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A Suite of Criticality Benchmarks for Validating Nuclear Data

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ABSTRACT

The continuous-energy neutron data library ENDF60 for use with MCNP™ was released in the fall of 1994, and was based on ENDF/B-VI evaluations through Release 2. As part of the data validation process for this library, a number of criticality benchmark calculations were performed. The original suite of nine criticality benchmarks used to test ENDF60 has now been expanded to 86 benchmarks. This report documents the specifications for the suite of 86 criticality benchmarks that have been developed for validating nuclear data.

I. Introduction

As part of the validation process for MCNP,[1] a suite of nine criticality benchmarks was implemented and documented in LA-12212.[2] Upon review of these criticality benchmarks, several errors were uncovered in the benchmark specifications, prompting a review of the benchmark suite and expansion to include a total of 42 criticality benchmarks.[3,4] Some of the 42 benchmarks were not of high enough quality to be used to validate nuclear data, and could only be used for inter-library comparisons. Results of applying these, and other, benchmarks to the continuous-energy neutron data library ENDF60[5] have been reported previously.[6,7] A new comprehensive look at the suite of criticality benchmarks has led to the establishment of a new suite of 86 criticality benchmarks suitable for validating nuclear data.

In choosing these benchmarks, we have tried to assemble a set of problems that would test different energy regions, such as the high-energy region of the fast critical assemblies and the thermal region of the solution experiments, test a variety of important reflector materials, and yet not have an unreasonably high number of benchmarks. This new suite by no means covers all isotopes and energy regions of interest. For example, we are awaiting new experimental measurements for intermediate-energy region (0.0001 – 0.100 MeV) critical assemblies[8] and adequate benchmark specifications for low-enrichment uranium metal assemblies. Suitable experiments utilizing ^{232}Th are also lacking.

For this suite, two compendiums of criticality experimental information have been used: the Cross Section Evaluation Working Group (CSEWG) specifications[9] and the International Criticality Safety Benchmark Evaluation Project (ICSBEP).[10] The ICSBEP compendium has detailed information on the experimental configuration and material specifications for the k_{eff} measurements but contains no other experimental information. The ICSBEP compendium also has a large number of Russian criticality benchmark experiments, some of which are included in this suite of benchmarks. The CSEWG compendium does not have as detailed information on the experimental configuration and materials but contains other measured quantities such as neutron leakage spectra, activation ratio measurements with a variety of materials, and central-fission ratio measurements for eight critical assemblies. The geometry and material specifications for the 86 benchmarks were therefore primarily taken from the ICSBEP compendium. For this report, we will focus only on the

benchmark specifications for the k_{eff} measurements. Future reports will detail the results of these keff benchmarks[11] and the specifications for the other measured quantities for the eight assemblies. [12]

II. Criticality Benchmark Descriptions

The current suite of criticality benchmarks is made up of five major categories; critical assemblies utilizing ^{233}U, intermediate-enriched ^{235}U (IEU), highly-enriched ^{235}U (HEU), ^{239}Pu, and mixed metal assembles. Within each category, there are bare, reflected, and solution assemblies. A variety of reflector materials have been utilized, such as Be, BeO, C, Al, Fe, Ni, W, Th, ^{233}U, and natural (normal) uranium U(N). Tables 1-5 contain a brief description of each of the criticality benchmarks, including its associated MCNP filename, for each of the major categories. In general, bare and reflected critical experiments conducted at American facilities are listed first, followed by those conducted at Russian facilities. Solution experiments are at the end of the tables. The notation of HEU(93.5) would indicate that highly-enriched uranium having 93.5 weight percent of ^{235}U was used in the experiment.

As you will note, there are two sets of specifications for five of the assemblies. For Flattop-23, a sphere of ^{233}U reflected by U(N), the CSEWG specification contains a small gap between the main fuel and the reflector whereas the ICSBEP specification has no gap. ICSBEP specifications for Godiva contain both the standard sphere of HEU as well as nested spherical shells of HEU. There are two specifications for the one- and two-dimensional model for Bigten, and for the water-reflected sphere of HEU. The thorium-reflected sphere of ^{239}Pu, Thor, also has a one- and two-dimensional representation. Therefore, there are a total of 91 MCNP files.

The references to the specific CSEWG and ICSBEP benchmarks and the benchmark k_{eff} values are detailed in Tables 6-10 for each of the five major categories. References in ()'s indicate a corresponding set of CSEWG specifications that were not used in these benchmarks.

Table 1: Criticality Benchmark Descriptions for ^{233}U Assemblies

MCNP Filename	1D/2D/3D	Benchmark Description
23umt1	1D	Jezebel-23, Bare Sphere of U233
23umt2a	1D	0.481" HEU-Reflected Sphere of U233; Planet Assembly
23umt2b	1D	0.783" HEU-Reflected Sphere of U233, Planet Assembly
23umt3a	1D	0.906" Normal Uranium-Reflected Sphere of U233, Planet Assembly
23umt3b	1D	2.09" Normal Uranium-Reflected Sphere of U233, Planet Assembly
23umt4a	1D	0.96" Tungsten-Reflected Sphere of U233, Planet Assembly
23umt4b	1D	2.28" Tungsten-Reflected Sphere of U233, Planet Assembly
23umt5a	1D	0.805" Be-Reflected Sphere of U233, Planet Assembly
23umt5b	1D	1.652" Be-Reflected Sphere of U233, Planet Assembly
23umt6	1D	Flattop-23, 7.84" Normal-Uranium Reflected Sphere of U233
flat23	1D	Flattop-23, CSEWG, U(N)-reflected U233 sphere + gap
23usl1a	1D	ORNL-5, 1.0226 g/l Unreflected 27.24" Sphere of U233 nitrate solution
23usl1b	1D	ORNL-6, 1.0253 g/l Unreflected 27.24" Sphere of U233 nitrate solution with Boron
23usl1c	1D	ORNL-7, 1.0274 g/l Unreflected 27.24" Sphere of U233 nitrate solution with Boron
23usl1d	1D	ORNL-8, 1.0275 g/l Unreflected 27.24" Sphere of U233 nitrate solution with Boron
23usl1e	1D	ORNL-9, 1.0286 g/l Unreflected 27.24" Sphere of U233 nitrate solution with Boron
23usl8	1D	ORNL-11, 1.0153 g/l Unreflected 48.04" Sphere of U233 nitrate solution with Boron

Table 2: Criticality Benchmark Descriptions for Intermediate Enriched ^{235}U Assemblies

MCNP Filename	1D/2D/3D	Benchmark Description
ieumt1a	2D	Jemima 1, Cylindrical Disks of HEU and Natural Uranium
ieumt1b	2D	Jemima 2, Cylindrical Disks of HEU and Natural Uranium
ieumt1c	2D	Jemima 3, Cylindrical Disks of HEU and Natural Uranium
ieumt1d	2D	Jemima 4, Cylindrical Disks of HEU and Natural Uranium
ieumt2	2D	Reflected Jemima, U(N)-Reflected Cylindrical Disks of HEU and Natural Uranium
ieumt3	1D	Bare IEU Sphere (36 wt.%), VNIIEF
ieumt4	1D	Graphite-Reflected IEU Sphere (36 wt.%), VNIIEF
ieumt5	1D	Steel-Reflected IEU Sphere (36 wt.%), VNIIEF
ieumt6	1D	Duralumin-Reflected IEU Sphere (36 wt.%), VNIIEF

Table 3: Criticality Benchmark Descriptions for Highly Enriched ^{235}U Assemblies

MCNP Filename	1D/2D/3D	Benchmark Description
umet1ss	1D	Godiva, Unreflected sphere of HEU, Simple Sphere representation
umet1ns	1D	Godiva, Unreflected sphere of HEU, Nested Spherical shell representation
bigten1	1D	BIGTEN, 1d model: U(N) reflected uranium sphere
bigten2	2D	BIGTEN, 2d model: U(N) reflected uranium cylinder
umet3a	1D	2" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3b	1D	3" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3c	1D	4" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3d	1D	5" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3e	1D	7" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3f	1D	8" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3g	1D	11" Tuballoy-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3h	1D	1.9" Tungsten Carbide-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3i	1D	2.9" Tungsten Carbide-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3j	1D	4.5" Tungsten Carbide-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3k	1D	6.5" Tungsten Carbide-Reflected HEU(93.5) Sphere, Topsy Assembly
umet3l	1D	8.0" Nickel-Reflected HEU(93.5) Sphere, Topsy Assembly
umet4a	2D	Water-Reflected HEU(97.675) Sphere, with plexiglass ring
umet4b	2D	Water-Reflected HEU(97.675) Sphere, Trans. Am. Nuc. Soc. 27, pg. 412 (1977)
umet8	3D	Bare HEU Sphere, VNIITF, 3D model
umet9a	3D	Be-Reflected HEU(~89.6) Sphere, VNIITF
umet9b	3D	BeO-Reflected HEU(~89.6) Sphere, VNIITF
umet11	3D	Polyethylene (CH2)-Reflected HEU(~89.6) Sphere, VNIITF
umet12	3D	Aluminium-Reflected HEU(~89.6) Sphere, VNIITF
umet13	3D	St.20 Steel-Reflected HEU(~89.6) Sphere, VNIITF
umet14	3D	Depleted Uranium-Reflected HEU(~89.6) Sphere, VNIITF
umet15	2D	Bare HEU Cylinder, VNIITF
umet18	1D	Simplified Bare HEU Sphere, VNIIEF
umet19	1D	Graphite-Reflected HEU Sphere, VNIIEF
umet20	1D	Polyethylene-Reflected HEU Sphere, VNIIEF
umet21	1D	Steel-Reflected HEU Sphere, VNIIEF
umet22	1D	Duralumin-Reflected HEU Sphere, VNIIEF
umet28	1D	Flattop-25, U(nat)-Reflected HEU SPHERE
usol13a	1D	ORNL-1, Unreflected Sphere of Uranyl(20.12 g/l) Nitrate
usol13b	1D	ORNL-2, Unreflected Sphere of Uranyl(23.53 g/l) Nitrate with Boron
usol13c	1D	ORNL-3, Unreflected Sphere of Uranyl(26.77 g/l) Nitrate with Boron
usol13d	1D	ORNL-4, Unreflected Sphere of Uranyl(28.45 g/l) Nitrate with Boron
usol32	1D	ORNL-10, Unreflected Sphere of Uranyl(28.45 g/l) Nitrate with Boron

Table 4: Criticality Benchmark Descriptions for ^{239}Pu Assemblies

MCNP Filename	1D/2D/3D	Benchmark Description
pumet1	1D	Jezebel-Pu (4.5%), Bare sphere of Pu-239 with 4.5% Pu-240
pumet2	1D	Jezebel-Pu (20%), Bare sphere of Pu-239 with 20% Pu-240
pumet5	1D	Tungsten-Reflected Pu(94.79) Sphere, Planet assembly
pumet6	1D	Normal Uranium-Reflected Pu(93.80) Sphere, Flattop assembly
pumet8a pumet8b	1D 2D	Thorium-Reflected Pu(93.59) Sphere, Thor Assembly, 1D Model Thorium-Reflected Pu(93.59) Sphere, Thor Assembly, 2D Model
pumet9	1D	Aluminum-Reflected Pu(94.8) Sphere, Comet Assembly
pumet10	1D	U(N)-Reflected Pu sphere
pumet11	1D	Water-Reflected alpha-phase Pu sphere
pumet18	1D	Be-Reflected Pu(94.79) Sphere, Planet Assembly
pumet19	3D	Be-Reflected Pu(~90) Sphere, VNIITF
pumet20	3D	Depleted Uranium-Reflected Pu(~90) Sphere, VNIITF
pumt21a	2D	Be-Reflected Pu Cylinder
pumt21b	2D	BeO-Reflected Pu Cylinder
pumet22	1D	Simplified Plutonium (98%)Bare Sphere, VNIIEF
pumet23	1D	Simplified Plutonium Sphere, Graphite reflector, VNIIEF
pumet24	1D	Simplified Plutonium Sphere, Polyethylene Reflector, VNIIEF
pumet25	1D	Simplified Plutonium Sphere, 1.55 cm Steel Reflector, VNIIEF
pumet26	1D	Simplified Plutonium Sphere, 11.9 cm Steel Reflector, VNIIEF
pnl1	1D	PNL-1, Idealized (No Container) Unreflected Sphere of Pu Nitrate Solution
pnl6	1D	PNL-6, Idealized (No Container) Unreflected Sphere of Pu Nitrate Solution; Revised PNL2
pusl11a	1D	PNL-3, Unreflected 18" Sphere of Pu(22.35 g/l) Nitrate Solution
pusl11b	1D	PNL-4, Unreflected 18" Sphere of Pu(27.49 g/l) Nitrate Solution
pusl11c	1D	PNL-5, Unreflected 16" Sphere of Pu(43.43g/l) Nitrate Solution
pusl11d	1D	Unreflected 16" Sphere of Pu(34.96g/l) Nitrate Solution

Table 5: Criticality Benchmark Descriptions for Mixed Metal Assemblies

MCNP Filename	1D/2D/3D	Benchmark Description
mixmet1	1D	HEU-Reflected Pu Sphere, Planet Assembly
mixmet3	3D	HEU-Reflected Pu Sphere, VNIITF
mixmet8	3D	ZEBRA 8A/2, Graphite and Natural Uranium reflected Pu

Table 6: Criticality Benchmark References for ^{233}U Assemblies

MCNP Filename	Assembly Name	CSEWG Reference	ICSBEP Reference	Benchmark k_{eff}
23umt1	Jezebel-23	(F-19)	233U-MET-FAST-001	1.000±0.001
23umt2a			233U-MET-FAST-002 Case 1	1.0000±0.0010
23umt2b			233U-MET-FAST-002 Case 2	1.0000±0.0011
23umt3a			233U-MET-FAST-003 Case 1	1.0000±0.0010
23umt3b			233U-MET-FAST-003 Case 2	1.0000±0.0010
23umt4a			233U-MET-FAST-004 Case 1	1.0000±0.0007
23umt4b			233U-MET-FAST-004 Case 2	1.0000±0.0008
23umt5a			233U-MET-FAST-005 Case 1	1.0000±0.0030
23umt5b			233U-MET-FAST-005 Case 2	1.0000±0.0030
23umt6	Flattop-23		233U-MET-FAST-006	1.0000±0.0014
flat23	Flattop-23	F-24		1.000±0.001
23usl1a	ORNL-5		233U-SOL-THERM-001 Case 1	1.0000±0.0031
23usl1b	ORNL-6		233U-SOL-THERM-001 Case 2	1.0005±0.0033
23usl1c	ORNL-7		233U-SOL-THERM-001 Case 3	1.0006±0.0033
23usl1d	ORNL-8		233U-SOL-THERM-001 Case 4	0.9998±0.0033
23usl1e	ORNL-9		233U-SOL-THERM-001 Case 5	0.9999±0.0033
23usl8	ORNL-11		233U-SOL-THERM-008	1.0006±0.0029

Table 7: Criticality Benchmark References for Intermediate Enriched ^{235}U Assemblies

MCNP Filename	Assembly Name	CSEWG Reference	ICSBEP Reference	Benchmark k_{eff}
ieumt1a	Jemima #1		IEU-MET-FAST-001 Case 1	0.9989
ieumt1b	Jemima #2		IEU-MET-FAST-001 Case 2	0.9997
ieumt1c	Jemima #3		IEU-MET-FAST-001 Case 3	0.9993
ieumt1d	Jemima #4		IEU-MET-FAST-001 Case 4	1.0002
ieumt2	Reflected Jemima		IEU-MET-FAST-002	1.000±0.003
ieumt3			IEU-MET-FAST-003	1.0000±0.0017
ieumt4			IEU-MET-FAST-004	1.0000±0.0030
ieumt5			IEU-MET-FAST-005	1.0000±0.0021
ieumt6			IEU-MET-FAST-006	1.0000±0.0023

Table 8: Criticality Benchmark References for Highly Enriched ^{235}U Assemblies

MCNP Filename	Assembly Name	CSEWG Reference	ICSBEP Reference	Benchmark k_{eff}
umet1ss	Godiva	(F-5)	HEU-MET-FAST-001 Case a	1.000±0.001
umet1ns			HEU-MET-FAST-001 Case b	1.000±0.001
bigten1	Bigten	F-10		0.996±0.003
bigten2				0.996±0.003
umet3a			HEU-MET-FAST-003 Case 1	1.0000±0.0050
umet3b			HEU-MET-FAST-003 Case 2	1.0000±0.0050
umet3c			HEU-MET-FAST-003 Case 3	1.0000±0.0050
umet3d			HEU-MET-FAST-003 Case 4	1.0000±0.0030
umet3e			HEU-MET-FAST-003 Case 5	1.0000±0.0030
umet3f			HEU-MET-FAST-003 Case 6	1.0000±0.0030
umet3g			HEU-MET-FAST-003 Case 7	1.0000±0.0030
umet3h			HEU-MET-FAST-003 Case 8	1.0000±0.0050
umet3i			HEU-MET-FAST-003 Case 9	1.0000±0.0050
umet3j			HEU-MET-FAST-003 Case 10	1.0000±0.0050
umet3k			HEU-MET-FAST-003 Case 11	1.0000±0.0050
umet3l			HEU-MET-FAST-003 Case 12	1.0000±0.0030
umet4a			HEU-MET-FAST-004 Case 2	1.002
umet4b			HEU-MET-FAST-004 (Case 1)	1.0003±0.0005
umet8			HEU-MET-FAST-008	0.9989±0016
umet9a			HEU-MET-FAST-009 Case 1	0.9992±0.0015
umet9b			HEU-MET-FAST-009 Case 2	0.9992±0.0015
umet11			HEU-MET-FAST-011	0.9989±0.0015
umet12			HEU-MET-FAST-012	0.9992±0.0018
umet13			HEU-MET-FAST-013	0.9990±0.0015
umet14			HEU-MET-FAST-014	0.9989±0.0017
umet15			HEU-MET-FAST-015	0.9996±0.0017
umet18			HEU-MET-FAST-018	1.0000±0.0016
umet19			HEU-MET-FAST-019	1.0000±0.0030
umet20			HEU-MET-FAST-020	1.0000±0.0030
umet21			HEU-MET-FAST-021	1.0000±0.0026
umet22			HEU-MET-FAST-022	1.0000±0.0021
umet28	Flattop-25	(F-22)	HEU-MET-FAST-028	1.0000±0.0030
usol13a	ORNL-1	(T-1)	HEU-SOL-THERM-003 Case 1	1.0012±0.0026
usol13b	ORNL-2	(T-2)	HEU-SOL-THERM-003 Case 2	1.0007±0.0036
usol13c	ORNL-3	(T-3)	HEU-SOL-THERM-003 Case 3	1.0009±0.0036
usol13d	ORNL-4	(T-4)	HEU-SOL-THERM-003 Case 4	1.0003±0.0036
usol32	ORNL-10	(T-5)	HEU-SOL-THERM-032	1.0015±0.0026

