Testing and QA of Nuclear Data for the NCSP

R. D. McKnight
R. M. Lell
D. M. Smith
D. W. Muir

Nuclear Engineering Division
Argonne National Laboratory

DOE NCSP Technical Seminar
March 1-2, 2011
Oak Ridge National Laboratory

Overview

- Principal Nuclear Data Activities supported at Argonne include:
  - **NCSP Data Testing and Validation**
  - **Support Development of Advanced Nuclear Data Covariance Methodologies**
  - Support the C_EdT Process
  - Chair Nuclear Data Advisory Group (NDAG)
  - Represent NCSP on various U.S. and International Working Groups and Expert Groups (including CSEWG, WPNCS, WPEC, UACSA, ADSNF)

This presentation will only summarize activities in the first two of the above activities.

NCSP Data Testing and Validation

- **Priority** to provide timely Testing and Reporting of Performance of new NCSP-supported Nuclear Data Evaluations
  - All NCSP-supported Data Evaluations are delivered to BNL when completed
  - These preliminary ENDF/B files are processed by BNL with checking codes and posted to the NNDC web site as ENDF/A files
  - ANL processes these new files into libraries; determines the appropriate integral benchmarks to test the files; performs data testing calculations; and reports results (performance) to CSEWG and evaluators

Testing results from FY10 and Nov FY11 will be summarized.

CSEWG 2009 Annual Meeting - Nov. 3-5, 2009

- **Performance of ENDF/A Evaluations for ^{240}Pu, Cl and W**
  - ^{240}Pu tested in Fast and Thermal Systems
    - C/E's reduced slightly in Fast Systems (see Slide 5)
      - Generally a slight improvement, except for Jezebel & Dirty Jezebel
      - Results for virtually all systems are within experimental uncertainties
    - C/E's generally increased slightly in Thermal Systems (see Slides 6&7)
      - These k_{eff}'s are overpredicted with ENDF/B-VII.0 and this overprediction increases with increasing Pu concentration for the PST-18 and PST-12 criticals
      - This overprediction is aggravated slightly (by ~0-100 pcm)
  - ^{35,37}Cl tested in Thermal Systems
    - "Best" systems to test Cl (HST-044 series) are unsuitable for data validation because of their large uncertainties (± 500-1000 pcm)
    - Nevertheless, the effect of the new Cl evaluation demonstrated to be very small (<10 pcm)
  - W tested using high-fidelity "as-built" models of ZPR-9 Assemblies 1-9
    - Results with new IAEA evaluation (available in ENDF/A) are a noticeable improvement, though not all discrepancies are eliminated

Performance in Fast Systems containing ^{240}Pu

	ENDF/B-VII.0 with ENDF/A ^{240}Pu	Benchmark k_{eff}	$k_{eff} \pm 1\sigma$	C/E ± 1σ
PU-MET-FAST-001	Jezebel	1.00000 ± 0.00340	0.99999 ± 0.00002	0.99999 ± 0.00200
			0.99986 ± 0.00002	0.99986 ± 0.00200
PU-MET-FAST-002	Jezebel-240	1.00000 ± 0.00200	0.99990 ± 0.00002	0.99990 ± 0.00200
			0.99962 ± 0.00002	0.99962 ± 0.00200
MIX-COMP-FAST-001	ZPR-6/7	1.00051 ± 0.00087	1.00150 ± 0.00005	1.00099 ± 0.00087
			1.00068 ± 0.00005	1.00017 ± 0.00087
MIX-COMP-FAST-002	ZPR-6/7 H240	1.0008 ± 0.00090	1.00028 ± 0.00005	0.99948 ± 0.00090
			0.99919 ± 0.00005	0.99839 ± 0.00090
ZPPR-LMFR-EXP-001	ZPPR-10A L07	1.00096 ± 0.00038	1.00103 ± 0.00005	1.00021 ± 0.00038
			1.00021 ± 0.00005	1.00103 ± 0.00038
MIX-COMP-FAST-003-1	ZPR-3/48	1.0013 ± 0.0007	1.00194 ± 0.00007	1.00064 ± 0.0007
			1.00139 ± 0.00007	1.00009 ± 0.0007
MIX-COMP-FAST-003-2	ZPR-3/48B	1.0017 ± 0.0007	1.00184 ± 0.00006	1.00014 ± 0.0007
			1.00137 ± 0.00006	0.99967 ± 0.0007
MIX-MISC-MIXED-001	BFS-97-4	1.00110 ± 0.00270	1.00229 ± 0.00007	1.00119± 0.00270
			1.00207 ± 0.00010	1.00097± 0.00270

