertainties. Except for concentrations, they give very good results for C_k and E_{sum} and quite good results (>0.60) for the G parameter. The biases are checked for consistency with these benchmarks (giving them a higher weight) for all applications except concentrations.

Evaluation of completeness parameters were made with all uranium benchmarks included. The completeness parameters are at least 0.591. The penalties have not been considered.

Table I4. B for thermal HEU UO_2 and UNH

Biases (mk) for thermal HEU UO_2 and UNH systems														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U	B[1]	2.3	3.8	2.9	2.8	-0.8	0.9	0.4	-1.1	0.5	0.5	5.2	1.5	1.0
	U	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
V	B	2.3	3.8	2.9	2.8	-0.8	0.9	0.4	-1.1	0.5	0.5	5.2	1.5	1.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Φ	B	2.3	3.8	2.9	2.8	-0.8	0.9	0.4	-1.1	0.5	0.5	5.2	1.5	1.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
S	B	2.3	3.8	2.9	2.8	-0.8	0.9	0.4	-1.1	0.5	0.5	5.2	1.5	1.0
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
C U	B	2.8	5.7	3.7	3.8	-0.5	1.3	0.6	-1.7	1.2	1.1	6.1	1.7	2.5
	U[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Table I5. BC for thermal U(100)O_2

Bias corrections (reference value units) for thermal U(100)O_2 systems														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (g)	BC	8.2	13.5	10.3	9.9	-2.8	3.2	1.4	-3.9	1.8	1.8	18.5	5.3	3.6
	U													
C U (g/l)	BC	0.066	0.134	0.087	0.089	-0.012	0.031	0.014	-0.040	0.028	0.026	0.143	0.040	0.059
	U													

Table I6. BC for thermal U(20)O_2

Bias corrections (reference value units) for thermal U(20)O_2 systems														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (g)	BC	60	99	76	73	-21	23	10	-29	13	13	136	39	26
	U													
V (ml)	BC	115	191	146	141	-40	45	20	-55	25	25	261	75	50
	U													
Φ (mm)	BC	0.75	1.23	0.94	0.91	-0.26	0.29	0.13	-0.36	0.16	0.16	1.68	0.49	0.32
	U													
S (mm)	BC	0.49	0.80	0.61	0.59	-0.17	0.19	0.08	-0.23	0.11	0.11	1.10	0.32	0.21
	U													
C U (g/l)	BC	0.367	0.747	0.485	0.498	-0.066	0.170	0.079	-0.223	0.157	0.144	0.799	0.223	0.328
	U													

[1] Uncertainties have not been evaluated. The example values are often too low.

Table I7. BC for thermal U(100)NH

Bias corrections (reference value units) for thermal U(100)NH systems														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (g)	BC	8.2	13.6	10.4	10.0	-2.9	3.2	1.4	-3.9	1.8	1.8	18.6	5.4	3.6
	U													
V (ml)	BC	63.9	105.6	80.6	77.8	-22.2	25.0	11.1	-30.6	13.9	13.9	144.6	41.7	27.8
	U													
Φ (mm)	BC	0.56	0.93	0.71	0.69	-0.20	0.22	0.10	-0.27	0.12	0.12	1.27	0.37	0.25
	U													
S (mm)	BC	0.36	0.59	0.45	0.44	-0.12	0.14	0.06	-0.17	0.08	0.08	0.81	0.23	0.16
	U													
C U (g/l)	BC	0.067	0.136	0.088	0.090	-0.012	0.031	0.014	-0.040	0.029	0.026	0.145	0.040	0.060
	U													

Table I8. BC for thermal U(20)NH

Bias corrections (reference value units) for thermal U(20)NH systems														
Method		S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (g)	BC	72	119	90	87	-25	28	12	-34	16	16	162	47	31
	U													
V (ml)	BC	179	296	226	218	-62	70	31	-86	39	39	406	117	78
	U													
Φ (mm)	BC	0.88	1.45	1.11	1.07	-0.31	0.34	0.15	-0.42	0.19	0.19	1.99	0.57	0.38
	U													
S (mm)	BC	0.58	0.95	0.73	0.70	-0.20	0.23	0.10	-0.28	0.13	0.13	1.30	0.38	0.25
	U													
C U (g/l)	BC	0.378	0.770	0.500	0.513	-0.068	0.176	0.081	-0.230	0.162	0.149	0.824	0.230	0.338
	U													

Thermal low-enriched uranium systems

Both moderation (EALF) and ^{235}U enrichment (wt-%) trends are evaluated. The EALF-related biases are determined from a sub-selection of benchmarks with reasonably low uncertainties. These benchmarks were LEU-CT-002 (cases 1 and 4), LEU-CT-013 (case 1), LEU-CT-014 (case 1), LEU-CT-039 (case 1), LEU-CT-061 (case 1), LEU-CT-070 (case 1), LEU-ST-007 (cases 1-5), LEU-ST-016 (cases 1-7), LEU-ST-017 (cases 1-6), LEU-ST-020 (cases 1-4) and LEU-ST-021 (cases 1-4).

The results indicate that the trend against EALF is quite strong. For ^{235}U enrichment, the trends are not so strong, in particular for newer cross-section libraries. It seems practical to limit the bias determination to EALF trends only.

The EALF values for the low-enriched uranium systems are found in Table I1.

Even though there are many benchmarks, the spread in results for similar systems indicates larger uncertainties in the benchmarks than what the ICSBEP Handbook specifies. All trends of biases against EALF have a negative slope, except the ABBN-93 results. Different modelling of a few benchmarks in the MCNP/SCALE calculations than in the ABBN-93 calculations could result in such a change in slope. There are only three different input models involved; SCALE, MCNP and ABBN93.

The SCALE5 TSUNAMI evaluations indicate that the benchmarks and the applications are very similar. The completeness parameters are above 0.77. The penalties have not been considered. For the low-enriched uranium systems, the biases are calculated from the equations generated by Microsoft Excel from the results for benchmarks with low uncertainties. All equations are in the form:

$$\text{Bias(EALF)} = a*\ln(\text{EALF}) + b$$

TABLE I9. Equation constants for low-enriched U

Constants a and b generated to fit the equation y = a*ln(EALF) + b to benchmark calculation results														
	S5-238	S5-27	S5-44	M5-E50	M5-E5X	M5-E62	M5-E66	M5-E68	M5-E7P	M5-F22	M5-F30	M5-J32	M5-J33	ABBN-93
a	-2.91	-2.08	-1.04	-2.47	-2.47	-2.09	-3.04	-3.01	-1.25	-0.38	-2.08	-1.79	-1.63	1.66
b	-7.24	-5.84	-0.90	-4.54	-4.54	-8.09	-8.39	-8.54	-3.85	-0.03	-5.60	1.23	-2.78	5.46

The corresponding biases in k_{eff} (mk) and bias corrections in reference value units are displayed in the following tables for the different methods.

A study of published evaluations of cross-section validation would help in finding likely causes or parameters for trends. Further, potential discrepancies between benchmarks may have been examined. The trends generated in this study are not very reliable. They are used as examples.

Table I10. B for low-enriched UO_2

Biases (B) and uncertainties (U) for low-enriched UO_2 applications (mk)														
Method	Type	S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U $U(5)O_2$	B	1.40	0.33	2.19	2.79	-1.89	0.63	0.39	-0.14	1.10	0.57	6.54	2.06	0.53
	U													
V $U(5)O_2$	B	-0.44	-0.98	1.53	1.24	-3.20	-1.28	-1.50	-0.93	0.86	-0.74	5.42	1.03	1.58
	U													
Φ $U(5)O_2$	B	-0.46	-1.00	1.52	1.21	-3.22	-1.31	-1.53	-0.94	0.85	-0.76	5.40	1.02	1.59
	U													
S $U(5)O_2$	B	-0.79	-1.23	1.41	0.94	-3.46	-1.65	-1.87	-1.08	0.81	-0.99	5.20	0.83	1.78
	U													
C U $U(5)O_2$	B	2.57	1.17	2.60	3.78	-1.05	1.85	1.60	0.36	1.25	1.41	7.26	2.71	-0.13
	U													
M U $U(4)O_2$	B	1.30	0.27	2.15	2.71	-1.95	0.53	0.30	-0.18	1.09	0.51	6.48	2.00	0.59
	U													
V $U(4)O_2$	B	-0.48	-1.01	1.51	1.19	-3.24	-1.33	-1.55	-0.95	0.85	-0.77	5.39	1.00	1.61
	U													
Φ $U(4)O_2$	B	-0.09	-0.73	1.65	1.53	-2.96	-0.92	-1.15	-0.78	0.90	-0.49	5.63	1.22	1.38
	U													
S $U(4)O_2$	B	-0.68	-1.15	1.44	1.03	-3.38	-1.54	-1.75	-1.03	0.83	-0.91	5.27	0.90	1.72
	U													
C U $U(4)O_2$	B	2.46	1.09	2.57	3.69	-1.12	1.74	1.49	0.32	1.24	1.33	7.20	2.65	-0.07
	U													
M U $U(3)O_2$	B	0.87	-0.05	2.00	2.34	-2.27	0.08	-0.16	-0.37	1.03	0.19	6.22	1.76	0.84
	U													
V $U(3)O_2$	B	-0.57	-1.07	1.48	1.12	-3.30	-1.42	-1.64	-0.99	0.84	-0.83	5.33	0.96	1.66
	U													
Φ $U(3)O_2$	B	-0.63	-1.11	1.46	1.07	-3.34	-1.48	-1.70	-1.01	0.83	-0.87	5.30	0.92	1.69
	U													
S $U(3)O_2$	B	-0.80	-1.23	1.40	0.93	-3.46	-1.66	-1.87	-1.08	0.81	-0.99	5.19	0.83	1.78
	U													
C U $U(3)O_2$	B	2.28	0.96	2.50	3.54	-1.26	1.55	1.30	0.24	1.21	1.20	7.08	2.55	0.03
	U													