Table 9: Criticality Benchmark References for ^{239}Pu Assemblies

MCNP Filename	Assembly Name	CSEWG Reference	ICSBEP Reference	Benchmark k_{eff}
pumet1	Jezebel-Pu (4.5%)	(F-1)	PU-MET-FAST-002	1.000±0.002
pumet2	Jezebel-Pu (20%)	(F-21)	PU-MET-FAST-001	1.000±0.002
pumet5			PU-MET-FAST-005	1.0000±0.0013
pumet6	Flattop-Pu	(F-23)	PU-MET-FAST-006	1.0000±0.0030
pumet8a pumet8b	Thor	(F-25)	PU-MET-FAST-008 Case 1 PU-MET-FAST-008 Case 2	1.0000±0.0030 1.000±0.0006
pumet9			PU-MET-FAST-009	1.0000±0.0027
pumet10			PU-MET-FAST-010	1.0000±0.0018
pumet11			PU-MET-FAST-011	1.0000±0.001
pumet18			PU-MET-FAST-018	1.0000±0.0030
pumet19			PU-MET-FAST-019	0.9992±0.0015
pumet20			PU-MET-FAST-020	0.9993±0.0017
pumt21a			PU-MET-FAST-021 Case 1	1.0000±0.0026
pumt21b			PU-MET-FAST-021 Case 2	1.0000±0.0026
pumet22			PU-MET-FAST-022	1.0000±0.0021
pumet23			PU-MET-FAST-023	1.0000±0.0020
pumet24			PU-MET-FAST-024	1.0000±0.0020
pumet25			PU-MET-FAST-025	1.0000±0.0020
pumet26			PU-MET-FAST-026	1.0000±0.0024
pnl1	PNL-1	T-13		
pnl6	PNL-2, PNL-6	T-14,T-24		
pusl11a	PNL-3	(T-15)	PU-SOL-THERM-011 Case 18-1	1.0000±0.0052
pusl11b	PNL-4	(T-16)	PU-SOL-THERM-011 Case 18-6	1.0000±0.0052
pusl11c	PNL-5	(T-17)	PU-SOL-THERM-011 Case 16-5	1.0000±0.0052
pusl11d			PU-SOL-THERM-011 Case 16-1	1.0000±0.0052

Table 10: Criticality Benchmark References for Mixed Metal Assemblies

MCNP Filename	Assembly Name	CSEWG Reference	ICSBEP Reference	Benchmark k_{eff}
mixmet1			MIX-MET-FAST-001	1.0000±0.0016
mixmet3			MIX-MET-FAST-003	0.9993±0.0016
mixmet8	ZEBRA 8A/2		MIX-MET-FAST-008 Case 1	0.9920±0.0063

III. MCNP Input Specifications

The MCNP input decks for each of the benchmarks detailed in Tables 1 – 5 are listed in Appendices A – E for the five major categories; critical assemblies utilizing ^{233}U, intermediate-enriched ^{235}U (IEU), highly-enriched ^{235}U (HEU), ^{239}Pu, and mixed metal assembles. The detailed geometry and material specifications are contained in these input decks and are quite easy to follow for the simple 1D and 2D problems. Specific MCNP commands are described in Chapter 3 of the manual.[1] A more thorough discussion of the geometry specifications for the complicated 3D problems can be found in the ICSBEP compendium. In general, atom densities were specified for the ICSBEP benchmarks whereas atom fractions are used in the CSEWG benchmarks. The input decks contain a comment line specifying whether atom densities or fractions were used, though it is generally obvious (atom fractions would add up to ~1.0 for a given material).

As an example, let us examine the one-dimensional representation of Bigten. The MCNP input deck is as follows:

```
1    1  0.04757  -1         imp:n=1
2    2  0.04807  +1 -2      imp:n=1
4    0           +2         imp:n=0

1    so  30.48
2    so  45.72

ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print
prdmp 3j  2
c      Materials specified with atom fractions
m1   92234. 0.00105  92235. 0.10175 92238. 0.8972
m2   92235. 0.00208  92238. 0.99792
```

The MCNP input deck begins with a comment line briefly describing the problem, and is followed by 3 lines specifying the inner sphere of HEU (cell #1), surrounded by a spherical shell of natural uranium (cell #2), and an external void (cell #3). Each cell is defined by a cell number, the material number, the atom or weight density, and then a geometric combination of operations for defining the volume of the cell region. In this particular input deck, the importance of each region is also defined using the 'imp' command. In this case, cell #3 has

been given zero importance, and so once the neutrons travel outside of the assembly, they are no longer transported. The next set of lines specify that the inner sphere centered at the origin (using the 'so' command) has radius of 30.48 cm, while the outside radius of the natural uranium is 45.72 cm. The material specifications are found on the 'm1' and 'm2' definitions and use atom fractions as noted on the comment line. The total atom density for each material is found in the cell definitions. The material specifications are sometimes made using atom densities (in number of atoms per barn•cm), which MCNP automatically converts to the proper atom fractions.

The source for this kcode problem is started at the origin as defined by the 'ksrc' command. Solution assemblies used the sdef card to initially distribute the source through the geometry, thereby ensuring that the source was sufficiently well distributed throughout the fissionable materials of each problem after the inactive cycles were completed. For all assemblies, 3000 source neutrons were run per kcode cycle. Forty inactive cycles and 360 active cycles were run for all metal assemblies benchmarks. For solution assemblies, forty inactive and 760 active cycles were run. These numbers ensured that enough active cycles were run to obtain good statistics for the k_{eff} calculation. Total nubar data were used for all of these benchmarks. Run times for the benchmarks ranged from ~10 minutes for simple, fast-spectrum problems like Jezebel to ~1200 minutes for thermal, solution benchmarks on an HP-735 workstation. These input decks do not contain any tallies for calculating other experimental measurements such as leakage spectra and reaction-rate ratios which will be detailed in a future report.[12] The addition of such tallies may greatly influence the run time for those problems.

IV. Summary

A comprehensive suite of 86 criticality benchmarks has been established for validating nuclear data. The suite contains benchmarks for five major categories; critical assemblies utilizing ^{233}U, intermediate-enriched ^{235}U (IEU), highly-enriched ^{235}U (HEU), ^{239}Pu, and mixed metal assembles. We have attempted to assemble a set of benchmarks that would test different energy regions, such as the high-energy regions of the fast assemblies and the thermal regions of the solution experiments, and a variety of important fissile and reflector

materials. Additionally, we have tried to keep from having an unreasonably large number of benchmarks in the test suite. Therefore this suite does not test all isotopes and energy regions of interest. For some materials, high-quality benchmark specifications are not available, and few intermediate-energy region experiments (0.0001 – 0.100 MeV) are available.

The benchmarks were based on specifications from two compendiums; the Cross Section Evaluation Working Group (CSEWG) [9] and the International Criticality Safety Benchmark Evaluation Project (ICSBEP).[10] For this report, we have focused on the specifications for calculating k_{eff} and have not included other experimental information such as leakage spectra. Future reports will detail the results of applying these benchmarks to our currently available continuous-energy MCNP neutron data libraries. They will also include the specifications and results for other experimentally measured quantities (leakage spectra, activation ratio, and central fission ratio measurements).

V. Acknowledgments

The author gratefully acknowledges the many useful discussions with Robert C. Little. Amzie Adams assisted in the earlier version of a criticality benchmark suite which served as the basis for this effort. The assistance of Judi Briesmeister and Art Forster is greatly appreciated in finalizing aspects of the MCNP specifications.

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Appendix A

^{233}U Criticality Benchmark Input Decks for MCNP

==> 23umt1 <==

```
CSEWG-F19: (Jezebel-23) U233 bare metal sphere:  U233-MET-FAST-001
1     1 0.04760215  -1
2     0         +1

1     so 5.9838

mode   n
imp:n  1 0
ksrc   0 0 0
kcode  3000 1.0 40 400
totnu
print
c      Materials specified with atom densities
m1     92233. 4.6712e-2 92234. 5.9026e-4 92235. 1.4281e-5
       92238. 2.8561e-4
```

==> 23umt2a <==

```
0.481" HEU REFLECTED U-233 SPHERE, PLANET: U233-MET-FAST-002
1 1 0.0481098 -1 imp:n=1
2 2 0.048126 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0444
2 so 6.2661

c      Materials specified with atom densities
m1   92233. 0.047253
     92234. 0.00052705
     92238. 0.00032975
m2   92238. 0.0032340
     92235. 0.044892
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt2b <==

```
0.783" HEU REFLECTED U-233 SPHERE, PLANET: U233-MET-FAST-002
1 1 0.04816985 -1 imp:n=1
2 2 0.048126 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 4.5999
2 so 6.5887

c      Materials specified with atom densities
m1   92233. 0.047312
     92234. 0.00052770
     92238. 0.00033015
m2   92238. 0.0032340
```

```
     92235. 0.044892
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt3a <==

```
0.906" NU REFLECTED U-233 SPHERE, 10 KG EXP, PLANET: U233-MET-FAST-003 Case 1
1 1 0.0481098 -1 imp:n=1
2 2 0.04786702 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0444
2 so 7.3456

c      Materials specified with atom densities
m1    92233. 0.047253
      92234. 0.00052705
      92238. 0.00032975
m2    92238. 0.047518
      92235. 0.00034902
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt3b <==

```
2.09" NU REFLECTED U-233 SPHERE, 7.6 KG EXP, PLANET: U233-MET-FAST-003 Case 2
1 1 0.04816985 -1 imp:n=1
2 2 0.04786702 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 4.5999
2 so 9.9085

c      Materials specified with atom densities
m1    92233. 0.047312
      92234. 0.00052770
      92238. 0.00033015
m2    92238. 0.047518
      92235. 0.00034902
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt4a <==

```
W REFLECTED 10.012 kg U-233 SPHERE, PLANET: U233-FAST-MET-004
1 1 0.0481098 -1 imp:n=1
2 2 0.06605308 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0444
2 so 7.4828

c      Materials specified with atom densities
m1   92233. 0.047253
     92234. 0.00052705
     92238. 0.00032975
m2   74182.  1.35361e-02
     74183.  7.34963e-03
     74184.  1.58007e-02
     74186.  1.47198e-02
     28058. 6.63066-3
     28060. 2.53494-3
     28061. 1.09750-4
     28062. 3.48675-4
     28064. 8.83828-5
     29063. 2.82034-3
     29065. 1.25706-3
     40000. 0.00079528
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt4b <==

```
W REFLECTED 7.601 kg U-233 SPHERE, PLANET: U233-FAST-MET-004
1 1 0.04816985 -1 imp:n=1
2 2 0.06605308 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 4.5999
2 so 10.3911

c      Materials specified with atom densities
m1   92233. 0.047312
     92234. 0.00052770
     92238. 0.00033015
m2   74182.  1.35361e-02
     74183.  7.34963e-03
     74184.  1.58007e-02
     74186.  1.47198e-02
     28058. 6.63066-3
     28060. 2.53494-3
     28061. 1.09750-4
     28062. 3.48675-4
     28064. 8.83828-5
     29063. 2.82034-3
     29065. 1.25706-3
```

```
     40000. 0.00079528
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt5a <==

```
BERYLLIUM REFLECTED 10.012 kg U-233 SPHERE, PLANET: U233-MET-FAST-005
1 1 0.0481098 -1 imp:n=1
2 2 0.1212076 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0444
2 so 7.0891

c      Materials specified with atom densities
m1   92233. 0.047253
     92234. 0.00052705
     92238. 0.00032975
m2   4009. 0.11983
     8016. 0.0013776
mt2  be.01t
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt5b <==

```
BERYLLIUM REFLECTED 7.601 kg U-233 SPHERE, PLANET: U233-MET-FAST-005
1 1 0.04816985 -1 imp:n=1
2 2 0.1212076 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 4.5999
2 so 8.7960

c      Materials specified with atom densities
m1   92233. 0.047312
     92234. 0.00052770
     92238. 0.00033015
m2   4009. 0.11983
     8016. 0.0013776
mt2  be.01t
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> 23umt6 <==

```
U-233 SPHERE Reflected by Normal Uranium, FLATTOP-23: U233-MET-FAST-006
1 1 0.047591468 -1 imp:n=1
2 2 0.0480675 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 4.2058
2 so 24.1194

c      Materials specified with atom densities
m1   92233. 0.046710
     92234. 0.00058772
     92235. 0.000014158
     92238. 0.00027959
m2   92235. 0.00035050
     92238. 0.047719
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> flat23 <==

```
Flattop-23, CSEWG-F24, U(N) reflected U233 sphere + gap
1    1  0.04759  -1         imp:n=1
2    0           +1 -2      imp:n=1
3    2  0.04808  +2 -3      imp:n=1
4    0           +3         imp:n=0

1    so  4.317
2    so  4.610
3    so  24.13

ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print
c      Materials specified with atom fractions
m1   92233. 0.98151 92234. 0.01240  92235. 0.00021
     92238. 0.00588
m2   92235. 0.00707  92238. 0.99293
```

==> 23usl1a <==

```
ORNL-5 1.0226 g/l Unreflected 27.24" Sphere; U233-SOL-THERM-001 #1
 1  1  0.099998 -1       $ Spherical Solution U(NO3)2-H2O
 2  2  0.060275 1 -2     $ Spherical Shell of Al-1100
 3  0  2

 1 so 34.595       $ Inner Radius of Al-1100 Sphell
 2 so 34.915       $ Outer RAdius of Al-1100 Sphell

mode n
```

```
imp:n 1 1 0
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.595
vol 173432. 4857.33 0.0
area 15039.6 15319.1
c Solution
c      Materials specified with atom densities
m1    1001. 6.6271e-02
      7014. 1.1819e-04 8016. 3.3564e-02
      90232. 1.9639e-07 92233. 4.3271e-05
      92234. 7.1442e-07 92235. 1.7565e-08
      92238. 2.7748e-07
c Al-1100
m2    13027. 5.9881e-02
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1   lwtr.01t
totnu
print
```

==> 23usl1b <==

```
ORNL-6  1.0253 g/l Unreflected 27.24" Sphere; U233-SOL-THERM-001 #2
 1 1 0.10016 -1     $ Spherical Solution U(NO3)2-H2O
 2 2 0.060275 1 -2  $ Spherical Shell of Al-1100
 3 0 2

 1 so 34.595    $ Inner Radius of Al-1100 Sphell
 2 so 34.915    $ Outer RAdius of Al-1100 Sphell

mode n
imp:n 1 1 0
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.595
vol 173432. 4857.33 0.0
area 15039.6 15319.1
c Solution
c      Materials specified with atom densities
m1    1001. 6.6362e-02 5010. 2.6481e-07
      5011. 1.0659e-06 7014. 1.2248e-04
      8016. 3.3628e-02 90232. 2.0489e-07
      92233. 4.5093e-05 92234. 7.4451e-07
      92235. 1.8305e-08 92238. 2.8917e-07
c Al-1100
m2    13027. 5.9881e-02
```

```
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1   lwtr.01t
totnu
print
```

==> 23usl1c <==

```
ORNL-7   1.0274 g/l Unreflected 27.24" Sphere;  U233-SOL-THERM-001 #3
 1 1 0.10026 -1 $ Spherical Solution U(NO3)2-H2O
 2 2 0.060275 1 -2 $ Spherical Shell of Al-1100
 3 0 2

 1 so 34.595 $ Inner Radius of Al-1100 Sphell
 2 so 34.915 $ Outer RAdius of Al-1100 Sphell

mode n
imp:n 1 1 0
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.595
vol 173432. 4857.33 0.0
area 15039.6 15319.1
c Solution
c      Materials specified with atom densities
m1    1001. 6.6413e-02 5010. 5.1591e-07
      5011. 2.0766e-06 7014. 1.2772e-04
      8016. 3.3674e-02 90232. 2.1331e-07
      92233. 4.6768e-05 92234. 7.7216e-07
      92235. 1.8984e-08 92238. 2.9991e-07
c Al-1100
m2    13027. 5.9881e-02
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1 lwtr.01t
totnu
print
```

==> 23usl1d <==

```
ORNL-8  1.0275 g/l Unreflected 27.24" Sphere;  U233-SOL-THERM-001 #4
1 1 0.10017 -1     $ Spherical Solution U(NO3)2-H2O
2 2 0.060275 1 -2  $ Spherical Shell of Al-1100
3 0 2

1 so 34.595    $ Inner Radius of Al-1100 Sphell
2 so 34.915    $ Outer RAdius of Al-1100 Sphell

mode n
imp:n 1 1 0
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.595
vol 173432. 4857.33 0.0
area 15039.6 15319.1
c Solution
c      Materials specified with atom densities
m1    1001. 6.6337e-02 5010. 7.6312e-07
      5011. 3.0716e-06 7014. 1.3173e-04
      8016. 3.3653e-02 90232. 2.2133e-07
      92233. 4.8433e-05 92234. 7.9965e-07
      92235. 1.9660e-08 92238. 3.1059e-07
c Al-1100
m2    13027. 5.9881e-02
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1 lwtr.01t
totnu
print
```

==> 23usl1e <==

```
ORNL-9  1.0286 g/l Unreflected 27.24" Sphere;  U233-SOL-THERM-001 #5
1 1 0.10019 -1      $ Spherical Solution U(NO3)2-H2O
2 2 0.060275 1 -2   $ Spherical Shell of Al-1100
3 0 2

1 so 34.595    $ Inner Radius of Al-1100 Sphell
2 so 34.915    $ Outer RAdius of Al-1100 Sphell

mode n
imp:n 1 1 0
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.595
```

```
vol 173432. 4857.33 0.0
area 15039.6 15319.1
c Solution
c      Materials specified with atom densities
m1    1001. 6.6329e-02 5010. 1.0114e-06
      5011. 4.0708e-06 7014. 1.3586e-04
      8016. 3.3666e-02 90232. 2.2691e-07
      92233. 5.0043e-05 92234. 8.2623e-07
      92235. 2.0314e-08 92238. 3.2091e-07
c Al-1100
m2    13027. 5.9881e-02
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1   lwtr.01t
totnu
print
```

==> 23usl8 <==