Performance in Thermal Systems containing ^{240}Pu

PU-SOL-THERM-018 Case	Pu Conc., gm/ℓ	Benchmark k_{eff}	$k_{eff} \pm 1\sigma$ (ENDF/B-VII.0)	C/E ± 1σ (ENDF/B-VII.0)
1	140.00	1.00000 ± 0.00340	1.00925 ± 0.00009	1.00925 ± 0.00343
			1.01034 ± 0.00009 (with ENDF/A ^{240}Pu)	1.01034 ± 0.00344 (with ENDF/A ^{240}Pu)
2	116.00	1.00000 ± 0.00340	1.01260 ± 0.00009	1.01260 ± 0.00344
			1.01336 ± 0.00009 (with ENDF/A ^{240}Pu)	1.01336 ± 0.00345 (with ENDF/A ^{240}Pu)
3	99.26	1.00000 ± 0.00320	1.01058± 0.00008	1.01058 ± 0.00323
			1.01134 ± 0.00009 (with ENDF/A ^{240}Pu)	1.01134 ± 0.00324 (with ENDF/A ^{240}Pu)
4	85.53	1.00000 ± 0.00300	1.00875± 0.00008	1.00875 ± 0.00303
			1.00911 ± 0.00008 (with ENDF/A ^{240}Pu)	1.00911 ± 0.00303 (with ENDF/A ^{240}Pu)
5	75.64	1.00000 ± 0.00300	1.00767± 0.00008	1.00767 ± 0.00303
			1.00813 ± 0.00008 (with ENDF/A ^{240}Pu)	1.00813 ± 0.00303 (with ENDF/A ^{240}Pu)
6	65.12	1.00000 ± 0.00310	1.00571± 0.00008	1.00571 ± 0.00313
			1.00608 ± 0.00008 (with ENDF/A ^{240}Pu)	1.00608 ± 0.00313 (with ENDF/A ^{240}Pu)
7	56.34	1.00000 ± 0.00320	1.00501± 0.00008	1.00501 ± 0.00323
			1.00518 ± 0.00008 (with ENDF/A ^{240}Pu)	1.00518 ± 0.00323 (with ENDF/A ^{240}Pu)
8	46.83	1.00000 ± 0.00330	1.00463± 0.00008	1.00463 ± 0.00334
			1.00486 ± 0.00008 (with ENDF/A ^{240}Pu)	1.00486 ± 0.00334 (with ENDF/A ^{240}Pu)
9	40.58	1.00000 ± 0.00340	1.00291± 0.00007	1.00291 ± 0.00343
			1.00305 ± 0.00007 (with ENDF/A ^{240}Pu)	1.00305 ± 0.00344 (with ENDF/A ^{240}Pu)

Performance in Thermal Systems containing ^{240}Pu (Continued)

PU-SOL-THERM-012 Case	Pu Conc., gm/ℓ	Benchmark k_{eff}	ENDF/B-VII.0 $k_{eff} \pm 1\sigma$	ENDF/B-VII.0 C/E ± 1σ
6	105.00	1.00000 ± 0.00070	1.00833 ± 0.00009	1.00833 ± 0.00071
			1.00861 ± 0.00009	1.00861 ± 0.00071
17	21.70	1.00000 ± 0.00430	1.00669 ± 0.00007	1.00669 ± 0.00433
			1.00663 ± 0.00007	1.00663 ± 0.00433

ENDF/B-VII.0
with ENDF/A ^{240}Pu

Summer 2010 mini-CSEWG Meeting - June 22, 2010

- **Benchmark Comparisons with ENDF/A ^{52,53}Cr in Fast and Intermediate Systems**

		Exp (BM or AB)			ENDF/B-V				ENDF/B-VI.8			
		k-eff	±	σ	k-eff	±	σ	C/E	k-eff	±	σ	C/E
PMI-002	ZPR-6/10 AB	1.00160	±	0.00130	0.9862	±	0.0005	0.985	1.0222	±	0.0006	1.021
HCI-005	CR - KBR-15	1.06400	±	0.01800	0.9020	±	0.0004	0.848	1.1636	±	0.0004	1.094
HCI-005	SS - KBR-9	1.05000	±	0.00800	1.0344	±	0.0004	0.985	1.1121	±	0.0004	1.059
MCF-001	ZPR-6/7 AB	1.00050	±	0.00090	0.9792	±	0.0004	0.979	0.9891	±	0.0005	0.989
ZPPR-10A	L07 - AB	1.00096	±	0.00038					1.0069	±	0.0001	1.006

		Exp (BM or AB)			ENDF/B-VII.0				Cr-52,-53 ENDF/A			
		k-eff	±	σ	k-eff	±	σ	C/E	k-eff	±	σ	C/E
PMI-002	ZPR-6/10 AB	1.00160	±	0.00130	1.03971	±	0.00022	1.03805	1.03378	±	0.00023	1.03213
HCI-005	CR - KBR-15	1.06400	±	0.01800	1.14605	±	0.00012	1.07711	1.17023	±	0.00013	1.09984
HCI-005	SS - KBR-9	1.05000	±	0.00800	1.09779	±	0.00012	1.04551	1.10490	±	0.00012	1.05229
MCF-001	ZPR-6/7 AB	1.00050	±	0.00090	1.00187	±	0.00016	1.00137	1.00141	±	0.00017	1.00091
ZPPR-10A	L07 - AB	1.00096	±	0.00038	1.00117	±	0.00015	1.00021	1.00137	±	0.00015	1.00041