Table I11. B for low-enriched UNH

Biases (B) and uncertainties (U) for low-enriched UNH applications (mk)														
Method	Type	S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U	B	1,29	0,25	2,15	2,70	-1,97	0,52	0,28	-0,19	1,08	0,49	6,47	2,00	0,60
U(5)NH	U													
V	B	0,46	-0,34	1,85	2,00	-2,56	-0,34	-0,57	-0,54	0,98	-0,10	5,97	1,53	1,07
U(5)NH	U													
Φ	B	0,44	-0,35	1,85	1,98	-2,57	-0,36	-0,59	-0,55	0,97	-0,11	5,96	1,52	1,08
U(5)NH	U													
S	B	0,36	-0,41	1,81	1,91	-2,63	-0,45	-0,68	-0,59	0,96	-0,17	5,90	1,48	1,13
U(5)NH	U													
C U	B	2,43	1,07	2,55	3,66	-1,15	1,71	1,46	0,30	1,23	1,31	7,18	2,63	-0,05
U(5)NH	U													
M U	B	1,09	0,11	2,08	2,53	-2,11	0,31	0,07	-0,27	1,06	0,35	6,35	1,88	0,71
U(4)NH	U													
V	B	0,38	-0,40	1,82	1,92	-2,62	-0,43	-0,66	-0,58	0,96	-0,16	5,91	1,49	1,12
U(4)NH	U													
Φ	B	0,39	-0,39	1,83	1,93	-2,61	-0,42	-0,65	-0,57	0,97	-0,15	5,92	1,49	1,11
U(4)NH	U													
S	B	0,29	-0,46	1,79	1,85	-2,68	-0,53	-0,76	-0,62	0,95	-0,22	5,86	1,44	1,17
U(4)NH	U													
C U	B	2,25	0,94	2,49	3,51	-1,28	1,52	1,27	0,22	1,21	1,18	7,06	2,53	0,05
U(4)NH	U													
M U	B	0,54	-0,28	1,88	2,07	-2,50	-0,26	-0,49	-0,51	0,99	-0,04	6,02	1,58	1,02
U(3)NH	U													
V	B	0,08	-0,61	1,72	1,67	-2,83	-0,75	-0,97	-0,71	0,93	-0,37	5,73	1,32	1,29
U(3)NH	U													
Φ	B	0,08	-0,61	1,72	1,67	-2,83	-0,74	-0,97	-0,71	0,93	-0,37	5,73	1,32	1,28
U(3)NH	U													
S	B	0,10	-0,60	1,72	1,69	-2,82	-0,73	-0,95	-0,70	0,93	-0,36	5,74	1,33	1,28
U(3)NH	U													
C U	B	1,86	0,67	2,35	3,19	-1,55	1,12	0,88	0,06	1,16	0,91	6,83	2,32	0,27
U(3)NH	U													

Table I12. BC for low-enriched UO_2

Bias corrections for low-enriched UO_2 applications (reference value units)														
Method	B/U	S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (g) $U(5)O_2$	BC	335	80	525	670	-453	152	95	-34	263	138	1570	494	128
	U													
V (ml) $U(5)O_2$	BC	-72	-162	254	205	-532	-213	-249	-154	143	-122	899	171	262
	U													
Φ (mm) $U(5)O_2$	BC	-0.26	-0.56	0.86	0.68	-1.82	-0.74	-0.86	-0.53	0.48	-0.43	3.04	0.57	0.90
	U													
S (mm) $U(5)O_2$	BC	-0.29	-0.45	0.51	0.34	-1.26	-0.60	-0.68	-0.39	0.30	-0.36	1.89	0.30	0.65
	U													
C U (g/l) $U(5)O_2$	BC	1.72	0.78	1.75	2.53	-0.70	1.24	1.07	0.24	0.84	0.94	4.87	1.82	-0.09
	U													
M U (g) $U(4)O_2$	BC	513	105	848	1068	-770	210	117	-71	428	199	2555	790	231
	U													
V (ml) $U(4)O_2$	BC	-111	-231	347	274	-741	-305	-355	-217	195	-176	1233	230	368
	U													
Φ (mm) $U(4)O_2$	BC	-0.06	-0.48	1.09	1.01	-1.96	-0.61	-0.76	-0.52	0.60	-0.33	3.72	0.81	0.92
	U													
S (mm) $U(4)O_2$	BC	-0.29	-0.49	0.62	0.44	-1.44	-0.66	-0.75	-0.44	0.35	-0.39	2.25	0.38	0.73
	U													
C U (g/l) $U(4)O_2$	BC	2.21	0.98	2.31	3.32	-1.01	1.57	1.34	0.28	1.11	1.20	6.47	2.38	-0.06
	U													
M U (g) $U(3)O_2$	BC	684	-37	1578	1849	-1792	61	-123	-291	812	153	4911	1391	661
	U													
V (ml) $U(3)O_2$	BC	-227	-426	589	445	-1310	-565	-652	-391	334	-331	2117	379	657
	U													
Φ (mm) $U(3)O_2$	BC	-0.54	-0.95	1.25	0.92	-2.86	-1.27	-1.45	-0.86	0.71	-0.75	4.53	0.79	1.44
	U													
S (mm) $U(3)O_2$	BC	-0.44	-0.69	0.78	0.52	-1.93	-0.92	-1.04	-0.60	0.45	-0.55	2.89	0.46	0.99
	U													
C U (g/l) $U(3)O_2$	BC	3.08	1.30	3.38	4.79	-1.70	2.10	1.76	0.32	1.64	1.63	9.58	3.45	0.04
	U													

Table I13. BC for low-enriched UNH

Bias corrections for low-enriched UNH applications (reference value units)														
Method	B/U	S58	S57	S54	M50	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M U (kg) U(5)NH	BC	0.85	0.17	1.41	1.77	-1.29	0.34	0.18	-0.12	0.71	0.33	4.26	1.31	0.39
	U													
V (l) U(5)NH	BC	0.31	-0.22	1.23	1.33	-1.70	-0.23	-0.38	-0.36	0.65	-0.06	3.97	1.02	0.71
	U													
Φ (mm) U(5)NH	BC	0.47	-0.37	1.96	2.10	-2.72	-0.38	-0.63	-0.58	1.03	-0.11	6.31	1.62	1.14
	U													
S (mm) U(5)NH	BC	0.24	-0.28	1.24	1.30	-1.79	-0.31	-0.46	-0.40	0.66	-0.12	4.02	1.00	0.77
	U													
C U (g/l) U(5)NH	BC	1.97	0.87	2.07	2.97	-0.93	1.38	1.18	0.24	1.00	1.06	5.82	2.14	-0.04
	U													
M U (kg) U(4)NH	BC	1.67	0.17	3.20	3.89	-3.25	0.47	0.11	-0.42	1.63	0.54	9.78	2.90	1.09
	U													
V (l) U(4)NH	BC	0.53	-0.55	2.55	2.69	-3.67	-0.61	-0.93	-0.81	1.35	-0.22	8.28	2.08	1.56
	U													
Φ (mm) U(4)NH	BC	0.60	-0.60	2.83	3.00	-4.05	-0.65	-1.01	-0.89	1.50	-0.23	9.18	2.31	1.72
	U													
S (mm) U(4)NH	BC	0.28	-0.46	1.78	1.84	-2.67	-0.53	-0.75	-0.61	0.95	-0.22	5.83	1.43	1.16
	U													
C U (g/l) U(4)NH	BC	2.63	1.10	2.91	4.11	-1.49	1.78	1.49	0.26	1.41	1.38	8.27	2.96	0.06
	U													
M U (kg) U(3)NH	BC	4.10	-2.08	14.17	15.57	-18.82	-1.94	-3.67	-3.81	7.43	-0.27	45.32	11.90	7.68
	U													
V (l) U(3)NH	BC	0.46	-3.60	10.14	9.88	-16.75	-4.41	-5.74	-4.18	5.47	-2.19	33.87	7.79	7.60
	U													
Φ (mm) U(3)NH	BC	0.27	-2.04	5.77	5.62	-9.52	-2.49	-3.25	-2.37	3.11	-1.23	19.26	4.44	4.31
	U													
S (mm) U(3)NH	BC	0.21	-1.30	3.74	3.66	-6.12	-1.58	-2.07	-1.52	2.01	-0.77	12.46	2.88	2.77
	U													
C U (g/l) U(3)NH	BC	3.97	1.42	5.01	6.79	-3.31	2.38	1.87	0.13	2.47	1.93	14.55	4.94	0.57
	U													

Fast plutonium systems

The applications involve both fast and thermal systems and a wide range of plutonium isotopic distributions. Unlike with uranium, the isotopic distributions don't change the main properties of the systems, such as going from fast to thermal systems when the distribution changes. Only trends against EALF will be evaluated.