```
ORNL-11 1.0153 g/l Unreflected 48.04" Sphere;  U233-SOL-THERM-008
 1 1 9.9935322e-02 -1
 2 2 6.0274697e-02 -2 1
 3 0 2

 1 so 61.011
 2 so 61.786

imp:n 1.0 1.0 0.0
c material cards
c      Materials specified with atom densities
m1    92233. 3.3441e-05 92234. 5.2503e-07 92235. 1.0184e-08
      92238. 2.5474e-07 7014. 7.4943e-05 8016. 3.3469e-02
      1001. 6.6357e-02
      90232. 1.4756e-07
mt1   lwtr.01
c
c al 1100
c
m2    13027. 5.9881e-02
      14000. 2.1790e-04
      25055. 1.4853e-05
      26054.  6.46522e-06
      26056.  1.00507e-04
      26057.  2.30118e-06
      26058.  3.06824e-07
      29063.  3.55285e-05
      29065.  1.58355e-05
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
```

```
sc1 Spherical Source
si1 60.0
print
```

Appendix B

Intermediate Enriched ^{235}U Criticality Benchmark Input Decks for MCNP

==> ieumt1a <==

```
c Jemima #1, Idealized Model; IEU-MET-FAST-001 Case 1
c
c Lower uranium pole.
1 5 4.55477e-02 101 -129 -2
c Lower uranium disks (without fillers).
51 4 4.79550e-02 101 -105 2 -12
52 3 4.80424e-02 105 -106 2 -12
53 4 4.79550e-02 106 -109 2 -12
54 3 4.80424e-02 109 -110 2 -12
55 4 4.79550e-02 110 -113 2 -12
56 3 4.80424e-02 113 -114 2 -12
57 4 4.79550e-02 114 -117 2 -12
58 3 4.80424e-02 117 -118 2 -12
59 4 4.79550e-02 118 -121 2 -12
60 3 4.80424e-02 121 -122 2 -12
61 4 4.79550e-02 122 -125 2 -12
62 3 4.80424e-02 125 -126 2 -12
63 4 4.79550e-02 126 -129 2 -12
c Upper Tu and Oy disks (homogenized).
64 3 4.80424e-02 129 -131 -10 $** tailored Tu disk **
65 4 4.79550e-02 131 -134 -12
66 3 4.80424e-02 134 -136 -12
67 4 4.79550e-02 136 -138 -12
68 3 4.80424e-02 138 -140 -12
69 4 4.79550e-02 140 -142 -12
70 3 4.80424e-02 142 -144 -12
71 4 4.79550e-02 144 -146 -12
c Extra tuballoy on top (disk equiv. to 1 pie + 1 filler).
72 3 4.80424e-02 146 -161 -12
c Cells defining support structures for uranium disks.
103 1 6.02041e-02 129 -131 10 -17
106 0 201 -101 -8
107 0 202 -201 3 -8
108 1 6.02041e-02 202 -101 8 -18
110 1 6.02041e-02 203 -201 -3
111 1 6.02041e-02 205 -203 -7
112 1 6.02041e-02 204 -202 12 -14
113 0 (204 -202 3 -12) (203: 7)
114 0 204 -202 14 -21
118 1 6.02041e-02 205 -204 11 -19
119 0 205 -204 7 -11
120 2 8.63195e-02 206 -205 -20
121 0 (202 -161 12 -21) (-129: 131: 17) (101: 18)
122 0 205 -204 19 -21
123 0 206 -205 20 -21
c External cell.
200 0 -206: 161: 21

c Cylindrical surfaces defining uranium disks and surrounding supports.
2 cz 1.11125 $** inner radius of uranium disks **
3 cz 1.74625 $** rad. of upper Al filler support cylinder **
7 cz 4.60375 $** rad. of lower Al filler support cylinder **
8 cz 12.06500 $** inner radius of lower Al support ring **
10 cz 12.66939 $** idlzd. Tu/Al bndry in upper supp. ring **
11 cz 12.70000 $** o.r. unique Tu disk; i.r. spacer platform **
```

```
12 cz 13.33500 $** outer radius of uranium disks **
14 cz 13.67711 $** outer rad. of idealized Al rect. spacers **
17 cz 15.29416 $** outer edge of idlzd. Al upper supp. ring **
18 cz 15.82055 $** outer rad. of idealized lower Al ring **
19 cz 17.19650 $** outer rad. of idealized Al platform spacer **
20 cz 19.22627 $** rad. of cyl. equiv. to 12"x15" Fe plate **
21 cz 21.00000 $** inner rad. ext. cell (idealized models) **
c Horizontal planes defining uranium disks and fillers.
101 pz 0.000 $** lower surface of bottom uranium disk **
105 pz 0.804
106 pz 1.408
109 pz 2.212
110 pz 2.816
113 pz 3.620
114 pz 4.224
117 pz 5.028
118 pz 5.632
121 pz 6.436
122 pz 7.040
125 pz 7.844
126 pz 8.448
129 pz 9.252 $** parting plane **
131 pz 9.856
134 pz 10.660
136 pz 11.264
138 pz 12.068
140 pz 12.672
142 pz 13.476
144 pz 14.080
146 pz 14.884
161 pz 14.9631
c Horizontal planes defining structural support below uranium disks.
201 pz -0.3175
202 pz -0.9525
203 pz -3.1750
204 pz -4.7625
205 pz -6.0325
206 pz -8.5725

kcode 3000 1.0 40 400
ksrc 8. 0. 00.402 0. 8. 00.402 -8. 0. 00.402 0. -8. 00.402&
0. 0. 00.402&
8. 0. 01.810 0. 8. 01.810 -8. 0. 01.810 0. -8. 01.810&
0. 0. 01.810&
8. 0. 03.218 0. 8. 03.218 -8. 0. 03.218 0. -8. 03.218&
0. 0. 03.218&
8. 0. 04.626 0. 8. 04.626 -8. 0. 04.626 0. -8. 04.626&
0. 0. 04.626&
8. 0. 06.034 0. 8. 06.034 -8. 0. 06.034 0. -8. 06.034&
0. 0. 06.034&
8. 0. 07.442 0. 8. 07.442 -8. 0. 07.442 0. -8. 07.442&
0. 0. 07.442&
8. 0. 08.850 0. 8. 08.850 -8. 0. 08.850 0. -8. 08.850&
0. 0. 08.850&
8. 0. 10.258 0. 8. 10.258 -8. 0. 10.258 0. -8. 10.258&
0. 0. 10.258&
8. 0. 11.666 0. 8. 11.666 -8. 0. 11.666 0. -8. 11.666&
0. 0. 11.666&
```

```
8. 0. 13.074 0. 8. 13.074 -8. 0. 13.074 0. -8. 13.074&
0. 0. 13.074&
8. 0. 14.482 0. 8. 14.482 -8. 0. 14.482 0. -8. 14.482&
0. 0. 14.482
imp:n 1 37r 0
totnu
c      Materials specified with atom fractions
m1   12000. 1.71000e-02 13027. 9.61193e-01 25055. 2.52173e-03
     29063. 1.32704e-02
     29065. 5.91480e-03
m2   24050. 8.32154e-3
     24052. 1.60475e-1
     24053. 1.81944e-2
     24054. 4.52945e-3
     26054. 4.32510e-2
     26056. 6.72370e-1
     26057. 1.53944e-2
     26058. 2.05259e-3
     28058. 5.14835e-2
     28060. 1.96824e-2
     28061. 8.52151e-4
     28062. 2.70728e-3
     28064. 6.86246e-4
m3   92234. 5.50000e-05 92235. 7.20000e-03 92238. 9.92745e-01
m4   92234. 1.02505e-02 92235. 9.34717e-01 92238. 5.50328e-02
m5   92234. 5.61200e-03 92235. 5.12718e-01 92238. 4.81670e-01
print
```

==> ieumt1b <==

```
Jemima #2, Idealized Model; IEU-MET-FAST-001 Case 2
c Note ... no uranium fillers.
1 0 101 -148 -2
c Uranium disks (without fillers).
51 4 4.79558e-02 101 -105 2 -12
52 3 4.80510e-02 105 -106 2 -12
53 4 4.79558e-02 106 -109 2 -12
54 3 4.80510e-02 109 -110 2 -12
55 4 4.79558e-02 110 -113 2 -12
56 3 4.80510e-02 113 -114 2 -12
57 4 4.79558e-02 114 -117 2 -12
58 3 4.80510e-02 117 -118 2 -12
59 4 4.79558e-02 118 -121 2 -12
60 3 4.80510e-02 121 -122 2 -12
61 4 4.79558e-02 122 -125 2 -12
62 3 4.80510e-02 125 -126 2 -12
63 4 4.79558e-02 126 -129 2 -12
64 3 4.80510e-02 129 -131 2 -10 $** tailored Tu disk **
65 4 4.79558e-02 131 -134 2 -12
66 3 4.80510e-02 134 -136 2 -12
67 4 4.79558e-02 136 -138 2 -12
68 3 4.80510e-02 138 -140 2 -12
69 4 4.79558e-02 140 -142 2 -12
70 3 4.80510e-02 142 -144 2 -12
71 4 4.79558e-02 144 -146 2 -12
72 3 4.80510e-02 146 -148 2 -12
c Note ... no extra tuballoy on top for this configuration.
c Cells defining support structures for uranium disks.
103 1 6.02041e-02 129 -131 10 -17
106 0 201 -101 -8
107 0 202 -201 3 -8
108 1 6.02041e-02 202 -101 8 -18
110 1 6.02041e-02 203 -201 -3
111 1 6.02041e-02 205 -203 -7
112 1 6.02041e-02 204 -202 12 -14
113 0 (204 -202 3 -12) (203: 7)
114 0 204 -202 14 -21
118 1 6.02041e-02 205 -204 11 -19
119 0 205 -204 7 -11
120 2 8.63195e-02 206 -205 -20
121 0 (202 -148 12 -21) (-129: 131: 17) (101: 18)
122 0 205 -204 19 -21
123 0 206 -205 20 -21
c External cell.
200 0 -206: 148: 21

c Cylindrical surfaces defining uranium disks and surrounding supports.
2 cz 1.11125 $** inner radius of uranium disks **
3 cz 1.74625 $** rad. of upper Al filler support cylinder **
7 cz 4.60375 $** rad. of lower Al filler support cylinder **
8 cz 12.06500 $** inner radius of lower Al support ring **
10 cz 12.66939 $** idlzd. Tu/Al bndry in upper supp. ring **
11 cz 12.70000 $** o.r. unique Tu disk; i.r. spacer platform **
12 cz 13.33500 $** outer radius of uranium disks **
14 cz 13.67711 $** outer rad. of idealized Al rect. spacers **
17 cz 15.29416 $** outer edge of idlzd. Al upper supp. ring **
```

```
18 cz 15.82055 $** outer rad. of idealized lower Al ring **
19 cz 17.19650 $** outer rad. of idealized Al platform spacer **
20 cz 19.22627 $** rad. of cyl. equiv. to 12"x15" Fe plate **
21 cz 21.00000 $** inner rad. ext. cell (idealized models) **
c Horizontal planes defining uranium disks and fillers.
101 pz 0.000 $** lower surface of bottom uranium disk **
105 pz 0.804
106 pz 1.408
109 pz 2.212
110 pz 2.816
113 pz 3.620
114 pz 4.224
117 pz 5.028
118 pz 5.632
121 pz 6.436
122 pz 7.040
125 pz 7.844
126 pz 8.448
129 pz 9.252 $** parting plane **
131 pz 9.856
134 pz 10.660
136 pz 11.264
138 pz 12.068
140 pz 12.672
142 pz 13.476
144 pz 14.080
146 pz 14.884
148 pz 15.488
c Horizontal planes defining structural support below uranium disks.
201 pz -0.3175
202 pz -0.9525
203 pz -3.1750
204 pz -4.7625
205 pz -6.0325
206 pz -8.5725

imp:n 1 37r 0
totnu
kcode 3000 1.0 40 400
ksrc 8. 0. 00.402 0. 8. 00.402 -8. 0. 00.402 0. -8. 00.402
     8. 0. 01.810 0. 8. 01.810 -8. 0. 01.810 0. -8. 01.810
     8. 0. 03.218 0. 8. 03.218 -8. 0. 03.218 0. -8. 03.218
     8. 0. 04.626 0. 8. 04.626 -8. 0. 04.626 0. -8. 04.626
     8. 0. 06.034 0. 8. 06.034 -8. 0. 06.034 0. -8. 06.034
     8. 0. 07.442 0. 8. 07.442 -8. 0. 07.442 0. -8. 07.442
     8. 0. 08.850 0. 8. 08.850 -8. 0. 08.850 0. -8. 08.850
     8. 0. 10.258 0. 8. 10.258 -8. 0. 10.258 0. -8. 10.258
     8. 0. 11.666 0. 8. 11.666 -8. 0. 11.666 0. -8. 11.666
     8. 0. 13.074 0. 8. 13.074 -8. 0. 13.074 0. -8. 13.074
     8. 0. 14.482 0. 8. 14.482 -8. 0. 14.482 0. -8. 14.482
c      Materials specified with atom fractions
m1   12000. 1.71000e-02 13027. 9.61193e-01 25055. 2.52173e-03
     29063. 1.32704e-2
     29065. 5.91480e-3
m2   24050. 8.32154e-3
     24052. 1.60475e-1
     24053. 1.81944e-2
     24054. 4.52945e-3
```

```
     26054. 4.32510e-2
     26056. 6.72370e-1
     26057. 1.53944e-2
     26058. 2.05259e-3
     28058. 5.14835e-2
     28060. 1.96824e-2
     28061. 8.52151e-4
     28062. 2.70728e-3
     28064. 6.86246e-4
m3   92234. 5.50000e-05 92235. 7.20000e-03 92238. 9.92745e-01
m4   92234. 1.02505e-02 92235. 9.34717e-01 92238. 5.50328e-02
print
```

==> ieumt1c <==

```
Jemima #3, Idealized Model; IEU-MET-FAST-001 Case 3
c Homogenized Tu and Oy disks.
51 3 4.80323e-02 101 -103 -12
52 4 4.79707-02 103 -106 -12
53 3 4.80323e-02 106 -108 -12
54 3 4.80323e-02 108 -109 -12
55 4 4.79707-02 109 -112 -12
56 3 4.80323e-02 112 -114 -12
57 3 4.80323e-02 114 -115 -12
58 4 4.79707-02 115 -118 -12
59 3 4.80323e-02 118 -120 -12
60 3 4.80323e-02 120 -121 -12
61 4 4.79707-02 121 -124 -12
62 3 4.80323e-02 124 -126 -12
63 3 4.80323e-02 126 -127 -12
64 4 4.79707-02 127 -130 -12
65 3 4.80323e-02 130 -132 -12
66 3 4.80323e-02 132 -133 -12
67 4 4.79707-02 133 -136 -12
68 3 4.80323e-02 136 -138 -12
69 3 4.80323e-02 138 -139 -12
70 4 4.79707-02 139 -142 -12
71 3 4.80323e-02 142 -144 -12
72 3 4.80323e-02 144 -146 -10 $** tailored Tu disk **
73 4 4.79707-02 146 -149 -12
74 3 4.80323e-02 149 -151 -12
75 3 4.80323e-02 151 -153 -12
76 4 4.79707-02 153 -155 -12
77 3 4.80323e-02 155 -157 -12
78 3 4.80323e-02 157 -159 -12
79 4 4.79707-02 159 -161 -12
80 3 4.80323e-02 161 -163 -12
81 3 4.80323e-02 163 -165 -12
82 4 4.79707-02 165 -167 -12
83 3 4.80323e-02 167 -169 -12
84 3 4.80323e-02 169 -171 -12
85 4 4.79707-02 171 -173 -12
86 3 4.80323e-02 173 -175 -12
87 3 4.80323e-02 175 -177 -12
c Extra tuballoy on top (disk equiv. to three pies).
88 3 4.80323e-02 177 -179 -12
c Cells defining support structure below uranium disks.
103 1 6.02041e-02 144 -146 10 -17
106 0 201 -101 -8
107 0 202 -201 3 -8
108 1 6.02041e-02 202 -101 8 -18
110 1 6.02041e-02 203 -201 -3
111 1 6.02041e-02 205 -203 -7
112 1 6.02041e-02 204 -202 12 -14
113 0 (204 -202 3 -12) (203: 7)
114 0 204 -202 14 -21
118 1 6.02041e-02 205 -204 11 -19
119 0 205 -204 7 -11
120 2 8.63195e-02 206 -205 -20
121 0 (202 -179 12 -21) (-144: 146: 17) (101: 18)
122 0 205 -204 19 -21
```

```
123 0 206 -205 20 -21
c External cell.
200 0 -206: 179: 21

c Cylindrical surfaces defining uranium disks and surrounding supports.
3 cz 1.74625 $** rad. of upper Al filler support cylinder **
7 cz 4.60375 $** rad. of lower Al filler support cylinder **
8 cz 12.06500 $** inner radius of lower Al support ring **
10 cz 12.66939 $** idlzd. Tu/Al bndry in upper supp. ring **
11 cz 12.70000 $** o.r. unique Tu disk; i.r. spacer platform **
12 cz 13.33500 $** outer radius of uranium disks **
14 cz 13.67711 $** outer rad. of idealized Al rect. spacers **
17 cz 15.29416 $** outer edge of idlzd. Al upper supp. ring **
18 cz 15.82055 $** outer rad. of idealized lower Al ring **
19 cz 17.19650 $** outer rad. of idealized Al platform spacer **
20 cz 19.22627 $** rad. of cyl. equiv. to 12"x15" Fe plate **
21 cz 21.00000 $** inner rad. ext. cell (idealized models) **
c Horizontal planes defining uranium disks and fillers.
101 pz 0.000 $** lower surface of bottom uranium disk **
103 pz 0.604
106 pz 1.408
108 pz 2.012
109 pz 2.616
112 pz 3.420
114 pz 4.024
115 pz 4.628
118 pz 5.432
120 pz 6.036
121 pz 6.640
124 pz 7.444
126 pz 8.048
127 pz 8.652
130 pz 9.456
132 pz 10.060
133 pz 10.664
136 pz 11.468
138 pz 12.072
139 pz 12.676
142 pz 13.480
144 pz 14.084 $** parting plane **
146 pz 14.688
149 pz 15.492
151 pz 16.096
153 pz 16.700
155 pz 17.504
157 pz 18.108
159 pz 18.712
161 pz 19.516
163 pz 20.120
165 pz 20.724
167 pz 21.528
169 pz 22.132
171 pz 22.736
173 pz 23.540
175 pz 24.144
177 pz 24.748
179 pz 24.9729
c Horizontal planes defining structural support below uranium disks.
```