- These systems have a very high sensitivity to Cr
  - For the "k-infinity" assemblies, results degrade
  - For the "reactor" critical assemblies, results are improved
- The new data are an improvement, but we have more to learn from these experiments

CSEWG 2010 Annual Meeting – Nov. 1-3, 2010

- **Argonne Data Testing of New Evaluations for ENDF/B**
  - Revised evaluations were downloaded about 3 weeks ago from NNDC for:
    - ^{239}Pu
    - ^{240}Pu
    - ^{55}Mn
    - $^{52,53}Cr$
    - $^{58,60}Ni$
    - Minor Cr and Ni isotopes were not tested
  - A set of benchmarks were selected which might test ^{240}Pu and the structural materials

Most discrepant benchmark analysis with ENDF/B-VII.0 ZPR-6/10 (A clean Pu/C/SST assembly)

PU-MET-INTER-002	Pu/C/Steel core – Steel reflector, Iron radial reflector – 6.25 v/o Pu / 37.5 v/o C / 56.25 v/o steel unit cell

	k_{eff}	C – E (in % Δk)
Experiment	1.0016 ± 0.0013	
ENDF/B-V	1.0009 ± 0.0007	-0.07 ± 0.15
ENDF/B-VI	1.0380 ± 0.0005	3.64 ± 0.14
ENDF/B-VII.0	1.0392 ± 0.0003	3.76 ± 0.13

- Note that there was NO bias with ENDF/B-V data.
- Using ENDF/B-VII.0 data with ENDF/B-V data for ^{239}Pu : reduces C/E by 1.1% Δk
- Using ENDF/B-VII.0 data with ENDF/B-V data for Cr : reduces C/E by 1.7% Δk
- Using ENDF/B-VII.0 data with ENDF/B-V data for Mn : reduces C/E by 0.6% Δk
- Using ENDF/B-VII.0 data with new ORNL data for Mn : reduces C/E by 0.6% Δk

Benchmarks with High Sensitivity to Structural Materials

Benchmark	Description	BM/AB k-eff	AVGE (MeV)	EALF (MeV)	Fission Distribution, % Therm	Inter	Fast	Capture Cr	Mn	Ni	Leakage	Prod
PMI-002	ZPR-6/10: Pu/C/Steel core – Steel reflector, Iron radial reflector – 6.25 v/o Pu / 37.5 v/o C / 56.25 v/o steel unit cell	1.00160	4.05E-01	1.09E-02	0.15	62.33	37.52	80.81	72.1	54.19	46.12	1019.7
HCI-005-2	KBR-9: K-infinity Experiments in Intermediate Neutron Spectra for Various Structural Materials (SST)	1.05000	1.22E-01	3.21E-03	0.03	79.33	20.64	74.39	50.41	65.43	34.61	1028.94
HCI-005-3	KBR-10: K-infinity Experiments in Intermediate Neutron Spectra for Various Structural Materials (SST / Mo)	1.03000	1.46E-01	6.37E-03	0.01	75.23	24.76	59.88	37.08	55.38	33.265	993.04
HCI-005-4	KBR-15: K-infinity Experiments in Intermediate Neutron Spectra for Various Structural Materials (Cr)	1.06400	1.09E-01	3.33E-03	0	83.3	16.7	270.94	7.08	8.16	176.46	916.19
ZPPR-LMFR-EXP-001	ZPPR-10A: A 650 MWe-Class Sodium-Cooled MOX-Fueled FBR EMC Assembly L07 JUPITER-I	1.00110	8.51E-01	1.13E-01	0	41.63	58.37					
MMF-008-3	ZEBRA 8C/2: K-infinity Experiments in Fast/Intermediate Neutron Spectra for Various Fissile Materials	0.98600	6.77E-01	7.09E-02	0	46.54	53.46	23.24	10.28	23.11	0.32	975.58

Benchmarks with High Sensitivity to Structural Materials (Cont.)