As for fast uranium systems, many fast plutonium systems involve bare systems. There are six benchmarks with low uncertainties; Pu-MF-001, Pu-MF-002, Pu-MF-005, Pu-MF-011, Pu-MF-022 and Pu-MF-029. Other benchmarks are Pu-MF-003 (cases 1-5) and Pu-MF-037 (cases 1, 5, 7, 10, 12, 15 and 16). While having larger uncertainties, they are valuable in showing trends against EALF.

The trends of biases against EALF appear to have significant negative slopes for all cross-section libraries, except for JEFF-3.0. This library also has the smallest spread of biases even though it is still very large. The spread may be more due to uncertainties in the benchmarks than in the cross-sections. The negative slopes are not obvious, considering the correlation between many of the benchmarks.

Pu-MF-011 has a low uncertainty and appears to be particularly similar to the applications. It is given a high weight when biases are determined. SCALE 5 TSUNAMI results confirm the similarity. The overall information leads to the conclusion that the single benchmark PuMF011 gives a reasonable basis for estimating the biases. The result for SCALE 5 with the 27 group library appears to be high and the uncertainty should be increased for this reason.

Results for fast plutonium systems are sensitive to the ^{239}Pu ENDF/B-5 cross-sections: the .50c "interim" set or the .55c final set. This is important when comparisons are made between cross-section libraries, in particular when benchmarks are re-calculated by people who are not as aware of the differences as the users of the library at the peak time of its popularity. MCNP5 calculations with JEFF-3.0, JENDL-3.2 and JENDL-3.3 libraries indicate significant bias differences between results for benchmarks Pu-MF-001 and Pu-MF-002. This may be due to other plutonium isotopes than ^{239}Pu.

The TSUNAMI-IP completeness parameters for the fast PuO_2 systems are quite high, between 0.55 and 0.80, for all plutonium isotope distributions. The penalties have not been considered.

The EALF values in the X scale of the plutonium charts (Figures F75 to F91) were divided by a suitable factor to allow the logarithmic scale to be used well.

Table I14. B for fast plutonium

Biases for fast plutonium: Volume (V), cylinder (Φ) and slab (S) geometry (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
V	B	-2.1	3.8	-0.1	9.3	0.1	-2.4	-2.8	-3.2	-1.2	-3.5	-2.6	-2.6	-1.9	-0.2
	U														
Φ	B	-2.1	3.8	-0.1	9.3	0.1	-2.4	-2.8	-3.2	-1.2	-3.5	-2.6	-2.6	-1.9	-0.2
	U														
S	B	-2.1	3.8	-0.1	9.3	0.1	-2.4	-2.8	-3.2	-1.2	-3.5	-2.6	-2.6	-1.9	-0.2
	U														

Table I15. BC for fast PuO_2

Bias corrections for fast PuO_2: Volume (V), cylinder (Φ) and slab (S) geometry (reference value units)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
V (ml) 100/0/0/0	BC	-8.8	16.3	-0.3	39.4	0.6	-10.2	-11.8	-13.4	-5.0	-14.7	-10.9	-11.0	-8.2	-0.9
	U														
Φ (mm) 100/0/0/0	BC	-0.24	0.44	-0.01	1.07	0.02	-0.28	-0.32	-0.37	-0.14	-0.40	-0.30	-0.30	-0.22	-0.02
	U														
S (mm) 100/0/0/0	BC	-0.13	0.24	-0.01	0.58	0.01	-0.15	-0.17	-0.20	-0.07	-0.22	-0.16	-0.16	-0.12	-0.01
	U														
V (ml) 95/5/0/0	BC	-9.2	16.9	-0.4	40.7	0.6	-10.6	-12.2	-13.9	-5.2	-15.2	-11.3	-11.4	-8.4	-0.9
	U														
Φ (mm) 95/5/0/0	BC	-0.25	0.46	-0.01	1.11	0.02	-0.29	-0.33	-0.38	-0.14	-0.42	-0.31	-0.31	-0.23	-0.03
	U														
S (mm) 95/5/0/0	BC	-0.14	0.25	-0.01	0.60	0.01	-0.16	-0.18	-0.21	-0.08	-0.23	-0.17	-0.17	-0.13	-0.01
	U														
V (ml) 80/10/10/0	BC	-10.0	18.3	-0.4	44.4	0.6	-11.5	-13.3	-15.1	-5.7	-16.6	-12.3	-12.4	-9.2	-1.0
	U														
Φ (mm) 80/10/10/0	BC	-0.25	0.47	-0.01	1.13	0.02	-0.29	-0.34	-0.39	-0.14	-0.42	-0.31	-0.32	-0.23	-0.03
	U														
S (mm) 80/10/10/0	BC	-0.14	0.26	-0.01	0.64	0.01	-0.16	-0.19	-0.22	-0.08	-0.24	-0.18	-0.18	-0.13	-0.01
	U														
V (ml) 90/10/0/0	BC	-10.0	18.5	-0.4	44.7	0.6	-11.6	-13.4	-15.3	-5.7	-16.7	-12.4	-12.5	-9.3	-1.0
	U														
Φ (mm) 90/10/0/0	BC	-0.25	0.47	-0.01	1.13	0.02	-0.29	-0.34	-0.39	-0.14	-0.42	-0.31	-0.32	-0.23	-0.03
	U														
S (mm) 90/10/0/0	BC	-0.14	0.26	-0.01	0.63	0.01	-0.16	-0.19	-0.22	-0.08	-0.24	-0.18	-0.18	-0.13	-0.01
	U														
V (ml) 80/15/5/0	BC	-10.5	19.3	-0.4	46.8	0.7	-12.1	-14.0	-16.0	-6.0	-17.5	-13.0	-13.1	-9.7	-1.1
	U														
Φ (mm) 80/15/5/0	BC	-0.26	0.48	-0.01	1.17	0.02	-0.30	-0.35	-0.40	-0.15	-0.44	-0.32	-0.33	-0.24	-0.03
	U														
S (mm) 80/15/5/0	BC	-0.14	0.27	-0.01	0.64	0.01	-0.17	-0.19	-0.22	-0.08	-0.24	-0.18	-0.18	-0.13	-0.01
	U														
V (ml) 71/17/11/1	BC	-10.9	20.1	-0.4	48.7	0.7	-12.6	-14.6	-16.6	-6.2	-18.2	-13.5	-13.6	-10.1	-1.1
	U														
Φ (mm) 71/17/11/1	BC	-0.26	0.49	-0.01	1.18	0.02	-0.30	-0.35	-0.40	-0.15	-0.44	-0.33	-0.33	-0.24	-0.03
	U														
S (mm) 71/17/11/1	BC	-0.15	0.27	-0.01	0.66	0.01	-0.17	-0.20	-0.22	-0.08	-0.25	-0.18	-0.18	-0.14	-0.01
	U														

Thermal plutonium systems

The bias trends against EALF have strong negative slopes for all methods. Two series of benchmarks, Pu-ST-022 and Pu-ST-025, had been found to be particularly important. The corresponding trend lines are for almost all methods consistent with the trend lines based on all benchmarks (not so surprising since they contain more than half of the selected benchmarks).

The TSUNAMI-IP evaluations show that the thermal PuO_2 systems have completeness parameters between 0.19 and 0.48. The penalties have not been considered.

As was done for the low-enriched uranium systems, biases will be determined from the equations generated by Microsoft Excel. All equations are in the form

$$\text{Bias(EALF)} = a*\ln(\text{EALF}) + b$$

Table I16. Equation constants for thermal Pu

Constants a and b generated to fit the equation y = a*ln(EALF) + b to benchmark calculation results														
	S5-238	S5-27	S5-44	M5-E50	M5-E5X	M5-E62	M5-E66	M5-E68	M5-E7P	M5-F22	M5-F30	M5-J32	M5-J33	ABBN-93
a	-5.33	-3.29	-4.75	-5.05	-5.34	-4.93	-4.62	-4.71	-4.49	-3.38	-3.78	-5.00	-4.18	-3.84
b	-10.5	3.58	-6.61	-7.28	-8.74	-13.1	-10.8	-11.5	-10.4	-3.44	-7.17	-8.34	-6.01	-13.0

The corresponding biases in k_{eff} (mk) and in reference value units (rvu) are displayed in the Tables I17-I24 for the different methods.