```
201 pz -0.3175
202 pz -0.9525
203 pz -3.1750
204 pz -4.7625
205 pz -6.0325
206 pz -8.5725

imp:n 1 52r 0
totnu
kcode 3000 1.0 40 400
ksrc 0. 0. 01.006
     8. 0. 01.006 0. 8. 01.006 -8. 0. 01.006 0. -8. 01.006
     0. 0. 03.018
     8. 0. 03.018 0. 8. 03.018 -8. 0. 03.018 0. -8. 03.018
     0. 0. 05.030
     8. 0. 05.030 0. 8. 05.030 -8. 0. 05.030 0. -8. 05.030
     0. 0. 07.042
     8. 0. 07.042 0. 8. 07.042 -8. 0. 07.042 0. -8. 07.042
     0. 0. 09.054
     8. 0. 09.054 0. 8. 09.054 -8. 0. 09.054 0. -8. 09.054
     0. 0. 11.066
     8. 0. 11.066 0. 8. 11.066 -8. 0. 11.066 0. -8. 11.066
     0. 0. 13.078
     8. 0. 13.078 0. 8. 13.078 -8. 0. 13.078 0. -8. 13.078
     8. 0. 15.090 0. 8. 15.090 -8. 0. 15.090 0. -8. 15.090
     0. 0. 15.090
     8. 0. 17.102 0. 8. 17.102 -8. 0. 17.102 0. -8. 17.102
     0. 0. 17.102
     8. 0. 19.114 0. 8. 19.114 -8. 0. 19.114 0. -8. 19.114
     0. 0. 19.114
     8. 0. 21.126 0. 8. 21.126 -8. 0. 21.126 0. -8. 21.126
     0. 0. 21.126
     8. 0. 23.138 0. 8. 23.138 -8. 0. 23.138 0. -8. 23.138
     0. 0. 23.138
c      Materials specified with atom fractions
m1   12000. 1.71000e-02 13027. 9.61193e-01 25055. 2.52173e-03
     29063. 1.32704e-2
     29065. 5.91480e-3
m2   24050. 8.32154e-3
     24052. 1.60475e-1
     24053. 1.81044e-2
     24054. 4.52945e-3
     26054. 4.32510e-2
     26056. 6.72370e-1
     26057. 1.53944e-2
     26058. 2.05259e-3
     28058. 5.14835e-2
     28060. 1.96824e-2
     28061. 8.52151e-4
     28062. 2.70728e-3
     28064. 6.86246e-4
m3   92234. 5.50000e-05 92235. 7.20000e-03 92238. 9.92745e-01
m4   92234. 1.02504e-02 92235. 9.34915e-01 92238. 5.48350e-02
print
```

==> ieumt1d <==

```
Jemima  #4, Idealized Model; IEU-MET-FAST-001 Case 4
c Note ... no uranium fillers.
1 0 101 -180 -2
c Uranium disks (without fillers).
51 3 4.80510e-02 101 -103 2 -12
52 4 4.79730e-02 103 -106 2 -12
53 3 4.80510e-02 106 -108 2 -12
54 3 4.80510e-02 108 -109 2 -12
55 4 4.79730e-02 109 -112 2 -12
56 3 4.80510e-02 112 -114 2 -12
57 3 4.80510e-02 114 -115 2 -12
58 4 4.79730e-02 115 -118 2 -12
59 3 4.80510e-02 118 -120 2 -12
60 3 4.80510e-02 120 -121 2 -12
61 4 4.79730e-02 121 -124 2 -12
62 3 4.80510e-02 124 -126 2 -12
63 3 4.80510e-02 126 -127 2 -12
64 4 4.79730e-02 127 -130 2 -12
65 3 4.80510e-02 130 -132 2 -12
66 3 4.80510e-02 132 -133 2 -12
67 4 4.79730e-02 133 -136 2 -12
68 3 4.80510e-02 136 -138 2 -12
69 3 4.80510e-02 138 -139 2 -12
70 4 4.79730e-02 139 -142 2 -12
71 3 4.80510e-02 142 -144 2 -12
72 3 4.80510e-02 144 -146 2 -10 $** tailored Tu disk **
73 4 4.79730e-02 146 -149 2 -12
74 3 4.80510e-02 149 -151 2 -12
75 3 4.80510e-02 151 -153 2 -12
76 4 4.79730e-02 153 -155 2 -12
77 3 4.80510e-02 155 -157 2 -12
78 3 4.80510e-02 157 -159 2 -12
79 4 4.79730e-02 159 -161 2 -12
80 3 4.80510e-02 161 -163 2 -12
81 3 4.80510e-02 163 -165 2 -12
82 4 4.79730e-02 165 -167 2 -12
83 3 4.80510e-02 167 -169 2 -12
84 3 4.80510e-02 169 -171 2 -12
85 4 4.79730e-02 171 -173 2 -12
86 3 4.80510e-02 173 -175 2 -12
87 3 4.80510e-02 175 -177 2 -12
88 4 4.79730e-02 177 -179 2 -12
c Extra tuballoy on top (disk equiv. to six pies).
89 3 4.80510e-02 179 -180 2 -12
c Cells defining support structure below uranium disks.
103 1 6.02041e-02 144 -146 10 -17
106 0 201 -101 -8
107 0 202 -201 3 -8
108 1 6.02041e-02 202 -101 8 -18
110 1 6.02041e-02 203 -201 -3
111 1 6.02041e-02 205 -203 -7
112 1 6.02041e-02 204 -202 12 -14
113 0 (204 -202 3 -12) (203: 7)
114 0 204 -202 14 -21
118 1 6.02041e-02 205 -204 11 -19
119 0 205 -204 7 -11
```

```
120 2 8.63195e-02 206 -205 -20
121 0 (202 -180 12 -21) (-144: 146: 17) (101: 18)
122 0 205 -204 19 -21
123 0 206 -205 20 -21
c External cell.
200 0 -206: 180: 21

c Cylindrical surfaces defining uranium disks and surrounding supports.
2 cz 1.11125 $** inner radius of uranium disks **
3 cz 1.74625 $** rad. of upper Al filler support cylinder **
7 cz 4.60375 $** rad. of lower Al filler support cylinder **
8 cz 12.06500 $** inner radius of lower Al support ring **
10 cz 12.66939 $** idlzd. Tu/Al bndry in upper supp. ring **
11 cz 12.70000 $** o.r. unique Tu disk; i.r. spacer platform **
12 cz 13.33500 $** outer radius of uranium disks **
14 cz 13.67711 $** outer rad. of idealized Al rect. spacers **
17 cz 15.29416 $** outer edge of idlzd. Al upper supp. ring **
18 cz 15.82055 $** outer rad. of idealized lower Al ring **
19 cz 17.19650 $** outer rad. of idealized Al platform spacer **
20 cz 19.22627 $** rad. of cyl. equiv. to 12"x15" Fe plate **
21 cz 21.00000 $** inner rad. ext. cell (idealized models) **
c Horizontal planes defining uranium disks and fillers.
101 pz 0.000 $** lower surface of bottom uranium disk **
103 pz 0.604
106 pz 1.408
108 pz 2.012
109 pz 2.616
112 pz 3.420
114 pz 4.024
115 pz 4.628
118 pz 5.432
120 pz 6.036
121 pz 6.640
124 pz 7.444
126 pz 8.048
127 pz 8.652
130 pz 9.456
132 pz 10.060
133 pz 10.664
136 pz 11.468
138 pz 12.072
139 pz 12.676
142 pz 13.480
144 pz 14.084 $** parting plane **
146 pz 14.688
149 pz 15.492
151 pz 16.096
153 pz 16.700
155 pz 17.504
157 pz 18.108
159 pz 18.712
161 pz 19.516
163 pz 20.120
165 pz 20.724
167 pz 21.528
169 pz 22.132
171 pz 22.736
173 pz 23.540
```

```
175 pz 24.144
177 pz 24.748
179 pz 25.552
180 pz 26.005
c Horizontal planes defining structural support below uranium disks.
201 pz -0.3175
202 pz -0.9525
203 pz -3.1750
204 pz -4.7625
205 pz -6.0325
206 pz -8.5725

imp:n 1 54r 0
totnu
kcode 3000 1.0 40 400
ksrc 8. 0. 01.006 0. 8. 01.006 -8. 0. 01.006 0. -8. 01.006
     8. 0. 03.018 0. 8. 03.018 -8. 0. 03.018 0. -8. 03.018
     8. 0. 05.030 0. 8. 05.030 -8. 0. 05.030 0. -8. 05.030
     8. 0. 07.042 0. 8. 07.042 -8. 0. 07.042 0. -8. 07.042
     8. 0. 09.054 0. 8. 09.054 -8. 0. 09.054 0. -8. 09.054
     8. 0. 11.066 0. 8. 11.066 -8. 0. 11.066 0. -8. 11.066
     8. 0. 13.078 0. 8. 13.078 -8. 0. 13.078 0. -8. 13.078
     8. 0. 15.090 0. 8. 15.090 -8. 0. 15.090 0. -8. 15.090
     8. 0. 17.102 0. 8. 17.102 -8. 0. 17.102 0. -8. 17.102
     8. 0. 19.114 0. 8. 19.114 -8. 0. 19.114 0. -8. 19.114
     8. 0. 21.126 0. 8. 21.126 -8. 0. 21.126 0. -8. 21.126
     8. 0. 23.138 0. 8. 23.138 -8. 0. 23.138 0. -8. 23.138
c      Materials specified with atom fractions
m1   12000. 1.71000e-02 13027. 9.61193e-01 25055. 2.52173e-03
     29063. 1.32704e-2
     29065. 5.91480e-3
m2   24050. 8.32154e-3
     24052. 1.60475e-1
     24053. 1.81944e-2
     24054. 4.52945e-3
     26054. 4.32510e-2
     26056. 6.72370e-1
     26057. 1.53944e-2
     26058. 2.05259e-3
     28058. 5.14835e-2
     28060. 1.96824e-2
     28061. 8.52151e-4
     28062. 2.70728e-3
     28064. 6.86246e-4
m3   92234. 5.50000e-05 92235. 7.20000e-03 92238. 9.92745e-01
m4   92234. 1.02504e-02 92235. 9.34915e-01 92238. 5.48350e-02
print
```

==> ieumt2 <==

```
Jemima, Idealized Natural U reflected stack of Natural U and HEU plates;
c IEU-MET-FAST-002
1 1 4.753313e-2 2 -3 -5
2 2 4.80596733e-2 1 -4 -6 #1
3 0 -1:4:6

1 pz 0
2 pz 7.62
3 pz 39.571
4 pz 47.0894
5 cz 19.05
6 cz 26.6446

imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
sdef erg=d1 rad=d2 ext=d3 pos 0 0 23.5447 axs 0 0 1
sp1 -3 .988 2.249
si2 0 26.6446
si3 23.5447
c      Materials specified with atom densities
m1   92234. 8.4430e-5 92235. 7.7777e-3 92238. 3.9671e-2
m2   92234. 2.6433e-6 92235. 3.4603e-4 92238. 4.7711e-2
print
```

==> ieumt3 <==

```
IEU Uranium (36 wt.%) Bare Sphere, VNIIEF; IEU-MET-FAST-003
C ENDF/B-V cross sections, W split by atomic abundance
C W-180 fraction added to W-182 because of cross sections
C Cell Cards
1 1 4.8180e-2 -1
2 0 1

C Surface Cards
1 so 15.324

C Data Cards
imp:n 1 0
totnu
kcode 3000 1.0 40 400
ksrc 0 0 0
c      Materials specified with atom densities
m1   92234. 1.5272e-4 92235. 1.7118e-2 92238. 2.9211e-2
     26054. 7.11422e-6
     26056. 1.10596e-4
     26057. 2.53218e-6
     26058. 3.37624e-7
     6000. 7.7389e-4
     29063. 2.63766e-4
     29065. 1.17564e-4
     28058. 2.81873e-4
     28060. 1.07762e-4
```

```
     28061. 4.66554e-6
     28062. 1.48224e-5
     28064. 3.75721e-6
     74182. 2.6650e-6
     74183. 1.4404e-6
     74184. 3.0967e-6
     74186. 2.8849e-6
print
```

==> ieumt4 <==

```
Graphite Reflected IEU sphere (36 wt.%), VNIIEF; IEU-MET-FAST-004
C ENDF/B-v Cross sections, W splitup by atomic abundance
C W-180 fraction added to W-182 because of cross sections
C Graphite thermal S(alpha,Beta) treatment applied at 300K
C Cell cards
1 0 -1
2 1 4.7991e-2 1 -2
3 2 7.7716e-2 2 -3
4 0 3

C Surface Cards
1 so 2.788
2 so 14.00
3 so 17.2

C Data Cards
imp:n 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 6 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 1.5652e-4
     92235. 1.7384e-2
     92238. 2.9662e-2
     6000. 6.5752e-4
     26054. 7.13782e-6
     26056. 1.10963e-4
     26057. 2.54058e-6
     26058. 3.38744e-7
     74182. 2.6740e-6
     74183. 1.4453e-6
     74184. 3.1071e-6
     74186. 2.8946e-6
m2   6000. 7.7716e-2
mt2 grph.01t
```

==> ieumt5 <==

```
Steel Reflected IEU sphere (36 wt.%), VNIIEF; IEU-MET-FAST-005
C ENDF/B-V cross sections, W splitup by atmomic abundance
C W-180 fraction added to W-182 because of cross sections
C All Mn taken to Mn-55, the only stable isotope
C Cell Cards
1 0 -1
2 1 4.7948e-2 1 -2
3 2 8.1601e-2 2 -3
4 3 8.2736e-2 3 -4
5 0 4

C Surface Cards
1 so 2.686
2 so 13.25
3 so 15.00
4 so 21.50

C Data Cards
imp:n 1 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 3 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 1.5511e-4
     92235. 1.7154e-2
     92238. 2.9297e-2
     26054. 7.27116e-6
     26056. 1.13036e-4
     26057. 2.58804e-6
     26058. 3.45072e-7
     6000. 6.4945e-4
     29063. 1.85313e-4
     29065. 8.25967e-5
     28058. 1.98038e-4
     28060. 7.57109e-5
     28061. 3.27790e-6
     28062. 1.04139e-5
     28064. 2.63973e-6
     74182. 2.8298e-6
     74183. 1.5295e-6
     74184. 3.2883e-6
     74186. 3.0633e-6
m2   26054. 4.67782e-3
     26056. 7.27202e-2
     26057. 1.66499e-3
     26058. 2.21998e-4
     6000. 1.1251e-3
     14000. 1.6038e-4
     24050. 1.12922e-5
     24052. 2.17762e-4
     24053. 2.46896e-5
     24054. 6.14640e-6
     25055. 3.2796e-4
     28058. 1.57192e-4
     28060. 6.00953e-5
```

```
     28061. 2.60183e-6
     28062. 8.26598e-6
     28064. 2.09528e-6
     29063. 1.47090e-4
     29065. 6.55600e-5
m3   26054. 4.74289e-3
     26056. 7.37319e-2
     26057. 1.68815e-3
     26058. 2.25086e-4
     6000. 1.1407e-3
     14000. 1.6261e-4
     24050. 1.14495e-5
     24052. 2.20795e-4
     24053. 2.50335e-5
     24054. 6.23201e-6
     25055. 3.3253e-4
     28058. 1.59376e-4
     28060. 6.09305e-5
     28061. 2.63799e-6
     28062. 8.38086e-6
     28064. 2.12330e-6
     29063. 1.49137e-4
     29065. 6.64726e-5
```

==> ieumt6 <==

```
Duralumin Reflected IEU sphere (36 wt.%), VNIIEF; IEU-MET-FAST-006
C Cell Cards
1 0 -1
2 1 4.7966e-2 1 -2
3 2 5.4286e-2 2 -3
4 3 5.4001e-2 3 -4
5 0 4

C Surface Cards
1 so 2.100
2 so 13.25
3 so 15.00
4 so 25.00

C Data Cards
imp:n 1 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 3 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 1.5518e-4
     92235. 1.7161e-2
     92238. 2.9310e-2
     26054. 7.28355e-6
     26056. 1.13228e-4
     26057. 2.59245e-6
     26058. 3.45660e-7
     6000. 6.4888e-4
```

```
     29063. 1.85964e-4
     29065. 8.24857e-5
     28058. 1.97771e-4
     28060. 7.56091e-5
     28061. 3.27350e-6
     28062. 1.03999e-5
     28064. 2.63618e-6
     74182. 2.8325e-6
     74183. 1.5310e-6
     74184. 3.2913e-6
     74186. 3.0662e-6
m2   13027. 5.2342e-2
     26054. 5.65149e-5
     26056. 8.78568e-4
     26057. 2.01155e-5
     26058. 2.68206e-6
     29063. 6.82113e-4
     29065. 3.04027e-4
m3   13027. 5.2067e-2
     26054. 5.62187e-5
     26056. 8.73963e-4
     26057. 2.00101e-5
     26058. 2.66801e-6
     29063. 6.78537e-4
     29065. 3.02433e-4
```

Appendix C

Highly Enriched ^{235}U Criticality Benchmark Input Decks for MCNP

==> umet1ss <==

```
c     Godiva : CSEWG-F5 and ICSBEP HEU-MET-FAST-001
c     Simple sphere representation
1     1 0.047984  -1
2     0          +1

1      so 8.7407

mode   n
imp:n  1 0
ksrc   0. 0. 0.
kcode  3000 1.0 40 400
totnu

print
c      Materials specified with atom fractions – CSEWG specs
c      m1     92234. 0.010252 92235. 0.937695 92238. 0.052053
c
c      Materials specified with atom densities
m1     92234.  4.9184e-4  92235.  4.4994e-2  92238.  2.4984e-3
```

==> umet1ns <==