Benchmark	Description	BM/AB k-eff	AVGE (MeV)	EALF (MeV)	Fission Distribution, % Therm	Inter	Fast	Capture Cr	Mn	Ni	Leakage	Prod
HCT-022-1	SPERT III Stainless-Steel-Clad Plate-Type Fuel in Water -- Case 1	1.00000	1.65E-02	9.40E-08	88.97	10.05	0.98	32.46	7.47	21.75	22.25	988.1
HCT-014-1	Experiments with Square-Pitched Lattices of Highly Enriched (~80% U235) Stainless-Steel Clad Fuel Rods -- Case 1	0.99860	2.55E-02	1.16E-07	87.96	10.57	1.47	36.85	9.09	26.43	97.64	998.76
HCT-014-2	Experiments with Square-Pitched Lattices of Highly Enriched (~80% U235) Stainless-Steel-Clad Fuel Rods -- Case 2	0.99860	2.23E-02	9.65E-08	89.84	8.89	1.27	34.54	8.33	24.74	81.23	998.53
HCT-011-1	Experiments with Square-Pitched Lattices of Highly Enriched (~80% U235) Stainless-Steel-Clad Fuel Rods -- Case 1	0.99880	5.16E-02	6.94E-07	68.46	28.1	3.44	33.6	9.35	25.1	67.38	998.66
HCT-011-2	Experiments with Square-Pitched Lattices of Highly Enriched (~80% U235) Stainless-Steel-Clad Fuel Rods -- Case 2	0.99880	4.91E-02	5.35E-07	71.5	25.25	3.25	34.7	9.44	25.79	80.08	998.77
HCT-011-3	Experiments with Square-Pitched Lattices of Highly Enriched (~80% U235) Stainless-Steel-Clad Fuel Rods -- Case 3	0.99880	4.59E-02	4.20E-07	74.18	22.83	2.99	33.96	9.08	25.19	72.75	998.26

Testing new ^{239}Pu Evaluation with THERM Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{239}Pu k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PST-001-1	1	1.00551	±	0.00029	1.00549	±	0.00028	1.00000	±	0.00500	-0.00002	±	0.00040
PST-001-2	2	1.00781	±	0.00029	1.00743	±	0.00030	1.00000	±	0.00500	-0.00038	±	0.00042
PST-001-3	3	1.01070	±	0.00029	1.01033	±	0.00029	1.00000	±	0.00500	-0.00037	±	0.00041
PST-001-4	4	1.00479	±	0.00029	1.00449	±	0.00028	1.00000	±	0.00500	-0.00030	±	0.00040
PST-001-5	5	1.00852	±	0.00029	1.00850	±	0.00028	1.00000	±	0.00500	-0.00002	±	0.00040
PST-001-6	6	1.00966	±	0.00030	1.00965	±	0.00029	1.00000	±	0.00500	-0.00001	±	0.00042
PST-002-1	1	1.00428	±	0.00027	1.00422	±	0.00028	1.00000	±	0.00470	-0.00006	±	0.00039
PST-002-3	3	1.00414	±	0.00027	1.00357	±	0.00027	1.00000	±	0.00470	-0.00057	±	0.00038
PST-002-5	5	1.00893	±	0.00028	1.00997	±	0.00028	1.00000	±	0.00470	0.00104	±	0.00040
PST-002-6	6	1.00525	±	0.00028	1.00557	±	0.00029	1.00000	±	0.00470	0.00032	±	0.00040
PST-002-7	7	1.00791	±	0.00028	1.00781	±	0.00028	1.00000	±	0.00470	-0.00010	±	0.00040
PST-003-1	1	1.00272	±	0.00025	1.00262	±	0.00025	1.00000	±	0.00470	-0.00010	±	0.00035
PST-003-4	4	1.00444	±	0.00025	1.00485	±	0.00026	1.00000	±	0.00470	0.00041	±	0.00036
PST-003-6	6	1.00613	±	0.00026	1.00589	±	0.00027	1.00000	±	0.00470	-0.00024	±	0.00037
PST-004-1	1	1.00392	±	0.00025	1.00410	±	0.00024	1.00000	±	0.00470	0.00018	±	0.00035
PST-004-6	6	1.00148	±	0.00025	1.00139	±	0.00026	1.00000	±	0.00470	-0.00009	±	0.00036
PST-004-9	9	1.00019	±	0.00026	1.00050	±	0.00026	1.00000	±	0.00470	0.00031	±	0.00037
PST-004-10	10	1.00157	±	0.00026	1.00194	±	0.00025	1.00000	±	0.00470	0.00037	±	0.00036
PST-004-11	11	1.00050	±	0.00026	1.00118	±	0.00026	1.00000	±	0.00470	0.00068	±	0.00037
PST-006-1	1	1.00031	±	0.00023	1.00026	±	0.00024	1.00000	±	0.00350	-0.00005	±	0.00033
PST-007-2	2	1.00933	±	0.00030	1.00926	±	0.00028	1.00000	±	0.00470	-0.00007	±	0.00041
PST-007-3	3	1.00315	±	0.00029	1.00362	±	0.00030	1.00000	±	0.00470	0.00047	±	0.00042
PST-007-7	7	1.00543	±	0.00030	1.00517	±	0.00028	1.00000	±	0.00470	-0.00026	±	0.00041
PST-007-10	10	1.00012	±	0.00029	1.00064	±	0.00028	1.00000	±	0.00470	0.00052	±	0.00040
PST-009-3	3	1.01902	±	0.00012	1.01911	±	0.00012	1.00000	±	0.00330	0.00009	±	0.00017
PST-011-16	16	1.01692	±	0.00029	1.01672	±	0.00029	1.00000	±	0.00520	-0.00020	±	0.00041
PST-011-18	18	0.99951	±	0.00026	0.99950	±	0.00026	1.00000	±	0.00520	-0.00001	±	0.00037