Table I17. B for thermal Pu(100, 95/5, 80/10/10)O2

Biases for thermal Pu(100/0/0/0)O_2, Pu(95/5/0/0)O_2 and Pu(80/10/10/0)O_2 applications (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu 100/0/0/0	B	4.99	13.14	7.19	7.39	6.78	1.23	2.63	2.19	2.65	6.38	3.81	6.19	6.14	-2.42
	U														
C Pu 100/0/0/0	B	10.5	16.6	12.1	12.7	12.3	6.36	7.44	7.09	7.32	9.90	7.75	11.4	10.5	1.37
	U														
M Pu 95/5/0/0	B	4.96	13.1	7.17	7.37	6.75	1.20	2.60	2.16	2.62	6.36	3.79	6.16	6.11	-2.44
	U														
C Pu 95/5/0/0	B	10.5	16.6	12.1	12.6	12.3	6.34	7.41	7.07	7.30	9.89	7.73	11.4	10.5	1.35
	U														
M Pu 80/10/10/0	B	5.03	13.2	7.23	7.43	6.82	1.26	2.66	2.22	2.68	6.41	3.84	6.23	6.17	-2.40
	U														
C Pu 80/10/10/0	B	10.5	16.6	12.1	12.7	12.3	6.36	7.44	7.09	7.32	9.90	7.75	11.4	10.5	1.37
	U														

Table I18. BC for thermal Pu(100, 95/5, 80/10/10)O_2

Biases for thermal Pu(90/10/0/0)O_2, Pu(80/15/5/0)O_2 and Pu(71/17/11/1)O_2 applications (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu 90/10/0/0	B	4.94	13.11	7.15	7.35	6.73	1.18	2.58	2.14	2.61	6.35	3.78	6.14	6.10	-2.46
	U														
C Pu 90/10/0/0	B	10.5	16.5	12.1	12.6	12.3	6.29	7.37	7.02	7.26	9.85	7.69	11.3	10.4	1.31
	U														
M Pu 80/15/5/0	B	4.95	13.12	7.16	7.36	6.74	1.19	2.59	2.15	2.61	6.36	3.79	6.15	6.11	-2.45
	U														
C Pu 80/15/5/0	B	10.5	16.5	12.1	12.6	12.3	6.29	7.37	7.02	7.26	9.85	7.69	11.3	10.4	1.31
	U														
M Pu 71/17/11/1	B	4.99	13.14	7.19	7.39	6.78	1.23	2.63	2.19	2.65	6.38	3.81	6.19	6.14	-2.42
	U														
C Pu 71/17/11/1	B	10.5	16.5	12.1	12.6	12.3	6.31	7.39	7.04	7.28	9.87	7.71	11.3	10.4	1.33
	U														

Table I19. B for thermal Pu(90/10, 80/15/5, 71/17/11/1)O_2

Biases for thermal Pu(90/10/0/0)O_2, Pu(80/15/5/0)O_2 and Pu(71/17/11/1)O_2 applications (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu 90/10/0/0	B	4.94	13.11	7.15	7.35	6.73	1.18	2.58	2.14	2.61	6.35	3.78	6.14	6.10	-2.46
	U														
C Pu 90/10/0/0	B	10.5	16.5	12.1	12.6	12.3	6.29	7.37	7.02	7.26	9.85	7.69	11.3	10.4	1.31
	U														
M Pu 80/15/5/0	B	4.95	13.12	7.16	7.36	6.74	1.19	2.59	2.15	2.61	6.36	3.79	6.15	6.11	-2.45
	U														
C Pu 80/15/5/0	B	10.5	16.5	12.1	12.6	12.3	6.29	7.37	7.02	7.26	9.85	7.69	11.3	10.4	1.31
	U														
M Pu 71/17/11/1	B	4.99	13.14	7.19	7.39	6.78	1.23	2.63	2.19	2.65	6.38	3.81	6.19	6.14	-2.42
	U														
C Pu 71/17/11/1	B	10.5	16.5	12.1	12.6	12.3	6.31	7.39	7.04	7.28	9.87	7.71	11.3	10.4	1.33
	U														

Table I20. BC for thermal Pu(90/10, 80/15/5, 71/17/11/1)O_2

Bias corrections for thermal Pu(90/10/0/0)O_2, Pu(80/15/5/0)O_2 and Pu(71/17/11/1)O_2 (ref. value units)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu (g) 90/10/0/0	BC	19	50	27	28	25	4	10	8	10	24	14	23	23	-9
	U														
C Pu (g/l) 90/10/0/0	BC	0.18	0.28	0.21	0.22	0.21	0.11	0.13	0.12	0.12	0.17	0.13	0.19	0.18	0.02
	U														
M Pu (g) 80/15/5/0	BC	23	61	33	34	31	6	12	10	12	29	18	29	28	-11
	U														
C Pu (g/l) 80/15/5/0	BC	0.20	0.31	0.23	0.24	0.23	0.12	0.14	0.13	0.14	0.19	0.15	0.21	0.20	0.02
	U														
M Pu (g) 71/17/11/1	BC	24	63	34	35	32	6	13	10	13	31	18	30	29	-12
	U														
C Pu (g/l) 71/17/11/1	BC	0.20	0.32	0.24	0.25	0.24	0.12	0.14	0.14	0.14	0.19	0.15	0.22	0.20	0.03
	U														

Table I21. B for thermal Pu(100, 95/5, 80/10/10)NH

Biases for thermal Pu(100/0/0/0)NH, Pu(95/5/0/0)NH and Pu(80/10/10/0)NH applications (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu 100/0/0/0	B	4.96	13.1	7.19	7.39	6.76	1.16	2.66	2.20	2.65	6.38	3.79	6.17	6.14	-1.87
	U														
V PuNH 100/0/0/0	B	-4.27	7.4	-1.04	-1.36	-2.49	-7.37	-5.34	-5.97	-5.14	0.52	-2.75	-2.48	-1.10	-8.52
	U														
Φ PuNH 100/0/0/0	B	-5.02	6.98	-1.71	-2.07	-3.23	-8.06	-5.98	-6.63	-5.77	0.05	-3.27	-3.18	-1.69	-9.06
	U														
S PuNH 100/0/0/0	B	-7.45	5.48	-3.87	-4.37	-5.67	-10.31	-8.09	-8.77	-7.81	-1.49	-5.00	-5.46	-3.60	-10.8
	U														
C Pu 100/0/0/0	B	10.5	16.6	12.1	12.6	12.3	6.29	7.47	7.10	7.32	9.90	7.72	11.4	10.5	2.12
	U														
M Pu 95/5/0/0	B	4.93	13.1	7.17	7.36	6.73	1.14	2.64	2.17	2.62	6.36	3.77	6.15	6.12	-1.89
	U														
V PuNH 95/5/0/0	B	-0.20	10.0	2.59	2.50	1.59	-3.61	-1.81	-2.37	-1.70	3.11	0.14	1.34	2.09	-5.59
	U														
Φ PuNH 95/5/0/0	B	-0.50	9.78	2.33	2.22	1.29	-3.88	-2.06	-2.63	-1.95	2.92	-0.07	1.06	1.86	-5.80
	U														
S PuNH 95/5/0/0	B	-1.41	9.21	1.51	1.35	0.38	-4.73	-2.86	-3.44	-2.72	2.34	-0.72	0.20	1.14	-6.46
	U														
C Pu 95/5/0/0	B	10.5	16.6	12.1	12.6	12.3	6.26	7.44	7.07	7.29	9.88	7.70	11.3	10.5	2.10
	U														
M Pu 80/10/10/0	B	5.00	13.2	7.23	7.43	6.80	1.20	2.70	2.23	2.68	6.41	3.82	6.21	6.17	-1.85
	U														
V PuNH 80/10/10/0	B	0.07	10.1	2.83	2.76	1.86	-3.35	-1.57	-2.12	-1.47	3.28	0.33	1.59	2.31	-5.39
	U														
Φ PuNH 80/10/10/0	B	-0.30	9.90	2.50	2.40	1.49	-3.70	-1.89	-2.45	-1.79	3.04	0.07	1.24	2.01	-5.66
	U														
S PuNH 80/10/10/0	B	-1.97	8.87	1.01	0.82	-0.18	-5.24	-3.34	-3.93	-3.20	1.98	-1.12	-0.33	0.70	-6.87
	U														
C Pu 80/10/10/0	B	10.5	16.6	12.1	12.7	12.3	6.30	7.48	7.11	7.33	9.91	7.73	11.4	10.5	2.13
	U														