```
HEU-MET-FAST-001:  Godiva with nested spherical shells of HEU
1     1 4.8150e-2   -1    imp:n=1
2     7 5.0306e-5  1 -2   imp:n=1
3     2 4.8154e-2  2 -3   imp:n=1
4     7 5.0306e-5  3 -4   imp:n=1
5     3 4.8154e-2  4 -5   imp:n=1
6     7 5.0306e-5  5 -6   imp:n=1
7     4 4.8152e-2  6 -7   imp:n=1
8     7 5.0306e-5  7 -8   imp:n=1
9     5 4.8154e-2  8 -9   imp:n=1
10    6 4.7780e-2  9 -10  imp:n=1
11    0            10     imp:n=0

1    so  1.0216
2    so  1.0541
3    so  6.2809
4    so  6.2937
5    so  7.7525
6    so  7.7620
7    so  8.2527
8    so  8.2610
9    so  8.7062
10   so  8.7499

ksrc   0.0  0.0  0.0
kcode  3000 1.0 40 400
print
c      Materials specified with atom densities
m1   92235.  4.4936e-2  92238.  2.7213e-3  92234.  4.9357e-4
m2   92235.  4.5244e-2  92238.  2.4168e-3  92234.  4.9357e-4
m3   92235.  4.5268e-2  92238.  2.3930e-3  92234.  4.9357e-4
```

```
m4   92235.  4.5090e-2  92238.  2.5690e-3  92234.  4.9357e-4
m5   92235.  4.5239e-2  92238.  2.4215e-3  92234.  4.9357e-4
m6   92235.  4.4874e-2  92238.  2.4169e-3  92234.  4.8974e-4
m7    7014.  3.5214e-5   8016.  1.5092e-5
```

==> bigten1 <==

```
Bigten, CSEWG-F20, 1d model: U(N) reflected uranium sphere
1    1  0.04757  -1         imp:n=1
2    2  0.04807  +1 -2      imp:n=1
4    0           +2         imp:n=0

1    so  30.48
2    so  45.72

ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print

c      Materials specified with atom fractions
m1   92234. 0.00105  92235. 0.10175 92238. 0.8972
m2   92235. 0.00208  92238. 0.99792
```

==> bigten2 <==

```
Bigten, CSEWG-F20, 2d model: U(N) reflected uranium cylinder
1    1  0.04757  (-1 -4 +5)       imp:n=1
2    2  0.04807  (-2 -3 +6) #1    imp:n=1
3    0           +2:+3:-6         imp:n=0

1    cz  26.67
2    cz  41.91
3    pz  48.26
4    pz  27.94
5    pz -27.94
6    pz -48.26

ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print

c      Materials specified with atom fractions
m1   92234. 0.00105  92235. 0.10175 92238. 0.8972
m2   92235. 0.00208  92238. 0.99792
```

==> umet3a <==

```
Topsy 2-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.7820
2 so 11.8620

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3b <==

```
Topsy 3-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.4423
2 so 14.0623

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3c <==

```
Topsy 4-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.2851
2 so 16.4451

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3d <==

```
Topsy 5-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.1535
2 so 18.8535

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3e <==

```
Topsy 7-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.0740
2 so 23.8540

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3f <==

```
Topsy 8-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.0509
2 so 26.3709

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3g <==

```
Topsy 11-in Tu tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 4.8009e-02 -1 imp:n=1
2 2 4.7817e-02 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.0276
2 so 33.9676

c      Materials specified with atom densities
m1   92235. 4.4917e-02 92238. 2.5993e-03 92234. 4.9210e-04
m2   92235. 3.4428e-04 92238. 4.7470e-02 92234. 2.6299e-06
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3h <==

```
1.9" WC tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 0.048009 -1 imp:n=1
2 2 0.096114 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.6020
2 so 11.4280

c      Materials specified with atom densities
m1   92234. 4.9210e-04
     92235. 4.4917e-02
     92238. 2.5993e-03
m2   6000. 4.8057e-02
     74182. 1.2697e-02
     74183. 6.8626e-03
     74184. 1.4754e-02
     74186. 1.3744e-02
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3i <==

```
2.9" WC tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 0.048009 -1 imp:n=1
2 2 0.096114 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.2527
2 so 13.6187

c      Materials specified with atom densities
m1   92234. 4.9210e-04
```

```
     92235. 4.4917e-02
     92238. 2.5993e-03
m2   6000. 4.8057e-02
     74182. 1.2697e-02
     74183. 6.8626e-03
     74184. 1.4754e-02
     74186. 1.3744e-02
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3j <==

```
4.5" WC tamper Sphere from LA-1114 : HEU-MET-FAST-003
 1 1 0.048009 -1 imp:n=1
2 2 0.096114 1 -2 imp:n=1
3 0 2 imp:n=0

 1 so 6.0509
 2 so 17.4809

c      Materials specified with atom densities
m1   92234. 4.9210e-04
     92235. 4.4917e-02
     92238. 2.5993e-03
m2   6000. 4.8057e-02
     74182. 1.2697e-02
     74183. 6.8626e-03
     74184. 1.4754e-02
     74186. 1.3744e-02
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3k <==

```
6.5" WC tamper Sphere from LA-1114: HEU-MET-FAST-003
 1 1 0.048009 -1 imp:n=1
 2 2 0.096114 1 -2 imp:n=1
 3 0 2 imp:n=0

 1 so 6.0159
 2 so 22.5259

c      Materials specified with atom densities
m1   92234. 4.9210e-04
     92235. 4.4917e-02
     92238. 2.5993e-03
m2   6000. 4.8057e-02
     74182. 1.2697e-02
     74183. 6.8626e-03
     74184. 1.4754e-02
```

```
     74186. 1.3744e-02
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet3l <==

```
8.0" Ni tamper Sphere from LA-1114: HEU-MET-FAST-003
1 1 0.048009 -1 imp:n=1
2 2 0.091322 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 6.4627
2 so 26.7827

c      Materials specified with atom densities
m1   92234. 4.9210e-04
     92235. 4.4917e-02
     92238. 2.5993e-03
m2   28058. 6.23455-2
     28060. 2.38350-2
     28061. 1.03194-3
     28062. 3.27846-3
     28064. 8.31030-4
kcode 3000 1.0 40 400
ksrc 0. 0. 0.
print
```

==> umet4a <==

```
Idealized HEU sphere (97.675 w/o) on Plexiglas ring in H2O: HEU-MET-FAST-004
1 1 0.048143 -1 $ HEU sphere
2 2 0.10827 5 -6 -7 8 $ seat as hollow cyl.
3 3 0.10021 1 2 -3 -4 #2 $ water
4 0 -2:3:4

1 so 6.5537 $ radius of HEU sphere
2 pz -32.500 $ lower surface of water
3 cz 30.000 $ outer radius of water
4 pz 23.054 $ upper surface of water
5 cz 3.974 $ inner radius of seat
6 cz 12.700 $ outer radius of seat
7 pz -5.212 $ top of seat
8 pz -7.752 $ bottom of seat

mode n
kcode 3000 1.0 40 400
imp:n 1.0 2r 0.0
sdef cel=1 erg=d1 rad=d2 pos=0.0 0.0 0.0
sp1 -3
si2 0.0 0.65537
sp2 -21 2
```

```
vol  1179.1 1161.0 154735. 0.0
area 539.74 2827.4 10472. 2827.4 63.422
     202.68 457.09 457.09
c HEU (97.675 w/o)
c      Materials specified with atom fractions
m1   92234. 0.011150
     92235. 0.97694
     92236. 0.0019919
     92238. 0.0099250
c Plexiglas
m2   1001. 0.53334
     6000. 0.33333
     8016. 0.13333
c Water
m3   1001. 0.66667
     8016. 0.33333
mt3  lwtr.01t
print
```

==> umet4b <==

```
Water reflected uranium sphere, Trans. Am. Nuc. Soc. 27, pg. 412 (1977)
1     1 0.04815 -1        imp:n=1
2     2 0.10019 1 -2 -3 4 imp:n=1
3     0 +2:+3:-4          imp:n=0

1     so 6.5537
2     cy 30
3     py 35
4     py -35

c
c  For 1-D model, use a sphere of water having radius of 33.471 cm
c  Case 1 of HEU-MET-FAST-004 uses a density for material 1 of 0.048143
c
ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print

c      Materials specified with atom fractions
m1    92234. 0.01101 92235. 0.97674 92236. 0.00207
      92238. 0.01018
m2    1001. 0.66667 8016. 0.33333
mt2   lwtr.01t
```

==> umet8 <==

```
Bare HEU Sphere, VNIITF: HEU-MET-FAST-008
1 0 -1 -10 $ cavity
2 0 12 -2 $ cav
3 1 4.7319e-2 1 -3 7 -10 $bottom inner U
4 1 4.7319e-2 2 -4 8 12 16 $ top inner U
5 2 4.8146e-2 3 -5 -10 16 $ bottom outer U
6 2 4.8146e-2 4 -6 12 16 $ top outer U
7 0 1 -3 -7 -10 $bottom groove
8 0 2 -4 -8 12 $ top groove
9 0 10 -11 -15 $ gap
10 3 8.1174e-2 11 -12 -20 17 $ diaphragm Fe
11 0 5 -15 -10 13 $ bottom outside
12 0 6 -15 12 $top outside
13 4 8.2365e-2 18 -9 -13 -10 $Cu cup
14 3 8.1174e-2 9 19 -14 -10 $ Fe cylinder
15 0 9 -15 14 -13 -10 $void under Cu cup
16 0 3 -5 -16 -10 $ bottom polar hole
17 0 2 -6 -16 12 $ top polar hole
18 0 11 -12 -17 $diaphr hole
19 0 5 -13 -18 -10 $ gap over cup
20 0 -14 -15 -19 $ void under cyl
21 0 11 -12 -15 20 $void outside diaphragm
22 0 15 $ outside

1 so 2
2 sz 1.207 2
3 so 9.15
4 sz 1.207 9.15
5 so 10.15
6 sz 1.207 10.15
7 cy 0.6
8 c/y 0 1.207 0.6
9 so 10.44
10 pz 0
11 pz 1.007
12 pz 1.207
13 cz 8.7
14 cz 2.5
15 so 16
16 cz 1.1
17 cz 9.8
18 so 10.29
19 pz -14.74
20 cz 15

imp:n 1 20r 0
totnu
kcode 3000 1.0 40 400
ksrc 0 0 -3
c      Materials specified with atom densities
m1   92235. 4.1031e-2 92238. 4.1021e-3 92234. 5.2273e-4
     92236. 8.8071e-5 6000. 3.8642e-4
     26054. 8.00158e-6
     26056. 1.24391e-4
     26057. 2.84802e-6
     26058. 3.79736e-7
```

```
     74182.  3.26515e-06
     74183.  1.77286e-06
     74184.  3.81141e-06
     74186.  3.55069e-06
     28058. 2.25025e-4
     28060. 8.60282e-5
     28061. 3.72459e-6
     28062. 1.18330e-5
     28064. 2.99945e-6
     29063. 4.91321e-4
     29065. 2.18989e-4
m2   92235. 4.2698e-2 92238. 4.0143e-3 92234. 5.3154e-4
     92236. 1.7489e-4 6000. 1.4403e-4
     26054. 2.24035e-6
     26056. 3.48279e-5
     26057. 7.97412e-7
     26058. 1.06322e-7
     13027. 5.4473e-4
     74182.  1.59662e-07
     74183.  8.66910e-08
     74184.  1.86374e-07
     74186.  1.73625e-07
m3   26054. 4.78927e-3
     26056. 7.44528e-2
     26057. 1.70465e-3
     26058. 2.27287e-4
m4   29063. 5.69719e-2
     29065. 2.53931e-2
```

==> umet9a <==

```
Be-Reflected HEU Sphere, Keff=0.9972+-0.0006: HEU-MET-FAST-009
1 0 -17 -3 $ equ hole
2 0 -16 6 -8 12 $polar hole in Refl
3 1 4.7328-2 -3 17 $U sphere
4 0 3 -4 12 $spheric crit gap
5 1 4.7328-2 3 -5 -10 17 $ bottom U
6 1 4.7328-2 4 -6 12 18 $top U
7 2 1.2103-1 5 -7 -19 $ bot refl
8 2 1.2103-1 6 -8 20 16 $top refl
9 0 3 10 -11 -15 $ crit gap
10 3 8.1174-2 2 11 -12 -15 $ diaphr
11 0 7 -15 -10 13 21 $bot void
12 0 8 -15 12 -22 $top void
13 4 8.2365-2 7 -9 -13 -10 $ Cu cup
14 3 8.1174-2 9 -15 -14 -10 21 $ Fe shaft
15 0 9 -15 14 -13 -10 21 $bot void 2
16 0 3 -2 11 -12 $ void in diaphr
17 0 5 -7 19 -10 $ bot Be cut
18 0 6 -8 12 -20 $top Be cut
19 0 -10 3 -5 -17 $ bot U groove
20 0 4 -6 12 -18 $ top U groove
23 0 15:-21:22$out

2 cz 7.75
3 so 7.55
```

```
4 sz 2.06 7.55
5 so 8.35
6 sz 2.06 8.35
7 so 11
8 sz 2.06 11
9 so 11.15
10 pz 0
11 pz 1.86
12 pz 2.06
13 cz 9.7
14 cz 2.5
15 cz 14
16 cz 1.1
17 cy 0.6
18 c/y 0 2.06 0.6
19 pz -0.15
20 pz 2.21
21 pz -14.15
22 pz 14

imp:n 1 19r 0
kcode 3000 1.0 40 400
ksrc 0 0 3
c      Materials specified with atom densities
m1   92235. 4.1000-2 92238. 4.0977-3 92234. 5.2195-4
     92236. 8.8422-5 6000. 3.9932-4
     29063. 5.07251-4
     29065. 2.26089-4
     26054. 7.98329-6
     26056. 1.24106-4
     26057. 2.84151-6
     26058. 3.78868-7
     28058. 2.32316-4
     28060. 8.88157-5
     28061. 3.84528-6
     28062. 1.22164-5
     28064. 3.09664-6
     74182. 3.2730-6 74183. 1.7771-6 74184. 3.8206-6
     74186. 3.5593-6
m2   4009. 1.2080-1 6000. 1.0019-4 8016. 8.2053-5
     26054. 3.00499-6
     26056. 4.67148-5
     26057. 1.06957-6
     26058. 1.42610-7
mt2  be.01t
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   29063. 5.69719-2
     29065. 2.53931-2
c
c CUT:N and PHYS:N cards removed
c cut:n 1e5 0
c phys:n 20 1e-6
```

==> umet9b <==

```
BeO-Reflected Sphere, Keff=0.9992+/- 0.0015: HEU-MET-FAST-009
1 0 1 -3 -17 $ equat hole
2 0 -16 6 -8 12 $polar hole in Refl
3 1 4.7335-2 1 -3 17 $U sphere
4 0 3 -4 12 $spheric crit gap
5 1 4.7335-2 3 -5 -10 17 $ bottom U
6 1 4.7335-2 4 -6 12 18 $top U
7 2 1.3527-1 5 -7 -19 $ bot refl
8 2 1.3527-1 6 -8 20 16 $top refl
9 0 3 10 -11 -15 $ crit gap
10 3 8.1174-2 2 11 -12 -15 $ diaphr
11 0 7 -15 -10 13 21 $bot void
12 0 8 -15 12 -22 $top void
13 4 8.2365-2 7 -9 -13 -10 $ Cu cup
14 3 8.1174-2 9 21 -14 -10 $ Fe shaft
15 0 9 -15 14 -13 -10 21 $bot void 2
16 0 3 -2 11 -12 $ void gap
17 0 5 -7 19 -10 $ bot Be cut
18 0 6 -8 12 -20 $top Be cut
19 0 -10 3 -5 -17 $ bot U groove
20 0 4 -6 12 -18 $ top U groove
21 0 -1 $ central cavity
23 0 15:-21:22 $out

1 so 1.4
2 cz 7.75
3 so 7.55
4 sz 2.74 7.55
5 so 8.35
6 sz 2.74 8.35
7 so 11
8 sz 2.74 11
9 so 11.15
10 pz 0
11 pz 2.54
12 pz 2.74
13 cz 9.7
14 cz 2.5
15 cz 14
16 cz 1.1
17 cy 0.6
18 c/y 0 2.74 0.6
19 pz -0.15
20 pz 2.89
21 pz -14.15
22 pz 14

imp:n 1 20r 0
kcode 3000 1.0 40 400
ksrc 0 0 -3
c      Materials specified with atom densities
m1   92235. 4.1011-2 92238. 4.0989-3 92234. 5.2209-4
     92236. 8.8453-5
     6000. 3.9946-4
     29063. 5.04471-4
```

```
     29065. 2.24849-4
     26054. 7.98624-6
     26056. 1.24152-4
     26057. 2.84256-6
     26058. 3.79008-7
     28058. 2.31046-4
     28060. 8.83302-5
     28061. 3.82426-6
     28062. 1.21496-5
     28064. 3.07971-6
     74182.  3.27435e-06  74183.  1.77786e-06  74184.  3.82215e-06
     74186.  3.56070e-06
m2   4009. 6.7634-2 8016. 6.7634-2
mt2  beo.01t
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   29063. 5.69719-2
     29065. 2.53931-2
c
c CUT:N and PHYS:N cards removed
c cut:n 1e5 0
c phys:n 20 1e-6
c
```

==> umet11 <==

```
CH2 Reflected HEU sphere: HEU-MET-FAST-011
1 0 -2 $ central cavity
3 1 4.7392-2 2 -3 $ core
4 0 3 -4 11 $ spheric gap
5 0 3 -5 6 -11 $ diaphr void
6 0 3 -6 10 -14 $ gap
7 2 1.1714-1 3 -7 -10 $ bottom refl
8 2 1.1714-1 4 -8 11 $ top refl
9 3 8.1174-2 5 6 -11 -14 $diaphr
11 0 7 -10 -14 $ bot void
12 0 8 11 -14 $ top void
15 0 14 $ outer

2 so 2
3 so 7.55
4 sz 1.96 7.55
5 cz 8.5
6 pz 1.66
7 so 18
8 sz 1.96 18
10 pz 0
11 pz 1.96
14 so 21.5

imp:n 1 9r 0
kcode 3000 1.0 40 400
ksrc 0 0 -3
c      Materials specified with atom densities
```

```
m1   92235. 4.1018-2 92238. 4.0942-3 92234. 5.1969-4
     92236. 8.9938-5 6000. 4.0450-4
     26054. 8.41989-6
     26056. 1.30894-4
     26057. 2.99691-6
     26058. 3.99588-7
     74182.  3.25989e-06
     74183.  1.77001e-06
     74184.  3.80527e-06
     74186.  3.54497e-06
     29063. 5.24908-4
     29065. 2.33972-4
     28058. 2.40420-4
     28060. 9.19138-5
     28061. 3.97941-6
     28062. 1.26425-5
     28064. 3.20466-6
m2   6000. 3.9047-2 1001. 7.8094-2
mt2  poly.01t
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
c   CUT:N and PHYS:N cards removed
```