Testing new ^{239}Pu Evaluation with INTER & FAST Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{239}Pu k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PCI-001		1.01153	±	0.00017	1.01189	±	0.00017	1.00000	±	0.01100	0.00036	±	0.00024
PMI-002		1.02693	±	0.00024	1.02711	±	0.00024	0.98690	±	0.00260	0.00018	±	0.00034
MMF-001		0.99965	±	0.00018	0.99934	±	0.00019	1.00000	±	0.00160	-0.00031	±	0.00026
MMF-002-1	1	1.00544	±	0.00022	1.00484	±	0.00021	1.00000	±	0.00420	-0.00060	±	0.00030
MMF-002-2	2	1.00547	±	0.00021	1.00542	±	0.00022	1.00000	±	0.00440	-0.00005	±	0.00030
MMF-002-3	3	1.00586	±	0.00022	1.00555	±	0.00021	1.00000	±	0.00480	-0.00031	±	0.00030
PMF-001		0.99981	±	0.00018	1.00015	±	0.00019	1.00000	±	0.00200	0.00034	±	0.00026
PMF-005		1.00954	±	0.00020	1.00948	±	0.00020	1.00000	±	0.00130	-0.00006	±	0.00028
PMF-006		1.00076	±	0.00022	1.00099	±	0.00022	1.00000	±	0.00300	0.00023	±	0.00031
PMF-009		1.00469	±	0.00020	1.00464	±	0.00020	1.00000	±	0.00270	-0.00005	±	0.00028
PMF-010		0.99948	±	0.00020	0.99957	±	0.00020	1.00000	±	0.00180	0.00009	±	0.00028
PMF-011		1.00008	±	0.00023	1.00039	±	0.00024	1.00000	±	0.00100	0.00031	±	0.00033
PMF-018		0.99620	±	0.00021	0.99645	±	0.00020	1.00000	±	0.00300	0.00025	±	0.00029
PMF-022		0.99839	±	0.00019	0.99837	±	0.00019	1.00000	±	0.00140	-0.00002	±	0.00027
PMF-023		0.99976	±	0.00019	0.99978	±	0.00019	1.00000	±	0.00200	0.00002	±	0.00027
PMF-024		1.00159	±	0.00021	1.00155	±	0.00020	1.00000	±	0.00200	-0.00004	±	0.00029
PMF-025		0.99904	±	0.00020	0.99910	±	0.00019	1.00000	±	0.00200	0.00006	±	0.00028
PMF026		0.99841	±	0.00020	0.99857	±	0.00020	1.00000	±	0.00240	0.00016	±	0.00028
PMF-027		1.00307	±	0.00025	1.00282	±	0.00024	1.00000	±	0.00220	-0.00025	±	0.00035
PMF-028		0.99919	±	0.00021	0.99924	±	0.00020	1.00000	±	0.00220	0.00005	±	0.00029
PMF-029		0.99528	±	0.00018	0.99502	±	0.00019	1.00000	±	0.00200	-0.00026	±	0.00026
PMF-030		1.00265	±	0.00020	1.00312	±	0.00019	1.00000	±	0.00210	0.00047	±	0.00028
PMF-031		1.00434	±	0.00023	1.00446	±	0.00024	1.00000	±	0.00210	0.00012	±	0.00033
PMF-032		0.99850	±	0.00019	0.99891	±	0.00019	1.00000	±	0.00200	0.00041	±	0.00027