Table I22. BC for thermal Pu(100, 95/5, 80/10/10)NH

Bias corrections for thermal Pu(100/0/0/0)NH, Pu(95/5/0/0)NH and Pu(80/10/10/0)NH (ref. value units)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu (g) 100/0/0/0	BC	12	31	17	17	16	3	6	5	6	15	9	14	14	-6
	U														
V (ml) 100/0/0/0	BC	-138	241	-34	-44	-80	-237	-174	-194	-166	17	-89	-80	-36	-283
	U														
Φ (mm) 100/0/0/0	BC	-1.33	1.86	-0.45	-0.55	-0.86	-2.13	-1.60	-1.77	-1.53	0.01	-0.87	-0.85	-0.45	-2.46
	U														
S (mm) 100/0/0/0	BC	-1.27	0.94	-0.66	-0.75	-0.97	-1.75	-1.39	-1.50	-1.34	-0.26	-0.85	-0.93	-0.62	-1.86
	U														
C Pu (g/l) 100/0/0/0	BC	0.15	0.23	0.17	0.18	0.17	0.09	0.10	0.10	0.10	0.14	0.11	0.16	0.15	0.02
	U														
M Pu (g) 95/5/0/0	BC	15	40	22	22	20	4	8	7	8	19	11	19	19	-7
	U														
V (ml) 95/5/0/0	BC	-9	496	129	125	80	-177	-93	-119	-85	155	7	67	104	-297
	U														
Φ (mm) 95/5/0/0	BC	-0.16	3.18	0.76	0.72	0.42	-1.25	-0.69	-0.86	-0.64	0.95	-0.02	0.35	0.60	-2.01
	U														
S (mm) 95/5/0/0	BC	-0.29	1.94	0.32	0.28	0.08	-0.99	-0.61	-0.73	-0.58	0.49	-0.15	0.04	0.24	-1.43
	U														
C Pu (g/l) 95/5/0/0	BC	0.16	0.26	0.19	0.20	0.19	0.10	0.11	0.11	0.11	0.15	0.12	0.18	0.16	0.02
	U														
M Pu (g) 80/10/10/0	BC	18	47	26	26	24	4	9	8	9	23	14	22	22	-9
	U														
V (ml) 80/10/10/0	BC	5	593	166	161	110	-194	-95	-125	-87	192	20	93	135	-338
	U														
Φ (mm) 80/10/10/0	BC	-0.10	3.51	0.89	0.85	0.53	-1.29	-0.69	-0.88	-0.64	1.08	0.03	0.44	0.71	-2.14
	U														
S (mm) 80/10/10/0	BC	-0.46	2.06	0.23	0.19	-0.04	-1.21	-0.79	-0.92	-0.75	0.46	-0.26	-0.08	0.16	-1.67
	U														
C Pu (g/l) 80/10/10/0	BC	0.17	0.27	0.20	0.21	0.20	0.10	0.12	0.12	0.12	0.16	0.13	0.19	0.17	0.02
	U														

Table I23. B for thermal Pu(90/10, 80/15/5, 71/17/11/1)NH

Biases for thermal Pu(90/10/0/0)NH, Pu(80/15/5/0)NH and Pu(71/17/11/1)NH applications (mk)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu 90/10/0/0	B	4.91	13.1	7.16	7.35	6.71	1.12	2.63	2.16	2.61	6.35	3.76	6.13	6.11	-1.90
	U														
V 90/10/0/0	B	0.39	10.3	3.12	3.06	2.18	-3.06	-1.30	-1.85	-1.21	3.48	0.55	1.89	2.55	-5.17
	U														
Φ 90/10/0/0	B	0.19	10.20	2.94	2.87	1.98	-3.25	-1.47	-2.02	-1.38	3.35	0.41	1.70	2.40	-5.31
	U														
S 90/10/0/0	B	-0.54	9.75	2.29	2.18	1.25	-3.92	-2.10	-2.66	-1.99	2.89	-0.10	1.02	1.83	-5.83
	U														
C Pu 90/10/0/0	B	10.4	16.5	12.1	12.6	12.2	6.22	7.41	7.04	7.26	9.86	7.67	11.3	10.4	2.07
	U														
M Pu 80/15/5/0	B	4.91	13.1	7.15	7.34	6.71	1.12	2.62	2.16	2.61	6.35	3.76	6.13	6.10	-1.91
	U														
V 80/15/5/0	B	0.58	10.4	3.29	3.24	2.37	-2.89	-1.13	-1.68	-1.05	3.60	0.69	2.07	2.70	-5.03
	U														
Φ 80/15/5/0	B	0.34	10.29	3.07	3.01	2.13	-3.11	-1.34	-1.89	-1.25	3.45	0.52	1.84	2.52	-5.20
	U														
S 80/15/5/0	B	-0.87	9.55	2.00	1.87	0.92	-4.22	-2.38	-2.95	-2.26	2.68	-0.33	0.71	1.57	-6.07
	U														
C Pu 80/15/5/0	B	10.4	16.5	12.1	12.6	12.2	6.22	7.41	7.04	7.26	9.85	7.67	11.3	10.4	2.07
	U														
M Pu 71/17/11/1	B	4.96	13.2	7.20	7.40	6.76	1.17	2.67	2.20	2.65	6.38	3.80	6.18	6.15	-1.87
	U														
V 71/17/11/1	B	0.57	10.4	3.28	3.23	2.37	-2.89	-1.14	-1.68	-1.05	3.60	0.69	2.06	2.70	-5.03
	U														
Φ 71/17/11/1	B	0.36	10.31	3.10	3.03	2.16	-3.08	-1.32	-1.87	-1.23	3.46	0.54	1.87	2.54	-5.18
	U														
S 71/17/11/1	B	-0.31	9.89	2.49	2.40	1.48	-3.71	-1.90	-2.46	-1.80	3.04	0.06	1.23	2.01	-5.67
	U														
C Pu 71/17/11/1	B	10.5	16.5	12.1	12.6	12.3	6.25	7.44	7.06	7.29	9.87	7.69	11.3	10.5	2.09
	U														

Table I124. BC for thermal Pu(90/10, 80/15/5, 71/17/11/1)NH

Bias corrections for thermal Pu(90/10/0/0)NH, Pu(80/15/5/0)NH and Pu(71/17/11/1)NH (ref. value units)															
Method		S58	S57	S54	M50	M5F	M62	M66	M68	M7P	M22	M30	M32	M33	IPPE
M Pu (g) 90/10/0/0	BC	19	51	28	29	26	5	10	8	10	25	15	24	24	-10
	U														
V (ml) 90/10/0/0	BC	27	674	203	200	143	-197	-88	-122	-79	227	37	124	166	-363
	U														
Φ (mm) 90/10/0/0	BC	0.08	3.81	1.10	1.07	0.74	-1.20	-0.57	-0.76	-0.52	1.25	0.16	0.64	0.89	-2.13
	U														
S (mm) 90/10/0/0	BC	-0.12	2.35	0.55	0.52	0.30	-0.93	-0.52	-0.65	-0.48	0.70	-0.02	0.25	0.44	-1.49
	U														
C Pu (g/l) 90/10/0/0	BC	0.18	0.29	0.21	0.22	0.21	0.11	0.13	0.12	0.13	0.17	0.13	0.20	0.18	0.02
	U														
M Pu (g) 80/15/5/0	BC	23	62	34	35	32	6	12	10	12	30	18	29	29	-12
	U														
V (ml) 80/15/5/0	BC	47	822	259	255	188	-223	-93	-133	-83	284	55	163	212	-427
	U														
Φ (mm) 80/15/5/0	BC	0.15	4.20	1.25	1.23	0.87	-1.25	-0.57	-0.78	-0.51	1.41	0.22	0.75	1.02	-2.28
	U														
S (mm) 80/15/5/0	BC	-0.23	2.58	0.54	0.50	0.25	-1.13	-0.66	-0.80	-0.61	0.72	-0.09	0.19	0.42	-1.73
	U														
C Pu (g/l) 80/15/5/0	BC	0.20	0.31	0.23	0.24	0.23	0.12	0.14	0.13	0.14	0.19	0.15	0.22	0.20	0.02
	U														
M Pu (g) 71/17/11/1	BC	26	69	38	39	36	6	14	12	14	34	20	33	32	-13
	U														
V (ml) 71/17/11/1	BC	49	863	271	267	197	-235	-98	-140	-87	297	58	171	223	-448
	U														
Φ (mm) 71/17/11/1	BC	0.16	4.31	1.29	1.27	0.91	-1.27	-0.57	-0.79	-0.52	1.45	0.23	0.78	1.06	-2.33
	U														
S (mm) 71/17/11/1	BC	-0.08	2.67	0.67	0.65	0.40	-0.99	-0.53	-0.67	-0.49	0.82	0.02	0.33	0.54	-1.63
	U														
C Pu (g/l) 71/17/11/1	BC	0.20	0.32	0.24	0.25	0.24	0.12	0.14	0.14	0.14	0.19	0.15	0.22	0.20	0.03
	U														