==> umet12 <==

```
Al Reflected HEU Sphere: HEU-MET-FAST-012
1 0 -1 -14 16 $ source cavity
2 0 -1 3 -5 -10 $ bottom equat hollow
3 1 4.7297e-2 -3 #1 $ core
4 0 3 -4 11 $ crescent gap
5 1 4.7297e-2 1 3 -5 -10 $ bot shell
6 1 4.7297e-2 4 -6 11 18 $ top shell
7 2 5.8566e-2 5 -7 -10 $ bott refl
8 2 5.8566e-2 6 -8 11 $ top shell
9 0 -2 3 -11 17 $ diaphr void
10 3 8.1174e-2 2 -11 -15 17 $ diaphragm
11 0 7 -10 12 -15 $ bot void
12 0 8 11 -15 $ top void
13 4 8.2365e-2 7 -9 -10 -12 $ cup
14 3 8.1174e-2 9 -10 -13 -15 $ shaft
15 0 9 -10 -12 13 -15 $ under cup
16 0 4 -6 11 -18 $ top equa hollow
17 0 3 10 -15 -17 $ gap
18 0 15 $

1 cy 0.6
2 cz 7.75
3 so 7.55
4 sz 1.17 7.55
5 so 9.15
6 sz 1.17 9.15
7 so 10
8 sz 1.17 12
9 so 10.15
```

```
10 pz 0
11 pz 1.17
12 cz 8.7
13 cz 2.5
14 py 0.5
15 so 14
16 py -0.5
17 pz 0.97
18 c/y 0 1.17 0.6

imp:n 1 16r 0
kcode 3000 1.0 40 400
ksrc 0 0 -1
c      Materials specified with atom densities
m1   92235.50 4.0999e-2 92238.50 4.0989e-3 92234.50 5.2246e-4
     92236.50 8.7970-5 6000.50 3.8652e-4
     26054. 7.99096-6
     26056. 1.24226-4
     26057. 2.84424-6
     26058. 3.79232-7
     74182. 3.26488e-06
     74183. 1.77272e-06
     74184. 3.81110e-06
     74186. 3.55040e-06
     29063. 4.98363-4
     29065. 2.22127-4
     28058. 2.28247-4
     28060. 8.72601-5
     28061. 3.77793-6
     28062. 1.20024-5
     28064. 3.04240-6
m2   13027. 5.8566-2
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   29063. 5.69719-2
     29065. 2.53931-2
c  CUT:N and PHYS:N cards removed


==> umet13 <==

Fe (Steel) Reflected HEU Sphere:  HEU-MET-FAST-013
1 0 -1
2 0 1 -3 -14
3 1 4.7336e-2 1 -3 14
4 0 3 -4 11
5 1 4.7336e-2 3 -5 -10 14
6 1 4.7336e-2 4 -6 11 16
7 2 8.4191e-2 5 -7 -10
8 2 8.4191e-2 6 -8 11
9 0 -2 3 10 -11
10 3 8.1174e-2 2 10 -11 -15
11 0 7 -15 -10 12
12 0 8 11 -15
13 4 8.2365e-2 7 -9 -12 -10
```

```
14 3 8.1174e-2 9 -15 -13 -10
15 0 9 -15 -12 13 -10
16 0 3 -5 -10 -14
17 0 4 -6 11 -16
18 0 15

1 so 1.4
2 cz 7.75
3 so 7.55
4 sz 0.2 7.55
5 so 8.35
6 sz 0.2 8.35
7 so 12
8 sz 0.2 12
9 so 12.15
10 pz 0
11 pz 0.2
12 cz 9.7
13 cz 2.5
14 cy 0.6
15 so 15
16 c/y 0 0.2 0.6

imp:n 1 16r 0
kcode 3000 1.0 40 400
ksrc 0 0 -2
c      Materials specified with atom densities
m1   92235. 4.1011-2 92238. 4.0989-3 92234. 5.2209-4
     92236. 8.8453-5 6000. 3.9946-4
     29063. 5.04471-4
     29065. 2.24849-4
     26054. 7.98624-6
     26056. 1.24152-4
     26057. 2.84256-6
     26058. 3.79008-7
     28058. 2.31046-4
     28060. 8.83302-5
     28061. 3.82426-6
     28062. 1.21496-5
     28064. 3.07971-6
     74182.  3.27435e-06
     74183.  1.77786e-06
     74184.  3.82215e-06
     74186.  3.56070e-06
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   29063. 5.69719-2
     29065. 2.53931-2
m2   26054. 4.87075-3
     26056. 7.57194-2
     26057. 1.73366-3
     26058. 2.31154-4
     6000. 7.7554-4 14000. 3.4825-4
     24050. 2.91901-6
     24052. 5.62910-5
     24053. 6.38220-6
```

```
     24054. 1.58883-6
     25055. 4.4508-4
c   CUT:N and PHYS:N cards removed
```

==> umet14 <==

```
D38 Depleted Uranium Reflected HEU sphere: HEU-MET-FAST-014
1 0 -1 -10 $ bottom central cavity
2 0 12 -2 $ top centr cav
3 1 4.7330e-2 1 -3 -10 16 18 $$ bot core
4 1 4.7330e-2 2 -4 12 16 19 $ top core
5 2 4.7065e-2 3 -5 -10 17$ $ bot inn refl
6 2 4.7065e-2 4 -6 12 17 $ top inn
7 2 4.7065e-2 5 -7 -10 $ bot outer refl
8 2 4.7065e-2 6 -8 12 20 $ top out refl
9 0 10 -11 -15 $ gap
10 3 8.1174e-2 11 -12 -15 $ diaphr
11 0 7 -15 -10 13
12 0 8 -15 12
13 4 6.0426e-2 7 -9 -13 -10 $ Dural Cup
14 4 6.0426e-2 9 -15 -14 -10 $ Dural shaft
15 0 9 -15 14 -13 -10
16 0 1 -3 -10 -16
17 0 2 -4 12 -16
18 0 3 -5 -17 -10
19 0 4 -6 12 -17
20 0 1 -3 -10 16 -18
21 0 2 -4 12 16 -19
22 0 6 -8 12 -20
23 0 15

1 so 3.15
2 sz 0.64 3.15
3 so 8.35
4 sz 0.64 8.35
5 so 9.15
6 sz 0.64 9.15
7 so 13
8 sz 0.64 13
9 so 13.2
10 pz 0
11 pz 0.44
12 pz 0.64
13 cz 11
14 cz 2.5
15 so 16
16 cz 1.1
17 cz 1.75
18 cy 0.6
19 c/y 0 0.64 0.6
20 cz 0.5

imp:n 1 21r 0
kcode 3000 1.0 40 400
ksrc 3 3 -3
c      Materials specified with atom densities
```

```
m1   92235. 4.1032-2 92238. 4.1010-3 92234. 5.2275-4
     92236. 8.8021-5 6000. 3.9536-4
     29063. 4.92843-4
     29065. 2.19667-4
     26054. 7.97208-6
     26056. 1.23932-4
     26057. 2.83752-6
     26058. 3.78336-7
     28058. 2.25714-4
     28060. 8.62918-5
     28061. 3.73601-6
     28062. 1.18693-5
     28064. 3.00864-6
     74182.  3.26804e-06
     74183.  1.77443e-06
     74184.  3.81478e-06
     74186.  3.55384e-06
m2   92235. 2.3832-4 92238. 4.6826-2
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   13027. 5.8077-2 12000.51 1.0332-3 25055 1.8284-4
     29063. 7.83627-4
     29065. 3.49273-4
c   CUT:N and PHYS:N cards removed
```

==> umet15 <==

```
Bare HEU Cylinder, VNIITF: HEU-MET-FAST-015
1 1 4.7832e-2 (5 -8 -1) #2 imp:n=1 $ bottom U
2 0 4 -6 -1 imp:n=1 $ source cavity
3 0 1 -8 -2 imp:n=1 $ gap
4 2 4.7767e-2 2 -8 -3 7 imp:n=1 $ top U
5 0 2 -7 -3 imp:n=1 $ top axial hole
6 3 8.1133e-2 11 -10 -5 imp:n=1 $ steel plate
7 0 11 10 -8 -5 imp:n=1 $ bot hollows
8 3 8.1133e-2 2 -12 8 -13 imp:n=1 $ diaphragm
9 0 (-9 -11):(-9 -2 8) imp:n=1 $ inner OUTSIDE 1
10 0 (-9 3):(-9 8 12) imp:n=1 $ inner outside 2
11 0 2 -9 -12 13 imp:n=1 $ outside diaphr
12 0 9 imp:n=0 $ outer OUTSIDE

1 pz 0
2 pz 0.05
3 pz 5.22
4 pz -1.0
5 pz -5.96
6 cz 0.6
7 cz 1.75
8 cz 9.995
9 so 15
10 cz 9.8
11 pz -6.17
12 pz 0.26
13 cz 13
```

```
mode n
totnu
kcode 3000 1.0 40 400
ksrc 0 0 -2
c      Materials specified with atom densities
m1   92235. 4.5774e-2 92238. 1.3381e-3 92234. 5.6597e-4
     6000. 1.0270e-4
     26054. 2.96186e-6
     26056. 4.60444e-5
     26057. 1.05422e-6
     26058. 1.40563e-7
     74182. 3.2083e-7
     74183. 1.7420e-7
     74184. 3.7451e-7
     74186. 3.4889e-7
m2   92235. 4.5708e-2 92238. 1.3404e-3 92234. 5.6404e-4
     6000. 1.0256e-4
     26054. 2.95773e-6
     26056. 4.59802e-5
     26057. 1.05275e-6
     26058. 1.40367e-7
     74182. 3.2041e-7
     74183. 1.7397e-7
     74184. 3.7402e-7
     74186. 3.4843e-7
m3   26054. 4.78685e-3
     26056. 7.44152e-2
     26057. 1.70379e-3
     26058. 2.27172e-4
```

==> umet18 <==

```
Simplified Bare HEU Sphere, VNIIEF; HEU-MET-FAST-018
C W-180 fraction added to W-182 because of cross sections
C Cell Cards
1 0 -1
2 1 4.8302e-2 1 -2
3 0 2

C Surface Cards
1 so 1.000
2 so 9.154

C Data Cards
imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 2 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 5.2111e-4
     92235. 4.2064e-2
     92238. 4.3626e-3
     6000. 1.1074e-3
```

```
     26054. 1.13988e-5
     26056. 1.77203e-4
     26057. 4.05720e-6
     26058. 5.40960e-7
     74182. 1.4213e-5
     74183. 7.6824e-6
     74184. 1.6416e-5
     74186. 1.5386e-5
```

==> umet19 <==

```
Graphite Reflected HEU Sphere, VNIIEF;  HEU-MET-FAST-019
C W-180 fraction added to W-182 because of cross sections
C Graphite thermal S(alpha,Beta) treatment applied at 300K
C Cell Cards
1 0 -1
2 1 4.8493e-2 1 -2
3 2 7.6716e-2 2 -3
4 0 3

C Surface Cards
1 so 4.029
2 so 9.150
3 so 12.60

C Data Cards
imp:n 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 6 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 5.2315e-4
     92235. 4.2256e-2
     92238. 4.3799e-3
     6000. 1.0894e-3
     26054. 1.12814e-5
     26056. 1.75378e-4
     26057. 4.01541e-6
     26058. 5.35388e-7
     74182. 1.4008e-5
     74183. 7.5711e-6
     74184. 1.6277e-5
     74186. 1.5163e-5
m2   6000. 7.6716e-2
mt2  grph.01t
```

==> umet20 <==

```
Polyethylene reflected HEU Sphere, VNIIEF;  HEU-MET-FAST-020
C W-180 fraction added to W-182 because of cross sections
C Polyethylene thermal S(alpha, beta) treatment applied at 300K
```

```
C Cell Cards
1 1 4.8522e-2 -1
2 2 1.1657e-1 1 -2
3 0 2

C Surface Cards
1 so 8.350
2 so 9.80

C Data Cards
imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 0 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 5.2428e-4
     92235. 4.2315e-2
     92238. 4.3901e-3
     6000. 1.0548e-3
     26054. 1.09899e-5
     26056. 1.70847e-4
     26057. 3.91167e-6
     26058. 5.21556e-7
     74182. 1.3749e-5
     74183. 7.4313e-6
     74184. 1.5976e-5
     74186. 1.4883e-5
m2   6000. 3.8856e-2
     1001. 7.7699e-2
     1002. 1.1657e-5
mt2  poly.01t
```

==> umet21 <==

```
Steel Reflected HEU Sphere, VNIIEF:  HEU-MET-FAST-021
C W-180 fraction added to W-182 becasuse of cross sections
C Cell Cards
1 0 -1
2 1 4.8246e-2 1 -2
3 2 8.1737e-2 2 -3
4 3 8.1354e-2 3 -4
5 0 4

C Surface Cards
1 so 0.890
2 so 7.550
3 so 11.00
4 so 17.25

C Data Cards
imp:n 1 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 2 0 0
```

```
C Material Cards
c      Materials specified with atom densities
m1   92234. 5.2087e-4
     92235. 4.2023e-2
     92238. 4.3613e-3
     26054. 1.14667e-5
     26056. 1.78258e-4
     26057. 4.08135e-6
     26058. 5.44180e-7
     6000. 1.0919e-3
     74182. 1.4544e-5
     74183. 7.8611e-6
     74184. 1.6900e-5
     74186. 1.5744e-5
m2   26054. 4.68560e-3
     26056. 7.28413e-2
     26057. 1.66776e-3
     26058. 2.22368e-4
     6000. 1.1269e-3
     14000. 1.6065e-4
     24050. 1.13109e-5
     24052. 2.18122e-4
     24053. 2.47304e-5
     24054. 6.15657e-6
     25055. 3.2851e-4
     28058. 1.57451e-4
     28060. 6.01944e-5
     28061. 2.60612e-6
     28062. 8.27962e-6
     28064. 2.09873e-6
     29063. 1.47339e-4
     29065. 6.56710e-5
m3   26054. 4.66366e-3
     26056. 7.25001e-2
     26057. 1.65995e-3
     26058. 2.21326e-4
     6000. 1.1217e-3
     14000. 1.5990e-4
     24050. 1.12579e-5
     24052. 2.17100e-4
     24053. 2.46145e-5
     24054. 6.12772e-6
     25055. 3.2697e-4
     28058. 1.56714e-4
     28060. 5.99126e-5
     28061. 2.59392e-6
     28062. 8.24085e-6
     28064. 2.08891e-6
     29063. 1.46647e-4
     29065. 6.53627e-5
```

==> umet22 <==

```
Duralumin Reflected HEU SPhere, VNIIEF;  HEU-MET-FAST-022
C W-180 fraction added to W-182 because of cross sections
C Cell Cards
1 0 -1
2 1 4.8224e-2 1 -2
3 2 5.5937e-2 2 -3
4 0 3

C Surface Cards
1 so 1.018
2 so 8.350
3 so 12.25

C Data Cards
imp:n 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 2 0 0
C Material Cards
c      Materials specified with atom densities
m1   92234. 5.2104e-4
     92235. 4.2055e-2
     92238. 4.3629e-3
     26054. 1.09233e-5
     26056. 1.69810e-4
     26057. 3.88794e-6
     26058. 5.18392e-7
     6000. 1.0482e-3
     74182. 1.3663e-5
     74183. 7.3846e-6
     74184. 1.5876e-5
     74186. 1.4790e-5
m2   13027. 5.3934e-2
     26054. 5.82342e-5
     26056. 9.05295e-4
     26057. 2.07274e-5
     26058. 2.76366e-6
     29063. 7.02836e-4
     29065. 3.13264e-4
```

==> umet28 <==

```
Flattop-25, U(nat) REFLECTED HEU SPHERE;  HEU-MET-FAST-028 and CSEWG-F22
1    1  0.04767449  -1         imp:n=1
2    2  0.048069744  +1 -2      imp:n=1
4    0           +2         imp:n=0

1    so  6.1156
2    so  24.1242

ksrc  0. 0. 0.
totnu
kcode  3000 1.0  40 400
print
c     Materials specified with atom fractions- CSEWG specs
c   m1   92234. 0.01027  92235. 0.93310 92238. 0.05663
c   m2   92235. 0.00707  92238. 0.99293
c
c      Materials specified with atom densities
m1   92234. 0.00048869     92235. 0.044482     92238. 0.0027038
m2   92234. 0.0000026438     92235. 0.0003461     92238. 0.047721
```

==> usol13a <==

```
c  ORNL-1 Uranyl nitrate in H2O Sphere;  HEU-SOL-THERM-013  case #1
c  and CSEWG: T-1
1 1 9.992137412e-2 -1    imp:n=1
2 2 6.0317237e-2    1 -2 imp:n=1
3 0                 2    imp:n=0

1 so 34.5948
2 so 34.9148

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.5
c material cards
c      Materials specified with atom densities
m1    92234. 5.3850e-7
      92235. 4.8042e-5
      92236. 1.3862e-7
      92238. 2.8050e-6
      7014. 1.8685e-4
      8016. 3.3642e-2
      1001. 6.6041e-2
m2    13027. 5.9699e-2
      14000. 5.5202e-4
      25055. 1.4853e-5
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1 lwtr.01t
totnu
print
```

==> usol13b <==

```
c  ORNL-2 Uranyl nitrate in H2O Sphere;  HEU-SOL-THERM-013  case #2
c  and CSEWG: T-2
1 1 9.983721129e-2 -1    imp:n=1
2 2 6.0317237e-2    1 -2 imp:n=1
3 0                 2    imp:n=0

1 so 34.5948
2 so 34.9148

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.5
c material cards
c      Materials specified with atom densities
m1    92234. 6.2962e-7
      92235. 5.6171e-5
      92236. 1.6207e-7
      92238. 3.2796e-6
      7014. 2.1276e-4
      5010. 1.0366e-6
      5011. 4.1724e-6
      8016. 3.3667e-2
      1001. 6.5892e-2
m2    13027. 5.9699e-2
      14000. 5.5202e-4
      25055. 1.4853e-5
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1   lwtr.01t
totnu
print
```