Testing new ^{240}Pu Evaluation with INTER & FAST Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{240}Pu k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PST-018-1	1	1.00925	±	0.00009	1.01561	±	0.00028	1.00000	±	0.00340	0.00636	±	0.00029
PST-018-2	2	1.01260	±	0.00009	1.01828	±	0.00029	1.00000	±	0.00340	0.00568	±	0.00030
PST-018-3	3	1.01058	±	0.00008	1.01596	±	0.00027	1.00000	±	0.00320	0.00538	±	0.00028
PST-018-4	4	1.00875	±	0.00008	1.01422	±	0.00028	1.00000	±	0.00300	0.00547	±	0.00029
PST-018-5	5	1.00767	±	0.00008	1.01293	±	0.00025	1.00000	±	0.00300	0.00526	±	0.00026
PST-018-6	6	1.00571	±	0.00008	1.01075	±	0.00026	1.00000	±	0.00310	0.00504	±	0.00027
PST-018-7	7	1.00501	±	0.00008	1.01024	±	0.00024	1.00000	±	0.00320	0.00523	±	0.00025
PST-018-8	8	1.00463	±	0.00008	1.00901	±	0.00023	1.00000	±	0.00330	0.00438	±	0.00024
PST-018-9	9	1.00291	±	0.00007	1.00739	±	0.00022	1.00000	±	0.00340	0.00448	±	0.00023
PST-012-6	6	1.00833	±	0.00009	1.01085	±	0.00029	1.00000	±	0.00070	0.00252	±	0.00030
PST-012-17	17	1.00669	±	0.00007	1.00765	±	0.00021	1.00000	±	0.00430	0.00096	±	0.00022
PMF-001		0.99989	±	0.00002	0.99995	±	0.00003	1.00000	±	0.00200	0.00006	±	0.00004
PMF-002		0.99990	±	0.00002	0.99996	±	0.00003	1.00000	±	0.00200	0.00006	±	0.00004
MCF-001		1.00150	±	0.00005	1.00134	±	0.00017	1.00051	±	0.00087	-0.00016	±	0.00018
MCF-002		1.00028	±	0.00005	1.00016	±	0.00015	1.00080	±	0.00090	-0.00012	±	0.00016
MCF-003-2	2	1.00184	±	0.00006	1.00198	±	0.00018	1.00170	±	0.00070	0.00014	±	0.00019
BFS-97-4		1.00229	±	0.00010	1.00341	±	0.00015	1.00110	±	0.00270	0.00112	±	0.00018

- Generally increases the over-prediction of the THERM systems
- No effect in the FAST systems

Testing new ^{55}Mn Evaluation with INTER & THERM Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{55}Mn k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PMI-002	ZPR-6/10 - AB	1.03955	±	0.00024	1.03332	±	0.00023	1.00160	±	0.00130	0.00623	±	0.00033
HCI-005-2	KBR-9 - SS	1.09779	±	0.00012	1.08698	±	0.00012	1.05000	±	0.00800	0.01081	±	0.00017
HCI-005-3	KBR-10 - SS/MO	1.04860	±	0.00012	1.04139	±	0.00012	1.03000	±	0.00600	0.00721	±	0.00017
HCT-022-1	Case 1	0.99494	±	0.00025	0.99509	±	0.00025	1.00000	±	0.00810	-0.00015	±	0.00035

- **Very nice reduction in the over-prediction of the FAST systems while retaining good agreement in the THERM system**

Testing new ^{52,53}Cr Evaluation with THERM, INTER & FAST Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{52,53}Cr k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PMI-002	ZPR-6/10 - AB	1.03955	±	0.00024	1.03386	±	0.00024	1.00160	±	0.00130	0.00569	±	0.00034
HCI-005-2	KBR-9 - SS	1.09779	±	0.00012	1.10493	±	0.00012	1.05000	±	0.00800	-0.00714	±	0.00017
HCI-005-3	KBR-10 - SS/MO	1.04860	±	0.00012	1.05544	±	0.00012	1.03000	±	0.00600	-0.00684	±	0.00017
HCI-005-4	KBR-15 - CR	1.14605	±	0.00012	1.17054	±	0.00012	1.06400	±	0.01800	-0.02449	±	0.00017
ZPPR-10A	L07 - AB	1.00117	±	0.00015				1.00110	±	0.00150			
MMF-008-3	ZEBRA 8C/2 - C. 3	0.99075	±	0.00014	0.99300	±	0.00014	0.98600	±	0.00440	-0.00225	±	0.00020
HCT-022-1	Case 1	0.99494	±	0.00025	0.99345	±	0.00023	1.00000	±	0.00810	0.00149	±	0.00034
HCT-014-1	Case 1	0.99863	±	0.00024	0.99670	±	0.00024	0.99860	±	0.00480	0.00193	±	0.00034
HCT-014-2	Case 2	0.99854	±	0.00024	0.99734	±	0.00022	0.99860	±	0.00490	0.00120	±	0.00033
HCT-011-1	Case 1	0.98970	±	0.00027	0.98689	±	0.00023	0.99880	±	0.00420	0.00281	±	0.00035
HCT-011-2	Case 2	0.99179	±	0.00025	0.98924	±	0.00024	0.99880	±	0.00420	0.00255	±	0.00035
HCT-011-3	Case 3	0.99327	±	0.00024	0.99051	±	0.00025	0.99880	±	0.00420	0.00276	±	0.00035

- **Increased the under-prediction of the THERM systems and mixed performance in the INTER and FAST systems**