Summary of bias corrections for all methods

Table I125. BC - SCALE 5 + 238 group cross-sections

Bias corrections (reference value units) for applications – SCALE 5 with 238-group cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0082	0.0000	0.0000	0.0000	0.0658
	20	0.0600	0.1155	0.0745	0.0485	0.3668
	5	0.3333	-0.0732	-0.0264	-0.0289	1.7117
	4	0.5107	-0.1123	-0.0067	-0.0293	2.2053
	3	0.6770	-0.2295	-0.0543	-0.0446	3.0646
UNH	100	0.0082	0.0639	0.0564	0.0359	0.0666
	20	0.0718	0.1794	0.0879	0.0575	0.3780
	5	0.8413	0.3016	0.0464	0.0239	1.9630
	4	1.6584	0.5162	0.0592	0.0277	2.6199
	3	4.0466	0.4196	0.0249	0.0194	3.9441
PuO_2	100/0/0/0	0.0117	-0.0088	-0.0241	-0.0130	0.1445
	95/5/0/0	0.0144	-0.0092	-0.0250	-0.0136	0.1617
	80/10/10/0	0.0169	-0.0100	-0.0254	-0.0143	0.1696
	90/10/0/0	0.0186	-0.0100	-0.0254	-0.0142	0.1797
	80/15/5/0	0.0228	-0.0105	-0.0262	-0.0144	0.1972
	71/17/11/1	0.0238	-0.0109	-0.0264	-0.0147	0.2033
PuNH	100/0/0/0	0.0116	-0.1384	-0.1335	-0.1274	0.1460
	95/5/0/0	0.0149	-0.0101	-0.0162	-0.0298	0.1623
	80/10/10/0	0.0177	0.0042	-0.0107	-0.0460	0.1724
	90/10/0/0	0.0192	0.0253	0.0070	-0.0130	0.1805
	80/15/5/0	0.0233	0.0456	0.0138	-0.0234	0.1981
	71/17/11/1	0.0261	0.0475	0.0152	-0.0084	0.2039

Table I26. BC - SCALE 5 + 27 group cross-sections

Bias corrections (reference value units) for applications – SCALE 5 with 27-group cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0135	0.1692	0.1998	0.1233	0.1340
	20	0.0992	0.1908	0.1231	0.0802	0.7467
	5	0.0785	-0.1628	-0.0564	-0.0449	0.7773
	4	0.1027	-0.2327	-0.0488	-0.0493	0.9776
	3	-0.0420	-0.4282	-0.0957	-0.0690	1.2896
UNH	100	0.0136	0.1056	0.0931	0.0593	0.1357
	20	0.1186	0.2964	0.1452	0.0950	0.7695
	5	0.1633	-0.2277	-0.0374	-0.0283	0.8630
	4	0.1601	-0.5629	-0.0609	-0.0464	1.0936
	3	-2.1201	-3.6338	-0.2058	-0.1306	1.4010
PuO_2	100/0/0/0	0.0309	0.0163	0.0444	0.0240	0.2285
	95/5/0/0	0.0384	0.0169	0.0460	0.0250	0.2553
	80/10/10/0	0.0444	0.0183	0.0467	0.0263	0.2682
	90/10/0/0	0.0496	0.0185	0.0467	0.0261	0.2835
	80/15/5/0	0.0609	0.0193	0.0483	0.0265	0.3125
	71/17/11/1	0.0629	0.0201	0.0486	0.0272	0.3223
PuNH	100/0/0/0	0.0308	0.2412	0.1858	0.0937	0.2304
	95/5/0/0	0.0398	0.4970	0.3188	0.1944	0.2566
	80/10/10/0	0.0466	0.5936	0.3514	0.2066	0.2719
	90/10/0/0	0.0512	0.6752	0.3815	0.2350	0.2860
	80/15/5/0	0.0623	0.8229	0.4200	0.2578	0.3140
	71/17/11/1	0.0692	0.8634	0.4320	0.2671	0.3227

Table I27. BC - SCALE 5 + 44 group cross-sections

Bias corrections (reference value units) for applications – SCALE 5 with 44-group cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0103	0.0658	0.0777	0.0480	0.0870
	20	0.0757	0.1456	0.0940	0.0612	0.4847
	5	0.5220	0.2526	0.0853	0.0508	1.7358
	4	0.8438	0.3445	0.1088	0.0613	2.2965
	3	1.5682	0.5848	0.1242	0.0776	3.3655
UNH	100	0.0104	0.0806	0.0711	0.0452	0.0881
	20	0.0905	0.2262	0.1108	0.0725	0.4995
	5	1.4052	1.2260	0.1946	0.1229	2.0623
	4	3.1778	2.5352	0.2814	0.1770	2.8995
	3	14.0888	10.0743	0.5731	0.3713	4.9841
PuO_2	100/0/0/0	0.0169	-0.0003	-0.0009	-0.0005	0.1672
	95/5/0/0	0.0210	-0.0004	-0.0010	-0.0005	0.1870
	80/10/10/0	0.0244	-0.0004	-0.0010	-0.0005	0.1962
	90/10/0/0	0.0271	-0.0004	-0.0010	-0.0005	0.2077
	80/15/5/0	0.0332	-0.0004	-0.0010	-0.0006	0.2283
	71/17/11/1	0.0344	-0.0004	-0.0010	-0.0006	0.2354
PuNH	100/0/0/0	0.0168	-0.0337	-0.0454	-0.0662	0.1688
	95/5/0/0	0.0217	0.1293	0.0759	0.0319	0.1877
	80/10/10/0	0.0256	0.1661	0.0888	0.0235	0.1992
	90/10/0/0	0.0279	0.2038	0.1099	0.0552	0.2090
	80/15/5/0	0.0340	0.2590	0.1254	0.0539	0.2294
	71/17/11/1	0.0379	0.2715	0.1297	0.0674	0.2360

Table I28. BC - MCNP5 + ENDF/B-50 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with ENDF/B-50 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0099	-0.0470	-0.0555	-0.0343	0.0893
	20	0.0731	0.1406	0.0907	0.0591	0.4978
	5	0.6670	0.2037	0.0679	0.0338	2.5245
	4	1.0640	0.2715	0.1003	0.0436	3.3098
	3	1.8392	0.4411	0.0909	0.0514	4.7656
UNH	100	0.0100	0.0778	0.0686	0.0437	0.0904
	20	0.0874	0.2184	0.1070	0.0700	0.5130
	5	1.7672	1.3223	0.2091	0.1293	2.9634
	4	3.8725	2.6796	0.2984	0.1828	4.0954
	3	15.4898	9.8198	0.5592	0.3640	6.7557
PuO_2	100/0/0/0	0.0174	0.0394	0.1074	0.0581	0.1741
	95/5/0/0	0.0215	0.0407	0.1111	0.0604	0.1948
	80/10/10/0	0.0250	0.0444	0.1130	0.0636	0.2044
	90/10/0/0	0.0278	0.0447	0.1130	0.0631	0.2164
	80/15/5/0	0.0341	0.0468	0.1167	0.0642	0.2378
	71/17/11/1	0.0354	0.0487	0.1176	0.0657	0.2452
PuNH	100/0/0/0	0.0173	-0.0441	-0.0550	-0.0747	0.1758
	95/5/0/0	0.0223	0.1247	0.0724	0.0285	0.1955
	80/10/10/0	0.0263	0.1616	0.0854	0.0191	0.2075
	90/10/0/0	0.0287	0.1999	0.1072	0.0525	0.2176
	80/15/5/0	0.0349	0.2552	0.1228	0.0505	0.2389
	71/17/11/1	0.0389	0.2675	0.1272	0.0647	0.2458

Table I29. BC - MCNP5 + ENDF/B-5F (.55c for 239Pu)

Bias corrections (rvu**) for applications – MCNP 5 with ENDF/B-5F cross-sections (.55c for ^{239}Pu)						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0099	-0.0470	-0.0555	-0.0343	0.0893
	20	0.0731	0.1406	0.0907	0.0591	0.4978
	5	0.6670	0.2037	0.0679	0.0338	2.5245
	4	1.0640	0.2715	0.1003	0.0436	3.3098
	3	1.8392	0.4411	0.0909	0.0514	4.7656
UNH	100	0.0100	0.0778	0.0686	0.0437	0.0904
	20	0.0874	0.2184	0.1070	0.0700	0.5130
	5	1.7672	1.3223	0.2091	0.1293	2.9634
	4	3.8725	2.6796	0.2984	0.1828	4.0954
	3	15.4898	9.8198	0.5592	0.3640	6.7557
PuO_2	100/0/0/0	0.0159	0.0006	0.0015	0.0008	0.1695
	95/5/0/0	0.0197	0.0006	0.0016	0.0008	0.1896
	80/10/10/0	0.0229	0.0006	0.0016	0.0009	0.1989
	90/10/0/0	0.0254	0.0006	0.0016	0.0009	0.2107
	80/15/5/0	0.0312	0.0007	0.0016	0.0009	0.2314
	71/17/11/1	0.0324	0.0007	0.0017	0.0009	0.2386
PuNH	100/0/0/0	0.0158	-0.0806	-0.0860	-0.0969	0.1711
	95/5/0/0	0.0204	0.0793	0.0422	0.0080	0.1903
	80/10/10/0	0.0241	0.1092	0.0529	-0.0043	0.2020
	90/10/0/0	0.0262	0.1425	0.0740	0.0301	0.2118
	80/15/5/0	0.0319	0.1868	0.0869	0.0249	0.2325
	71/17/11/1	0.0356	0.1957	0.0903	0.0400	0.2392