==> usol13c <==

```
c  ORNL-3 Uranyl nitrate in H2O Sphere;  HEU-SOL-THERM-013  case #3
c  and CSEWG: T-3
1 1 9.985904038e-2 -1    imp:n=1
2 2 6.0317237e-2    1 -2 imp:n=1
3 0                 2    imp:n=0

1 so 34.5948
2 so 34.9148

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.5
c material cards
c      Materials specified with atom densities
m1    92234. 7.1630e-7
```

```
      92235. 6.3904e-5
      92236. 1.8438e-7
      92238. 3.7311e-6
      7014. 2.3909e-4
      5010. 2.0725e-6
      5011. 8.3421e-6
      8016. 3.3726e-2
      1001. 6.5815e-2
m2    13027. 5.9699e-2
      14000. 5.5202e-4
      25055. 1.4853e-5
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1    lwtr.01t
totnu
print
```

==> usol13d <==

```
c  ORNL-4 Uranyl nitrate in H2O Sphere;  HEU-SOL-THERM-013  case #4
c  and CSEWG: T-4
1 1 1.00161279e-1 -1    imp:n=1
2 2 6.0317237e-2   1 -2 imp:n=1
3 0                2    imp:n=0

1 so 34.5948
2 so 34.9148

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 34.5
c material cards
c      Materials specified with atom densities
m1    92234. 7.6139e-7
      92235. 6.7926e-5
      92236. 1.9599e-7
      92238. 3.9659e-6
      7014. 2.5463e-4
      5010. 2.5472e-6
      5011. 1.0253e-5
      8016. 3.3857e-2
      1001. 6.5964e-2
m2    13027. 5.9699e-2
      14000. 5.5202e-4
      25055. 1.4853e-5
      29063.  3.55285e-05
      29065.  1.58355e-05
mt1   lwtr.01t
totnu
print
```

==> usol32 <==

```
c ICSBEP HEU-SOL-THERM-032  (ORNL-10) and CSEWG: T-5
c
c     cell cards
1    1  1.0016089e-01    -1
2    2  6.0274336e-02    -2   1
3    0                    2

c     surface cards
1   so  61.011
2   so  61.786

c     importance card
imp:n   1.0 1.0 0.0
c     material cards
c      Materials specified with atom densities
m1   92233.  3.9124e-09     92234.  4.0905e-07
     92235.  3.6157e-05     92236.  2.0858e-07
     92238.  1.9878e-06      1001.  6.6409e-02
      7014.  1.1212e-04      8016.  3.3601e-02
mt1  lwtr.01t
c
c     al 1100
c
m2   13027.  5.9881e-02
     14000.  2.1790e-04
     25055.  1.4853e-05
     26054.  6.46522e-06
     26056.  1.00507e-04
     26057.  2.30118e-06
     26058.  3.06824e-07
     29063.  3.55292e-05
     29065.  1.58358e-05
kcode    3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 60.0
print
```

Appendix D

^{239}Pu Criticality Benchmark Input Decks for MCNP

==> pumet1 <==

```
Jezebel - Bare sphere of Pu-239 with 4.5% Pu-240 CSEWG-F1 and PU-MET-FAST-001
1     1 0.0402901 -1
2     0          +1

1     so   6.38493

imp:n 1 0
mode  n
ksrc  0 0 0
kcode  3000  1.0  40  400
totnu
print

c    Materials specified with atom fractions - CSEWG
c    m1    94239.  0.919515  94240. 0.043457  94241. 0.002904
c       31000.  0.034125
c
c      Materials specified with atom densities
m1      94239.  3.7047e-2
      94240.  1.7512e-3
      94241.  1.1674e-4
      31000.  1.3752e-3
```

==> pumet2 <==

```
Jezebel -  Bare sphere of Pu-239  with 20% Pu-240 CSEWG-F21 and PU-MET-FAST-002
1     1 0.04055292  -1
2     0          +1

1     so 6.6595

mode  n
imp:n 1 0
ksrc  0 0 0
kcode 3000 1.0 40 400
totnu
print

c    Materials specified with atom fractions - CSEWG
c    m1    94239.  0.738441 94240.  0.194486 94241.  0.029665
c         94242.  0.003576 31000.  0.033832
c
c      Materials specified with atom densities
m1  94239.  2.9934e-2
      94240.  7.8754e-3
      94241.  1.2146e-3
      94242.  1.5672e-4
      31000.  1.3722e-3
```

==> pumet5 <==

```
TUNGSTEN REFLECTED PU(4.9) SPHERE [PLANET]: PU-MET-FAST-005
1   1   0.04070346 -1   imp:n=1
2   2   0.06605308 1 -2 imp:n=1
3   0   2              imp:n=0

1   so   5.0419
2   so   9.7409

kcode 3000 1.0 40 400
ksrc  0 0 0
print
c      Materials specified with atom densities
m1    94239. 0.037291
      94240. 0.0019277
      94241. 0.00012196
      31000. 0.0013628
m2    74182. 1.35361e-2 74183. 7.34963e-3
      74184. 1.58007e-2 74186. 1.47198e-2
      28058. 6.3066e-3  28060. 2.53494e-3 28061. 1.0975e-4
      28062. 3.48675e-4 28064. 8.83828e-5
      29063. 2.82034e-3 29065. 1.25706e-3
      40000. 0.00079528
```

==> pumet6 <==

```
U(nat) REFLECTED PU SPHERE - FLATTOP: PU-MET-FAST-006 and CSEWG-F23
1   1   0.04015889  -1  imp:n=1
2   1   0.04015889  +1 -2  imp:n=1
3   2   0.048069744   +2  -3  imp:n=1
4   0   +3  imp:n=0

1 so    1.0
2 so    4.5332
3 so    24.142

kcode 3000 1.0 40 400
ksrc 0 0 0
print

c      Materials specified with atom densities
m1   94239. 0.036697
     94240. 0.0018700
     94241. 0.00011639
     31000. 0.0014755
m2   92234. 0.0000026438
     92235. 0.0003461
     92238. 0.047721
```

==> pumet8a <==

```
THORIUM REFLECTED PU(5.1) SPHERE, ONe-D, CSEWG F-25 : PU-MET-FAST-008a
1 1 0.03945359 -1 imp:n=1
2 2 0.030054 1 -2 imp:n=1
4 0 2 imp:n=0

1 so 5.31
2 so 29.88

c      Materials specified with atom fractions - CSEWG specs
c    m1   94239. 0.91711  94240. 0.04918 31000. 0.03371
c    m2   90232.  1.00000
c
c      Materials specified with atom densities
m1   94239. 0.036049
     94240. 0.0019562
     94241. 0.00011459
     31000. 0.0013338
m2   90232. 0.030054
kcode 3000 1.0 40 400
ksrc 0 0 0
print
```

==> pumet8b <==

```
PU(5.1) SPHERE, REFLECTED BY CYLINDER OF TH-232 : PU-MET-FAST-008b
1 1 0.03945359 -1 imp:n=1
2 2 0.030054 1 -2 -3 4 imp:n=1
3 0 2:3:-4 imp:n=0

1 so 5.31
2 cx 26.67
3 px 26.67
4 px -26.67

c      Materials specified with atom densities
m1   94239. 0.036049
     94240. 0.0019562
     94241. 0.00011459
     31000. 0.0013338
m2   90232. 0.030054
kcode 3000 1.0 40 400
ksrc 0 0 0
print
```

==> pumet9 <==

```
AL(2014) REFLECTED PU(4.9) SPHERE: PU-MET-FAST-009
1 1 0.04101817 -1 imp:n=1
2 2 0.06080142 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.5118
2 so 13.4366

c      Materials specified with atom densities
m1   94239. 0.037592
     94240. 0.0019349
     94241. 0.00011797
     31000. 0.0013733
m2   13027. 0.058787
     29063. 0.00081337
     29065. 0.00036253
     14000. 0.00024187
     25055. 0.00024729
     12000. 0.00034936
kcode 3000 1.0 40 400
ksrc 0 0 0
print
```

==> pumet10 <==

```
PU-MET-FAST-010:  U(N) reflected Pu sphere
1    1   -15.778  -1         imp:n=1
2    2   -18.92  1 -2        imp:n=1
3    0   2                   imp:n=0

1   so   5.0419
2   so   9.1694

mode  n
ksrc  0 0 0
kcode   3000 1.0 40 400
totnu
print

c      Materials specified with atom densities
m1    94239.  3.7291e-2
      94240.  1.9277e-3
      94241.  1.2196e-4
      31000.  1.3628e-3
m2    92235.  3.4902e-4
      92238.  4.7518e-2
```

==> pumet19 <==

```
Be-REFLECTED PU SPHERE [VNIITF FACILITY]: PU-MET-FAST-019
1 0 -1 $ cavity
2 1 4.2157e-2 1 -3 $ Pu Core
3 0 3 -4 12 $
4 0 3 -5 11 -12
5 2 1.2105e-1 3 -7 -16 $ Bottom Reflector
6 2 1.2105e-1 4 6 -8 12 $ top reflector
7 0 3 10 -11 -15
8 3 8.1174e-2 5 11 -12 -15 $ diaphragm
9 0 7 -10 13 -15
10 0 8 12 -15
11 4 8.2365e-2 7 -9 -13 -10 $ copper cup
12 3 8.1174e-2 9 -10 -14 -15 $ shaft
13 0 9 -10 -13 14 -15
14 0 3 -7 -10 16
15 0 4 -6 -8 12 $ polar hole in Top Reflector
16 0 15

1 so 1.4
3 so 5.35
4 sz 1.05 5.35
5 cz 5.50
6 cz 1.1
7 so 11
8 sz 1.05 11
9 so 11.15
10 pz 0
11 pz 1
12 pz 1.20
13 cz 9.7
14 cz 2.5
15 so 14
16 pz -0.15

imp:n 1 14r 0
kcode 3000 1.0 40 400
ksrc 0 0 -1.41
c      Materials specified with atom densities
m1   94239. 3.3930-2 94240. 3.5043-3 94241. 3.9189-4
     31000. 2.2105-3 6000. 3.0246-4
     28058. 9.68546-4
     28060. 3.70281-4
     28061. 1.60313-5
     28062. 5.09313-5
     28064. 1.29102-5
     26054. 1.91898-5
     26056. 2.98319-4
     26057. 6.83025-6
     26058. 9.10700-7
     74182. 1.9577-5
     74183. 1.0581-5
     74184. 2.2749-5
     74186. 2.1193e-5
m2   4009. 1.2081-1 6000. 1.0020-4 8016. 8.2064-5
     26054. 3.00540-6
     26056. 4.67212-5
```

==> pumet11 <==

```
PU-MET-FAST-011:  Water reflected alpha-phase Pu sphere
1    1   0.04971635 -1         imp:n=1
2    2   0.100149  1 -2        imp:n=1
3    0   2                     imp:n=0

1   so   4.1217
2   so   29.5217

mode  n
ksrc  0 0 0
kcode   3000 1.0 40 400
totnu
print
c      Materials specified with atom densities
m1    94239.  4.6982e-2
      94240.  2.5852e-3
      94241.  1.4915e-4
      94242.  9.9432e-6
m2     1001.  0.066766
       8016.  0.033383
mt2   lwtr.01t
```

==> pumet18 <==

```
BERYLLIUM REFLECTED PU SPHERE [PLANET]: PU-MET-FAST-018
1 1 0.04070346 -1 imp:n=1
2 2 0.1212076 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0419
2 so 8.7300

c      Materials specified with atom densities
m1   94239. 0.037291
     94240. 0.0019277
     94241. 0.00012196
     31000. 0.0013628
m2   4009. 0.11984
     8016. 0.0013776
mt2  be.01t
kcode 3000 1.0 40 400
ksrc 0 0 0
print
```

```
     26057. 1.06972-6
     26058. 1.42629-7
mt2  be.01t
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   29063. 5.69719-2
     29065. 2.53931-2
```

==> pumet20 <==

```
D38 (DEPLETED URANIUM) REFLECTED PU SPHERE [VNIITF]: PU-MET-FAST-020
1 0 -1 -10
2 0 12 -2
3 1 4.21575-2 1 -3 -10
4 1 4.21575-2 2 -4 12
5 2 4.69754-2 3 -5 -10 17
6 2 4.69754-2 4 -6 12 17
7 2 4.69754-2 5 -7 -10
8 2 4.69754-2 6 -8 12 18
9 0 10 -11 -15
10 3 8.1174-2 11 -12 -15
11 0 7 -15 -10 13
12 0 8 -15 12
13 4 6.0426-2 7 -9 -13 -10
14 4 6.0426-2 9 -15 -14 -10
15 0 9 -15 14 -13 -10
16 0 3 -5 -17 -10
17 0 4 -6 -17 12
18 0 6 -8 12 -18
19 0 15

1 so 1.4
2 sz 0.61 1.4
3 so 5.35
4 sz 0.61 5.35
5 so 9.15
6 sz 0.61 9.15
7 so 13
8 sz 0.61 13
9 so 13.2
10 pz 0
11 pz 0.41
12 pz 0.61
13 cz 11
14 cz 2.5
15 so 16
17 cz 1.75
18 cz 0.5

imp:n 1 17r 0
kcode 3000 1.0 40 400
ksrc 0 0 -1.41
```

```
c      Materials specified with atom densities
m1   94239. 3.3930-2 94240. 3.5043-3 94241. 3.9189-4
     31000. 2.2105-3 6000. 3.0246-4
     28058. 9.68546-4
     28060. 3.70281-4
     28061. 1.60313-5
     28062. 5.09313-5
     28064. 1.29102-5
     26054. 1.91898-5
     26056. 2.98319-4
     26057. 6.83025-6
     26058. 9.10700-7
     74182. 1.9577-5
     74183. 1.0581-5
     74184. 2.2749-5
     74186. 2.1193e-5
m2   92235. 2.3787-4 92238. 4.6738-2
m3   26054. 4.78927-3
     26056. 7.44528-2
     26057. 1.70465-3
     26058. 2.27287-4
m4   13027. 5.8077-2 12000. 1.0332-3 25055. 1.8284-4
     29063. 7.83627-4
     29065. 3.49273-4
```

==> pumt21a <==

```
Be-REFLECTED PU CYLINDER, ASSEMBLE 50 (#2115): PU-MET-FAST-021a
1 2 7.6215e-2 11 -7 -1 imp:n=1 $ Fe
2 1 4.6924e-2 12 -7 -11 imp:n=1 $ Pu
3 2 7.6215e-2 13 -7 -12 imp:n=1 $ Fe
4 1 4.6924e-2 14 -7 -13 imp:n=1 $ Pu
5 2 7.6215e-2 15 -7 -14 imp:n=1 $ Fe
6 1 4.6924e-2 16 -7 -15 imp:n=1 $ Pu
7 2 7.6215e-2 17 -7 -16 imp:n=1 $ Fe
8 1 4.6924e-2 18 -7 -17 imp:n=1 $ Pu
9 2 7.6215e-2 19 -7 -18 imp:n=1 $ Fe
10 1 4.6924e-2 20 -7 -19 imp:n=1 $ Pu
11 2 7.6215e-2 5 -7 -20 imp:n=1 $ Fe
12 0 1 -32 -2 imp:n=1 $ vacuum
13 2 7.6215e-2 2 -7 -21 imp:n=1 $ Fe
14 1 4.6924e-2 21 -7 -22 imp:n=1 $ Pu
15 2 7.6215e-2 22 -7 -23 imp:n=1 $ Fe
16 1 4.6924e-2 23 -7 -24 imp:n=1 $ Pu
17 2 7.6215e-2 24 -7 -25 imp:n=1 $ Fe
18 1 4.6924e-2 25 -7 -26 imp:n=1 $ Pu
19 2 7.6215e-2 26 -7 -27 imp:n=1 $ Fe
20 1 4.6924e-2 27 -7 -28 imp:n=1 $ Pu
21 2 7.6215e-2 28 -7 -29 imp:n=1 $ Fe
22 1 4.6924e-2 29 -7 -30 imp:n=1 $ Pu
23 2 7.6215e-2 30 -7 -3 imp:n=1 $ Fe
24 2 7.6215e-2 5 7 -8 -1 imp:n=1 $ Fe
25 2 7.6215e-2 2 7 -8 -3 imp:n=1 $ Fe
26 3 1.2204e-1 6 -9 -5 imp:n=1 $ Be
27 3 1.2204e-1 31 -9 -4 imp:n=1 $ Be
28 0 34 32 -9 -33 imp:n=1 $ vacuum
```

```
29 0 -10 #(6 -9 -4) imp:n=1 $ OUTSIDE
30 4 3.9462e-2 -1 5 8 -32 imp:n=1 $ Al centric rings
31 4 9.0639e-3 2 8 -31 -32 imp:n=1 $ Al basket
32 0 3 -8 -31 imp:n=1 $ top clearance
33 4 6.0426e-2 -9 -31 32 33 imp:n=1 $ Al top support rings
34 4 6.0426e-2 5 -9 32 -34 imp:n=1 $ Al bott centring ring
35 0 10 imp:n=0 $ OUTSIDE

1 pz 0.
2 pz 0.01
3 pz 2.46
4 pz 17.375
5 pz -2.45
6 pz -17.345
7 cz 5.995
8 cz 6.063
9 cz 9.995
10 so 22
11 pz -.02
12 pz -.47
13 pz -.51
14 pz -.96
15 pz -1.0
16 pz -1.45
17 pz -1.49
18 pz -1.94
19 pz -1.98
20 pz -2.43
21 pz .03
22 pz .48
23 pz .52
24 pz .97
25 pz 1.01
26 pz 1.46
27 pz 1.5
28 pz 1.95
29 pz 1.99
30 pz 2.44
31 pz 2.48
32 cz 6.263
33 pz 2.28
34 pz -2.25

mode n
kcode 3000 1.0 40 400
ksrc 0 0 -0.2
c      Materials specified with atom densities
m1   94239. 4.4422e-2 94240. 2.1326e-3 94241. 9.2538e-5
     6000. 1.9515e-4
     26054. 4.83464-6
     26056. 7.51581-5
     26057. 1.72080-6
     26058. 2.29440-7
m2   26054. 3.02552-3
     26056. 4.70340-2
     26057. 1.07688-3
     26058. 1.43584-4
     6000. 3.4757e-4 14000. 8.9185e-4
```

```
     22000. 6.1034e-4
     24050. 6.27939-4
     24052. 1.21093-2
     24053. 1.37294-3
     24054. 3.41790-4
     25055. 1.5198e-3
     28058. 4.85611-3
     28060. 1.85652-3
     28061. 8.03780-5
     28062. 2.55360-4
     28064. 6.47292-5
m3   4009. 1.2099e-1 8016. 1.0449e-3
mt3  be.01t
m4   13027. 5.8077e-2 12000. 1.0332e-3 25055. 1.8284e-4
     29063. 7.83627-4
     29065. 3.49273-4
c
c  CUT:N and PHYS:N cards removed
c  phys:n 20 1e-3
c  cut:n 1e6 0
c
```