Testing new ^{58,60}Ni Evaluation with THERM, INTER & FAST Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{58,60}Ni k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PMI-002	ZPR-6/10 - AB	1.03955	±	0.00024	1.03990	±	0.00025	1.00160	±	0.00130	-0.00035	±	0.00035
HCI-005-1	KBR-7 - NI	1.02547	±	0.00011	1.03097	±	0.00013	1.03200	±	0.00400	-0.00550	±	0.00017
HCI-005-2	KBR-9 - SS	1.09779	±	0.00012	1.09835	±	0.00012	1.05000	±	0.00800	-0.00056	±	0.00017
HCI-005-3	KBR-10 - SS/MO	1.04860	±	0.00012	1.04900	±	0.00011	1.03000	±	0.00600	-0.00040	±	0.00016
ZPPR-10A	L07 - AB	1.00117	±	0.00015				1.00110	±	0.00150			
MMF-008-3	ZEBRA 8C/2 - C. 3	0.99075	±	0.00014	0.99114	±	0.00013	0.98600	±	0.00440	-0.00039	±	0.00019
HMF-003	HEU sph, Ni refl	1.00845	±	0.00020	1.00624	±	0.00020	1.00000	±	0.00300	0.00221	±	0.00028
MCF-004	ZPR-3/56 - AB	1.00293	±	0.00018	1.00278	±	0.00018	0.99950	±	0.00110	0.00015	±	0.00025
PMF-045-1	Pu core-Ni refl	1.01070	±	0.00021	1.00993	±	0.00021	1.00000	±	0.00470	0.00077	±	0.00030
PMF-045-2	Pu core-Ni/Fe refl	1.00853	±	0.00021	1.00800	±	0.00021	1.00000	±	0.00460	0.00053	±	0.00030
PMF-045-3	Pu core-Ni/Fe refl	1.01334	±	0.00020	1.01257	±	0.00022	1.00000	±	0.00440	0.00077	±	0.00030
PMF-045-4	Pu core-Ni refl	1.01210	±	0.00021	1.01155	±	0.00020	1.00000	±	0.00460	0.00055	±	0.00029
PMF-045-5	Pu core-Ni refl	1.01816	±	0.00021	1.01739	±	0.00022	1.00000	±	0.00450	0.00077	±	0.00030
HCT-022-1	Case 1	0.99494	±	0.00025	0.99560	±	0.00023	1.00000	±	0.00810	-0.00066	±	0.00034
HCT-014-1	Case 1	0.99863	±	0.00024	0.99865	±	0.00025	0.99860	±	0.00480	-0.00002	±	0.00035
HCT-014-2	Case 2	0.99854	±	0.00024	0.99909	±	0.00023	0.99860	±	0.00490	-0.00055	±	0.00033
HCT-011-1	Case 1	0.98970	±	0.00027	0.98986	±	0.00026	0.99880	±	0.00420	-0.00016	±	0.00037
HCT-011-2	Case 2	0.99179	±	0.00025	0.99167	±	0.00026	0.99880	±	0.00420	0.00012	±	0.00036
HCT-011-3	Case 3	0.99327	±	0.00024	0.99340	±	0.00025	0.99880	±	0.00420	-0.00013	±	0.00035

- **Most of these systems are insensitive to Ni; the only two systems with significant changes are improved.**

Summary

- **^{239}Pu** – generally small changes on THERM, INTER and FAST systems.

- **^{240}Pu** – Generally increases the over-prediction of the THERM systems; no effect in the FAST systems.

- **^{55}Mn** – Nice improvement in FAST systems; little effect in THERMAL systems.

- **^{52,53}Cr** – Increased the under-prediction of the THERM systems and mixed performance in the INTER and FAST systems.

- **^{58,60}Ni** – Most of these systems are insensitive to Ni; the only two systems with significant changes are improved.

Support Development of Advanced Nuclear Data Covariance Methodologies

- A few years ago, D. M. Smith, D. W. Muir and R. D. McKnight considered how Argonne might contribute to the NCSP Nuclear Data program element
- Our conclusion was **Covariance Data**
- Initial emphasis has focused on two areas
  - Quality Assurance for new Covariance Data for ENDF/B
  - Advance Covariance Methodologies

Quality Assurance for ENDF/B-VII.1 Covariances

- Work has been in progress for over a year to develop a reasonable set of QA requirements for ENDF/B-VI.1 covariances
- Extensive discussions on this topic were held during the three previous CSEWG meetings
- The following slides (generated by D. Smith and D. Muir and their interactions within the CSEWG community) reflect a number of compromises that had to be made to gain adequate acceptance
- Improvements can be made to these QA requirements in future releases of ENDF/B as covariance methods, processing methods, and individual user needs evolve over time

1. Basic Mathematical Requirements

- ***1.1*** *The numerical data and recipes provided in an evaluated full covariance file must enable complete (square and symmetric) matrices that yield correlations as well as standard deviations (uncertainties) to be generated from the included values by the most widely used contemporary processing codes.*
- ***1.2*** *Correlation matrices derived from the evaluated covariance data should have unity values along the matrix diagonal, and off-diagonal elements with magnitudes less than unity, to the extent allowed by the numerical precision of the file and consistent with the limitations of the ENDF formats.*
- ***1.3*** *Covariance matrices for evaluated normalized neutron-emission spectra (MF = 35) should satisfy the mathematically mandatory "sum-to-zero" property for rows and columns of the matrix to the extent allowed by the numerical precision of the applicable file and consistent with the limitations of the ENDF formats.*