Table I30. BC - MCNP5 + ENDF/B-62 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with ENDF/B-62 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	-0.0028	-0.0188	-0.0222	-0.0137	-0.0118
	20	-0.0209	-0.0402	-0.0259	-0.0169	-0.0655
	5	-0.4534	-0.5318	-0.1818	-0.1258	-0.7043
	4	-0.7705	-0.7418	-0.1959	-0.1443	-1.0107
	3	-1.7942	-1.3109	-0.2858	-0.1929	-1.7039
UNH	100	-0.0029	-0.0222	-0.0196	-0.0125	-0.0119
	20	-0.0250	-0.0624	-0.0306	-0.0200	-0.0675
	5	-1.2950	-1.7059	-0.2726	-0.1794	-0.9308
	4	-3.2541	-3.6706	-0.4049	-0.2673	-1.4952
	3	-18.8302	-16.7596	-0.9521	-0.6125	-3.3150
PuO_2	100/0/0/0	0.0027	-0.0102	-0.0278	-0.0150	0.0864
	95/5/0/0	0.0034	-0.0106	-0.0288	-0.0156	0.0968
	80/10/10/0	0.0041	-0.0115	-0.0293	-0.0165	0.1014
	90/10/0/0	0.0043	-0.0116	-0.0293	-0.0163	0.1077
	80/15/5/0	0.0053	-0.0121	-0.0302	-0.0166	0.1176
	71/17/11/1	0.0056	-0.0126	-0.0305	-0.0170	0.1213
PuNH	100/0/0/0	0.0027	-0.2388	-0.2144	-0.1762	0.0874
	95/5/0/0	0.0034	-0.1800	-0.1265	-0.0997	0.0970
	80/10/10/0	0.0042	-0.1966	-0.1313	-0.1222	0.1033
	90/10/0/0	0.0044	-0.2003	-0.1215	-0.0945	0.1077
	80/15/5/0	0.0053	-0.2274	-0.1268	-0.1140	0.1181
	71/17/11/1	0.0061	-0.2390	-0.1292	-0.1001	0.1218

Table I31. BC - MCNP5 + ENDF/B-66 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with ENDF/B-66 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0032	-0.0658	-0.0777	-0.0480	0.0306
	20	0.0235	0.0452	0.0292	0.0190	0.1703
	5	0.1522	-0.2125	-0.0738	-0.0600	1.2420
	4	0.2116	-0.3049	-0.0612	-0.0656	1.5708
	3	0.0614	-0.5650	-0.1268	-0.0923	2.0980
UNH	100	0.0032	0.0250	0.0221	0.0140	0.0309
	20	0.0281	0.0702	0.0344	0.0225	0.1755
	5	0.3414	-0.2297	-0.0382	-0.0308	1.3894
	4	0.4740	-0.6061	-0.0650	-0.0524	1.7827
	3	-1.9315	-4.3992	-0.2490	-0.1573	2.3820
PuO_2	100/0/0/0	0.0063	-0.0118	-0.0321	-0.0174	0.1028
	95/5/0/0	0.0077	-0.0122	-0.0332	-0.0181	0.1151
	80/10/10/0	0.0091	-0.0133	-0.0338	-0.0190	0.1206
	90/10/0/0	0.0100	-0.0134	-0.0338	-0.0189	0.1279
	80/15/5/0	0.0122	-0.0140	-0.0349	-0.0192	0.1401
	71/17/11/1	0.0128	-0.0146	-0.0352	-0.0196	0.1445
PuNH	100/0/0/0	0.0062	-0.1729	-0.1592	-0.1384	0.1039
	95/5/0/0	0.0080	-0.0902	-0.0673	-0.0603	0.1154
	80/10/10/0	0.0096	-0.0921	-0.0672	-0.0779	0.1227
	90/10/0/0	0.0102	-0.0849	-0.0550	-0.0506	0.1282
	80/15/5/0	0.0125	-0.0892	-0.0547	-0.0644	0.1408
	71/17/11/1	0.0140	-0.0939	-0.0552	-0.0514	0.1450

Table I32. BC - MCNP5 + ENDF/B-68 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with ENDF/B-68 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0014	-0.0564	-0.0666	-0.0411	0.0141
	20	0.0104	0.0201	0.0130	0.0084	0.0786
	5	0.0955	-0.2488	-0.0861	-0.0678	1.0762
	4	0.1189	-0.3549	-0.0759	-0.0748	1.3492
	3	-0.1212	-0.6513	-0.1453	-0.1043	1.7669
UNH	100	0.0014	0.0111	0.0098	0.0062	0.0143
	20	0.0125	0.0312	0.0153	0.0100	0.0810
	5	0.1866	-0.3811	-0.0623	-0.0462	1.1897
	4	0.1147	-0.9232	-0.1001	-0.0749	1.4966
	3	-3.6490	-5.7207	-0.3241	-0.2059	1.8692
PuO_2	100/0/0/0	0.0052	-0.0134	-0.0367	-0.0198	0.0977
	95/5/0/0	0.0064	-0.0139	-0.0379	-0.0206	0.1094
	80/10/10/0	0.0075	-0.0151	-0.0386	-0.0217	0.1146
	90/10/0/0	0.0082	-0.0153	-0.0386	-0.0215	0.1216
	80/15/5/0	0.0101	-0.0160	-0.0398	-0.0219	0.1331
	71/17/11/1	0.0106	-0.0166	-0.0401	-0.0224	0.1372
PuNH	100/0/0/0	0.0051	-0.1933	-0.1762	-0.1501	0.0987
	95/5/0/0	0.0066	-0.1180	-0.0856	-0.0725	0.1096
	80/10/10/0	0.0079	-0.1245	-0.0871	-0.0916	0.1166
	90/10/0/0	0.0084	-0.1207	-0.0756	-0.0642	0.1218
	80/15/5/0	0.0102	-0.1320	-0.0770	-0.0797	0.1337
	71/17/11/1	0.0116	-0.1389	-0.0782	-0.0665	0.1377

Table I33. BC - MCNP5 + ENDF/B-7P cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with ENDF/B-7P cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	-0.0039	-0.0282	-0.0333	-0.0206	-0.0400
	20	-0.0287	-0.0552	-0.0356	-0.0232	-0.2227
	5	-0.0338	-0.1540	-0.0530	-0.0393	0.2417
	4	-0.0712	-0.2173	-0.0517	-0.0441	0.2849
	3	-0.2919	-0.3917	-0.0864	-0.0603	0.3194
UNH	100	-0.0039	-0.0306	-0.0270	-0.0172	-0.0405
	20	-0.0343	-0.0858	-0.0420	-0.0275	-0.2295
	5	-0.1238	-0.3618	-0.0583	-0.0400	0.2457
	4	-0.4234	-0.8112	-0.0890	-0.0615	0.2632
	3	-3.8171	-4.1813	-0.2373	-0.1518	0.1242
PuO_2	100/0/0/0	0.0062	-0.0050	-0.0137	-0.0074	0.1007
	95/5/0/0	0.0077	-0.0052	-0.0142	-0.0077	0.1128
	80/10/10/0	0.0090	-0.0057	-0.0144	-0.0081	0.1182
	90/10/0/0	0.0099	-0.0057	-0.0144	-0.0080	0.1253
	80/15/5/0	0.0122	-0.0060	-0.0149	-0.0082	0.1373
	71/17/11/1	0.0127	-0.0062	-0.0150	-0.0084	0.1415
PuNH	100/0/0/0	0.0062	-0.1664	-0.1534	-0.1336	0.1018
	95/5/0/0	0.0080	-0.0850	-0.0637	-0.0575	0.1131
	80/10/10/0	0.0095	-0.0864	-0.0635	-0.0745	0.1202
	90/10/0/0	0.0102	-0.0790	-0.0515	-0.0479	0.1257
	80/15/5/0	0.0124	-0.0824	-0.0509	-0.0611	0.1379
	71/17/11/1	0.0139	-0.0868	-0.0514	-0.0485	0.1421