2. Matrix Eigenvalues Requirement

- ***2.1*** *Full covariance matrices generated from information provided by the evaluator must be positive definite (i.e., involve only positive eigenvalues) on the evaluator's original energy grid, to the extent allowed by the numerical precision of the file and consistent with the limitations of the ENDF formats, unless the occurrence of zero eigenvalues is mandated mathematically by certain physical constraints such as normalization or consistency of partial reaction channel data and those for sums or differences of data for these reaction channels.*

3. Requirement of "Realistic" Covariances

- ***3.1*** *Covariance data uncertainties and correlations should be consistent in magnitude with the contemporary expectations of experienced nuclear data evaluators as well as addressing the needs of users of these nuclear data for applications.*
- ***3.2*** *For evaluated cross sections that exceed 1% of the total cross section in magnitude, uncertainties greater than 50% predicted by the provided covariance data should be treated by reviewers as potentially unrealistic and flagged for possible rejection unless they can be amply substantiated by the evaluator. However, for cross sections smaller than 1% of the total cross section, a specified uncertainty that is greater than 50% (but always less than 100%) can be considered as representing a flag signifying that the evaluator believes that the evaluated data should be viewed as qualitatively very uncertain. Reviewers should then treat such large assigned uncertainties as acceptable under the circumstances.*
- ***3.3*** *Uncertainties which are very small, e.g., smaller than those assigned to neutron reaction cross section standards for the same process types, should be treated by reviewers as potentially unrealistic and flagged for possible rejection unless they can be amply substantiated by the evaluator. Reviewers should refer to the following table for general guidance in making these judgments, with the understanding that there will be some exceptions based on physical considerations*

Table of Minimum "Reasonable" Uncertainties *

Reaction	*Minimum Uncertainty*
(n,tot)	*1%*
(n,el)	*2%*
(n,γ)	*2%*
(n,inel)	*3%*
(n,f)	*0.7%*
nu-bar	*0.7%*
Other	*3%*

* Deviations encountered in a review should trigger examination of potential causes

4. Covariance Evaluation Consistency Requirement

- ***4.1*** *The provided uncertainties for an evaluation must be reasonably consistent in magnitude with the uncertainties in all relevant experimental data, as well as with the evaluator's estimates of the uncertainties associated with nuclear modeling practices employed in the present evaluation (see also Section 3).*

5. Covariance Format Requirement

- ***5.1*** *Covariance information must be specified using only approved formats as defined in the contemporary ENDF Formats Manual.*

6. Documentation Requirement

- ***6.1*** *A textual section must be provided within the evaluated file in the category "Descriptive Comments" (MF = 1; MT = 451) that describes how the provided covariance information was generated and also gives a justification for any uncertainty values which appear to be unrealistic (i.e., either unusually small or large as defined in Section 3). If references are available to more detailed descriptions of the procedures used to generate the provided covariance information, including links to information available from the Internet, then they must also be provided in this section.*

7. Checking Code and Visual Inspection Requirements

- ***7.1*** *The evaluated covariance files must pass all the numerical tests that can be performed by the contemporary suite of ENDF library checking codes provided by the NNDC.*
- ***7.2*** *An evaluated covariance file must pass a visual inspection of plots of uncertainties and correlations by at least one independent reviewer in order to weed out obvious errors and nonsensical values, and to identify situations where the results appear to be otherwise unrealistic, so that they can be examined further and the issues resolved before the file is accepted (see Section 3).*

8. Processing Requirements

- ***8.1*** *The covariance data included in ENDF/B-VII.1 evaluations must be capable of being processed by the most widely used contemporary data processing codes, i.e., by NJOY and PUFF, for typical group structures that are employed in contemporary nuclear applications.*
- ***8.2*** *The covariance data generated from processing of ENDF files by NJOY and PUFF in comparable situations should agree numerically to within reasonable precision, consistent with the limitations associated with the ENDF formats and differences in the computational methodologies of these codes.*

Summary for Covariance Activities

- Approximately a year remains until the planned release of ENDF/B-VII.1. It is important to the CSEWG/ENDF community to insure that these QA requirements are met.
- With regard to Advanced Covariance Methodologies, Argonne has helped to develop two stochastic methods currently being used to produce consistent nuclear data and covariance evaluations. These provide valuable independent covariance data – which also develop full correlations among the evaluations.
- The Criticality Safety community has invested heavily in Sensitivity/Uncertainty (S/U) methods. These represent powerful and valuable tools – **if they are provided quality covariance data.**