Table I34. BC - MCNP5 + JEF-2.2 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with JEF-2.2 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0018	-0.0470	-0.0555	-0.0343	0.0282
	20	0.0131	0.0251	0.0162	0.0106	0.1572
	5	0.2678	0.1450	0.0491	0.0301	0.8509
	4	0.4348	0.1986	0.0608	0.0359	1.1296
	3	0.8258	0.3397	0.0725	0.0460	1.6664
UNH	100	0.0018	0.0139	0.0123	0.0078	0.0286
	20	0.0156	0.0390	0.0191	0.0125	0.1620
	5	0.7246	0.6606	0.1049	0.0666	1.0155
	4	1.6547	1.3731	0.1523	0.0964	1.4370
	3	7.5534	5.5638	0.3165	0.2048	2.5069
PuO_2	100/0/0/0	0.0150	-0.0147	-0.0401	-0.0217	0.1364
	95/5/0/0	0.0186	-0.0152	-0.0415	-0.0226	0.1525
	80/10/10/0	0.0216	-0.0166	-0.0422	-0.0238	0.1601
	90/10/0/0	0.0240	-0.0167	-0.0422	-0.0236	0.1694
	80/15/5/0	0.0295	-0.0175	-0.0436	-0.0240	0.1863
	71/17/11/1	0.0305	-0.0182	-0.0439	-0.0245	0.1921
PuNH	100/0/0/0	0.0149	0.0169	0.0013	-0.0255	0.1376
	95/5/0/0	0.0193	0.1550	0.0952	0.0493	0.1531
	80/10/10/0	0.0227	0.1922	0.1080	0.0462	0.1625
	90/10/0/0	0.0248	0.2276	0.1254	0.0697	0.1705
	80/15/5/0	0.0302	0.2838	0.1407	0.0725	0.1872
	71/17/11/1	0.0336	0.2976	0.1452	0.0820	0.1925

Table I35. BC - MCNP5 + JEFF-3.0 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with JEFF-3.0 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0018	-0.0564	-0.0666	-0.0411	0.0259
	20	0.0131	0.0251	0.0162	0.0106	0.1441
	5	0.1381	-0.1220	-0.0426	-0.0359	0.9450
	4	0.2005	-0.1765	-0.0325	-0.0389	1.2025
	3	0.1536	-0.3308	-0.0747	-0.0553	1.6276
UNH	100	0.0018	0.0139	0.0123	0.0078	0.0262
	20	0.0156	0.0390	0.0191	0.0125	0.1485
	5	0.3267	-0.0633	-0.0112	-0.0114	1.0659
	4	0.5420	-0.2174	-0.0226	-0.0219	1.3858
	3	-0.2594	-2.1778	-0.1230	-0.0771	1.9317
PuO_2	100/0/0/0	0.0089	-0.0109	-0.0298	-0.0161	0.1063
	95/5/0/0	0.0110	-0.0113	-0.0308	-0.0168	0.1189
	80/10/10/0	0.0129	-0.0123	-0.0314	-0.0177	0.1247
	90/10/0/0	0.0142	-0.0124	-0.0314	-0.0175	0.1321
	80/15/5/0	0.0175	-0.0130	-0.0324	-0.0178	0.1450
	71/17/11/1	0.0182	-0.0135	-0.0326	-0.0182	0.1495
PuNH	100/0/0/0	0.0089	-0.0890	-0.0871	-0.0854	0.1073
	95/5/0/0	0.0114	0.0069	-0.0023	-0.0152	0.1193
	80/10/10/0	0.0135	0.0194	0.0024	-0.0260	0.1267
	90/10/0/0	0.0147	0.0363	0.0154	-0.0024	0.1327
	80/15/5/0	0.0179	0.0544	0.0212	-0.0090	0.1457
	71/17/11/1	0.0200	0.0569	0.0226	0.0017	0.1499

Table I36. BC - MCNP5 + JENDL-3.2 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with JENDL-3.2 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0185	0.0376	0.0444	0.0274	0.1434
	20	0.1357	0.2610	0.1685	0.1097	0.7991
	5	1.5705	0.8993	0.3046	0.1893	4.8652
	4	2.5558	1.2336	0.3725	0.2249	6.4718
	3	4.9110	2.1172	0.4530	0.2894	9.5835
UNH	100	0.0186	0.1446	0.1274	0.0811	0.1452
	20	0.1622	0.4056	0.1986	0.1300	0.8235
	5	4.2612	3.9745	0.6316	0.4021	5.8220
	4	9.7817	8.2822	0.9182	0.5831	8.2687
	3	45.3284	33.8797	1.9268	1.2464	14.5452
PuO_2	100/0/0/0	0.0145	-0.0110	-0.0300	-0.0162	0.1566
	95/5/0/0	0.0180	-0.0114	-0.0311	-0.0169	0.1752
	80/10/10/0	0.0209	-0.0124	-0.0316	-0.0178	0.1838
	90/10/0/0	0.0232	-0.0125	-0.0316	-0.0176	0.1946
	80/15/5/0	0.0285	-0.0131	-0.0326	-0.0179	0.2137
	71/17/11/1	0.0296	-0.0136	-0.0329	-0.0184	0.2204
PuNH	100/0/0/0	0.0144	-0.0804	-0.0846	-0.0934	0.1581
	95/5/0/0	0.0186	0.0667	0.0345	0.0042	0.1758
	80/10/10/0	0.0220	0.0933	0.0441	-0.0076	0.1867
	90/10/0/0	0.0239	0.1234	0.0636	0.0246	0.1956
	80/15/5/0	0.0291	0.1629	0.0752	0.0192	0.2148
	71/17/11/1	0.0325	0.1706	0.0782	0.0333	0.2210

Table I37. BC - MCNP5 + JENDL-3.3 cross-sections

Bias corrections (reference value units) for applications – MCNP 5 with JENDL-3.3 cross-sections						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0.0053	0.0752	0.0888	0.0548	0.0400
	20	0.0392	0.0753	0.0486	0.0317	0.2227
	5	0.4955	0.1723	0.0577	0.0306	1.8214
	4	0.7929	0.2313	0.0813	0.0385	2.3926
	3	1.3952	0.3815	0.0794	0.0466	3.4582
UNH	100	0.0054	0.0417	0.0368	0.0234	0.0405
	20	0.0468	0.1170	0.0573	0.0375	0.2295
	5	1.3177	1.0252	0.1623	0.1009	2.1436
	4	2.9097	2.0890	0.2324	0.1434	2.9735
	3	11.9483	7.8314	0.4458	0.2898	4.9503
PuO_2	100/0/0/0	0.0144	-0.0082	-0.0223	-0.0120	0.1445
	95/5/0/0	0.0179	-0.0084	-0.0230	-0.0125	0.1616
	80/10/10/0	0.0208	-0.0092	-0.0234	-0.0132	0.1696
	90/10/0/0	0.0231	-0.0093	-0.0234	-0.0131	0.1795
	80/15/5/0	0.0284	-0.0097	-0.0242	-0.0133	0.1973
	71/17/11/1	0.0294	-0.0101	-0.0244	-0.0136	0.2035
PuNH	100/0/0/0	0.0144	-0.0358	-0.0449	-0.0615	0.1459
	95/5/0/0	0.0185	0.1044	0.0606	0.0241	0.1622
	80/10/10/0	0.0218	0.1351	0.0715	0.0163	0.1722
	90/10/0/0	0.0238	0.1670	0.0896	0.0440	0.1806
	80/15/5/0	0.0290	0.2131	0.1026	0.0424	0.1982
	71/17/11/1	0.0323	0.2233	0.1062	0.0542	0.2039

Table I38. BC: IPPE-ABBN93 (ABBN-93)

Bias corrections (reference value units) for applications – ABBN-93						
Material	Isotopes	Mass (kg)	Volume (l)	Cylinder (cm)	Slab (cm)	Conc. (g/l)
UO_2	100	0,0036	0,0376	0,0444	0,0274	0,0588
	20	0,0261	0,0502	0,0324	0,0211	0,3275
	5	0,1279	0,2620	0,0899	0,0648	-0,0896
	4	0,2313	0,3677	0,0916	0,0733	-0,0648
	3	0,6605	0,6574	0,1444	0,0994	0,0426
UNH	100	0,0036	0,0278	0,0245	0,0156	0,0595
	20	0,0312	0,0780	0,0382	0,0250	0,3375
	5	0,3924	0,7105	0,1141	0,0767	-0,0435
	4	1,0940	1,5614	0,1718	0,1161	0,0572
	3	7,6756	7,5994	0,4314	0,2768	0,5694
PuO_2	100/0/0/0	-0,0057	-0,0009	-0,0023	-0,0013	0,0189
	95/5/0/0	-0.0071	-0.0009	-0.0024	-0,0013	0,0208
	80/10/10/0	-0.0081	-0.0010	-0.0024	-0.0014	0,0222
	90/10/0/0	-0.0093	-0.0010	-0.0024	-0.0014	0,0225
	80/15/5/0	-0.0114	-0.0010	-0.0025	-0.0014	0,0248
	71/17/11/1	-0.0116	-0.0011	-0.0025	-0.0014	0,0260
PuNH	100/0/0/0	-0.0057	-0,2830	-0.2459	-0.1864	0,0188
	95/5/0/0	-0.0074	-0.2971	-0.2006	-0.1431	0,0206
	80/10/10/0	-0.0085	-0.3380	-0.2137	-0.1669	0,0225
	90/10/0/0	-0.0096	-0.3630	-0.2128	-0.1490	0,0227
	80/15/5/0	-0.0117	-0.4270	-0.2279	-0.1730	0,0250
	71/17/11/1	-0.0127	-0.4484	-0.2333	-0.1628	0,0260