==> pumt21b <==

```
BeO-REFLECTED PU CYLINDER, ASSEMBLE 51 (#2116): PU-MET-FAST-021b
1 2 7.6215e-2 11 -7 -1 imp:n=1 $ Fe
2 1 4.6924e-2 12 -7 -11 imp:n=1 $ Pu
3 2 7.6215e-2 13 -7 -12 imp:n=1 $ Fe
4 1 4.6924e-2 14 -7 -13 imp:n=1 $ Pu
5 2 7.6215e-2 15 -7 -14 imp:n=1 $ Fe
6 1 4.6924e-2 16 -7 -15 imp:n=1 $ Pu
7 2 7.6215e-2 17 -7 -16 imp:n=1 $ Fe
8 1 4.6924e-2 18 -7 -17 imp:n=1 $ Pu
9 2 7.6215e-2 19 -7 -18 imp:n=1 $ Fe
10 1 4.6924e-2 20 -7 -19 imp:n=1 $ Pu
11 2 7.6215e-2 5 -7 -20 imp:n=1 $ Fe
12 0 1 -32 -2 imp:n=1 $ vacuum
13 2 7.6215e-2 2 -7 -21 imp:n=1 $ Fe
14 1 4.6924e-2 21 -7 -22 imp:n=1 $ Pu
15 2 7.6215e-2 22 -7 -23 imp:n=1 $ Fe
16 1 4.6924e-2 23 -7 -24 imp:n=1 $ Pu
17 2 7.6215e-2 24 -7 -25 imp:n=1 $ Fe
18 1 4.6924e-2 25 -7 -26 imp:n=1 $ Pu
19 2 7.6215e-2 26 -7 -27 imp:n=1 $ Fe
20 1 4.6924e-2 27 -7 -28 imp:n=1 $ Pu
21 2 7.6215e-2 28 -7 -29 imp:n=1 $ Fe
22 1 4.6924e-2 29 -7 -30 imp:n=1 $ Pu
23 2 7.6215e-2 30 -7 -3 imp:n=1 $ Fe
24 2 7.6215e-2 5 7 -8 -1 imp:n=1 $ Fe
25 2 7.6215e-2 2 7 -8 -3 imp:n=1 $ Fe
26 3 1.3808e-1 6 -9 -5 imp:n=1 $ BeO
27 3 1.3808e-1 31 -9 -4 imp:n=1 $ top BeO
28 0 34 32 -9 -33 imp:n=1 $ vacuum
29 0 -10 #(6 -9 -4) imp:n=1 $ OUTSIDE
30 4 3.9462e-2 -1 5 8 -32 imp:n=1 $ Al centric rings
31 4 9.0639e-3 2 8 -31 -32 imp:n=1 $ Al basket
```

```
32 0 3 -8 -31 imp:n=1 $ top clearance
33 4 6.0426e-2 -9 -31 32 33 imp:n=1 $ Al top support rings
34 4 6.0426e-2 5 -9 32 -34 imp:n=1 $ Al bottom aligning ring
35 0 10 imp:n=0 $ OUTSIDE

1 pz -0.12
2 pz 0.12
3 pz 2.57
4 pz 17.51
5 pz -2.57
6 pz -17.51
7 cz 5.995
8 cz 6.063
9 cz 9.995
10 so 22
11 pz -.14
12 pz -.59
13 pz -.63
14 pz -1.08
15 pz -1.12
16 pz -1.57
17 pz -1.61
18 pz -2.06
19 pz -2.10
20 pz -2.55
21 pz .14
22 pz .59
23 pz .63
24 pz 1.08
25 pz 1.12
26 pz 1.57
27 pz 1.61
28 pz 2.06
29 pz 2.10
30 pz 2.55
31 pz 2.59
32 cz 6.263
33 pz 2.39
34 pz -2.37

mode n
kcode 3000 1.0 40 400
ksrc 0 0 -0.25
c      Materials specified with atom densities
m1   94239. 4.4422e-2 94240. 2.1326e-3 94241. 9.2538e-5
     6000. 1.9515e-4
     26054. 4.83464-6
     26056. 7.51581-5
     26057. 1.72080-6
     26058. 2.29440-7
m2   26054. 3.02552-3
     26056. 4.70340-2
     26057. 1.07688-3
     26058. 1.43584-4
     6000. 3.4757e-4 14000. 8.9185e-4
     22000. 6.1034e-4
     24050. 6.27939-4
     24052. 1.21093-2
```

```
     24053. 1.37294-3
     24054. 3.41790-4
     25055. 1.5198e-3
     28058. 4.85611-3
     28060. 1.85652-3
     28061. 8.03780-5
     28062. 2.55360-4
     28064. 6.47292-5
m3   4009. 6.9041e-2 8016. 6.9041e-2
mt3  beo.01t
m4   13027. 5.8077e-2 12000. 1.0332e-3 25055. 1.8284e-4
     29063. 7.83627-4
     29065. 3.49273-4
c
c  CUT:N and PHYS:N cards removed
c  phys:n 20 1e-3
c  cut:n 1e6 0
c
```

==> pumet22 <==

```
Simplified Plutonium (98%)Bare Sphere, VNIIEF:  PU-MET-FAST-022
C Cell Cards
1 0 -1
2 1 4.1788e-2 1 -2
3 0 2

C Surface Cards
1 so 1.400
2 so 6.670

C Data Cards
imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 2 0 0
C Material Cards
c      Materials specified with atom densities
m1   94239. 3.6623e-2
     94240. 6.6951e-4
     31000. 2.1979e-3
     26054. 8.40573e-6
     26056. 1.30673e-4
     26057. 2.99187e-6
     26058. 3.98916e-7
     6000. 2.9311e-4
     28058. 1.27146e-3
     28060. 4.86086e-4
     28061. 2.10451e-5
     28062. 6.68602e-5
     28064. 1.69478e-5
```

==> pumet23 <==

```
Simplified Plutonium Sphere, Graphite reflector, VNIIEF:  PU-MET-FAST-023
C Graphite thermal S(alpha,beta) treatment applied at 300K
C Cell Cards
1 0 -1
2 1 4.1846e-2 1 -2
3 2 9.1842e-2 2 -3
4 0 3

C Surface Cards
1 so 1.715
2 so 6.000
3 so 8.35

C Data Cards
imp:n 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 2 0 0
C Material Cards
c      Materials specified with atom densities
m1   94239. 3.6603e-2
     94240. 6.6913e-4
     31000. 2.1956e-3
     26054. 8.31074e-6
     26056. 1.29197e-4
     26057. 2.95806e-6
     26058. 3.94408e-7
     6000. 2.8927e-4
     28058. 1.33017e-3
     28060. 5.08532e-4
     28061. 2.20169e-5
     28062. 6.99476e-5
     28064. 1.77304e-5
m2   6000. 9.1842e-2
mt2  grph.01t
```

==> pumet24 <==

```
Simplified Plutonium Sphere, Polyethylene Reflector, VNIIEF:  PU-MET-FAST-024
C Polyethylene thermal S(alpha,beta) treatment applied at 300K
C Cell Cards
1 1 4.1891e-2 -1
2 2 1.1644e-1 1 -2
3 0 2

C Surface Cards
1 so 6.000
2 so 7.550

C Data Cards
imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
```

```
ksrc 0 0 0
C Material Cards
c      Materials specified with atom densities
m1   94239. 3.6620e-2
     94240. 6.6944e-4
     31000. 2.1962e-3
     26054. 8.33434e-6
     26056. 1.29564e-4
     26057. 2.96646e-6
     26058. 3.95528e-7
     6000. 2.8972e-4
     28058. 1.34820e-3
     28060. 5.15423e-4
     28061. 2.23152e-5
     28062. 7.08953e-5
     28064. 1.79707e-5
m2   6000. 3.8814e-2
     1001. 7.7616e-2
     1002. 1.1644e-5
m2t  poly.01t
```

==> pumet25 <==

```
Simplified Plutonium Sphere, 1.55 cm Steel Reflector, VNIIEF:  PU-MET-FAST-025
C Cell Cards
1 1 4.1988e-2 -1
2 2 8.1881e-2 1 -2
3 0 2

C Surface Cards
1 so 6.000
2 so 7.55

C Data Cards
imp:n 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 1 0 0
C Material Cards
c      Materials specified with atom densities
m1   94239. 3.6704e-2
     94240. 6.7099e-4
     31000. 2.2013e-3
     26054. 8.35381e-6
     26056. 1.29866e-4
     26057. 2.97338e-6
     26058. 3.96452e-7
     6000. 2.9038e-4
     28058. 1.35134e-3
     28060. 5.16623e-4
     28061. 2.23672e-5
     28062. 7.10605e-5
     28064. 1.80125e-5
m2   26054. 4.69386e-3
     26056. 7.29697e-2
```

```
     26057. 1.67070e-3
     26058. 2.22760e-4
     6000. 1.1289e-3
     14000. 1.6093e-4
     24050. 1.13309e-5
     24052. 2.18508e-4
     24053. 2.47741e-5
     24054. 6.16745e-6
     25055. 3.2909e-4
     28058. 1.57731e-4
     28060. 6.03014e-5
     28061. 2.61075e-6
     28062. 8.29434e-6
     28064. 2.10246e-6
     29063. 1.47595e-4
     29065. 6.57851e-5
```

==> pumet26 <==

```
Simplified Plutonium Sphere, 11.9 cm Steel Reflector, VNIIEF: PU-MET-FAST-026
C Cell Cards
1 0 -1
2 1 4.1864e-2 1 -2
3 2 8.1736e-2 2 -3
4 3 8.1225e-2 3 -4
5 0 4

C Surface Cards
1 so 0.770
2 so 5.350
3 so 11.00
4 so 17.25

C Data Cards
imp:n 1 1 1 1 0
totnu
kcode 3000 1.0 40 400
ksrc 1 0 0
C Material Cards
c      Materials specified with atom densities
m1   94239. 3.6603e-2
     94240. 6.6917e-4
     31000. 2.2043e-3
     26054. 8.20454e-6
     26056. 1.27546e-4
     26057. 2.92026e-6
     26058. 3.89368e-7
     6000. 2.8435e-4
     28058. 1.34096e-3
     28060. 5.12656e-4
     28061. 2.21955e-5
     28062. 7.05148e-5
     28064. 1.78742e-5
m2   26054. 4.68554e-3
     26056. 7.28404e-2
```

```
     26057. 1.66774e-3
     26058. 2.22365e-4
     6000. 1.1269e-3
     14000. 1.6065e-4
     24050. 1.13109e-5
     24052. 2.18122e-4
     24053. 2.47304e-5
     24054. 6.15657e-6
     25055. 3.2850e-4
     28058. 1.57451e-4
     28060. 6.01944e-5
     28061. 2.60612e-6
     28062. 8.27962e-6
     28064. 2.09873e-6
     29063. 1.47332e-4
     29065. 6.56679e-5
m3   26054. 4.65622e-3
     26056. 7.23845e-2
     26057. 1.65730e-3
     26058. 2.20973e-4
     6000. 1.1199e-3
     14000. 1.5964e-4
     24050. 1.12401e-5
     24052. 2.16756e-4
     24053. 2.45756e-5
     24054. 6.11802e-6
     25055. 3.2645e-4
     28058. 1.56461e-4
     28060. 5.98160e-5
     28061. 2.58973e-6
     28062. 8.22756e-6
     28064. 2.08554e-6
     29063. 1.46412e-4
     29065. 6.52579e-5
```

==> pnl1 <==

```
CSEWG-T13: PNL-1  Unreflected Pu-solution sphere
1    1    1.0091e-1 -1   imp:n=1      $ sphere of Pu and water
2    0    1              imp:n=0      $ Outside everything

1    so  19.509

mode  n
kcode    3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 19.5
totnu
print

c      Materials specified with atom densities
m1    1001. 6.563e-2
      8016. 3.456e-2
      7014. 6.216e-4
```

```
      94239. 9.373e-5
      94240. 4.501e-6
m1t   lwtr.01t
```

==> pnl6 <==

```
c  CSEWG-T24: PNL-6  Unreflected Pu-solution sphere
c  Correction to original specifications for CSEWG-T14, PNL-2
1    1    0.0990839  -1   imp:n=1     $ sphere of Pu and water
2    0    1              imp:n=0     $ Outside everything

1    so  19.5085    $ effective radius

mode  n
kcode  3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source
si1 19.5
totnu
print
c      Materials specified with atom densities
m1    1001. 5.4182e-2
      8016. 3.9764e-2
      7014. 4.7224e-3
     26054. 2.10111e-7
     26056. 3.26633e-6
     26057. 7.47852e-8
     26058. 9.97136e-9
     94239. 4.1307e-4
     94240. 1.9752e-5
     94241. 1.3251e-6
     94242. 2.4899e-8
mt1  lwtr.01t
```

==> pusl11a <==

```
c   PNL-3  18" Cad. Cov. Bare Sph,22.35 gPu/l,4.2 wt% Pu-240;
c   PU-SOL-THERM-011 Case 18-1 and CSEWG: T-15
1 1 1.004758-01 -1 imp:n=1 $ Pu(NO3)4 Solution
2 2 8.6914-02 1 -2 imp:n=1 $ SS347 Sphere
3 3 4.6340-02 2 -3 imp:n=1 $ Cad. Cov. Sphere
4 0 3 imp:n=0 $ Outside Everything

1 so 22.6974 $ Sphere Inner Radius
2 so 22.8244 $ Sphere Outer Radius
3 so 22.8752 $ Cad. Cov. Outer Radius

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source about origin
si1 22.6973
c      Materials specified with atom densities
m1    94239. 5.3938-05
```

```
      94240. 2.3549-06 $ Solution
      7014. 7.3930-04
      1001. 6.5147-02
      8016. 3.4534-02
      26054.  7.63460e-08
      26056.  1.18686e-06
      26057.  2.71740e-08
      26058.  3.62320e-09
mt1   lwtr.01t $ S(Alpha,Beta)
m2    26054.  3.56277e-03
      26056.  5.53860e-02
      26057.  1.26811e-03
      26058.  1.69081e-04
      24050.  7.24659e-04
      24052.  1.39745e-02
      24053.  1.58441e-03
      24054.  3.94435e-04
      28058.  6.72487e-03
      28060.  2.57095e-03
      28061.  1.11310e-04
      28062.  3.53629e-04
      28064.  8.96386e-05
m3    48000.50c 4.6340-02      $ Cadmium
totnu
print
```

==> pusl11b <==

```
c  PNL-4  18" Cad. Cov. Bare Sph, 27.49 g Pu/l, 4.2 wt% Pu-240;
c  PU-SOl-THERM-011 Case 18-6 and CSEWG: T-16
c
 1 1 1.003191-01 -1 imp:n=1 $ Pu(NO3)4 Solution
 2 2 8.6914-02 1 -2 imp:n=1 $ SS347 Sphere
 3 3 4.6340-02 2 -3 imp:n=1 $ Cad. Cov. Sphere
 4 0 3 imp:n=0 $ Outside Everything

 1 so 22.6974 $ Sphere Inner Radius
 2 so 22.8244 $ Sphere Outer Radius
 3 so 22.8752 $ Cad. Cov. Outer Radius

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source about origin
 si1 22.6973
c      Materials specified with atom densities
m1    94239. 6.6343-05
      94240. 2.8964-06 $ Solution
      7014. 2.7753-03
      1001. 6.0264-02
      8016. 3.7209-02
      26054.  8.97036e-08
      26056.  1.39451e-06
      26057.  3.19284e-08
      26058.  4.25712e-09
```

```
mt1   lwtr.01t $ S(Alpha,Beta)
m2    26054.  3.56277e-03
      26056.  5.53860e-02
      26057.  1.26811e-03
      26058.  1.69081e-04
      24050.  7.24659e-04
      24052.  1.39745e-02
      24053.  1.58441e-03
      24054.  3.94435e-04
      28058.  6.72487e-03
      28060.  2.57095e-03
      28061.  1.11310e-04
      28062.  3.53629e-04
      28064.  8.96386e-05
m3    48000.50c 4.6340-02 $ Cadmium
totnu
print
```

==> pusl11c <==

```
c  PNL-5  16" Bare Sphere,43.43g Pu/l,4.17 wt% Pu-240;
c  PU-SOL-THERM-011 Case 16-5  and CSEWG: T-17
1 1 1.002582-01 -1 imp:n=1 $ Pu(NO3)4 Solution
2 2 8.6914-02 1 -2 imp:n=1 $ SS347 Sphere
3 0 2 imp:n=0 $ Outside Everything

1 so 20.1206 $ Sphere Inner Radius
2 so 20.2476 $ Sphere Outer Radius

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source about origin
si1 20.1205
c      Materials specified with atom densities
m1    94239. 1.0484-04
      94240. 4.5432-06
      7014. 2.7369-03
      1001. 6.0233-02
      8016. 3.7177-02
      26054.  1.13882e-07
      26056.  1.77038e-06
      26057.  4.05342e-08
      26058.  5.40456e-09
mt1   lwtr.01t $ S(Alpha,Beta)
m2    26054.  3.56277e-03
      26056.  5.53860e-02
      26057.  1.26811e-03
      26058.  1.69081e-04
      24050.  7.24659e-04
      24052.  1.39745e-02
      24053.  1.58441e-03
      24054.  3.94435e-04
      28058.  6.72487e-03
      28060.  2.57095e-03
```

```
      28061.  1.11310e-04
      28062.  3.53629e-04
      28064.  8.96386e-05
totnu
print
```

==> pusl11d <==

```
16" Bare Sphere, 34.96 g Pu/l, 4.17 wt% Pu-240; PU-SOL-THERM-011 Case 16-1
1 1 1.00630-01 -1 imp:n=1 $ Pu(NO3)4 Solution
2 2 8.6914-02 1 -2 imp:n=1 $ SS347 Sphere
3 0 2 imp:n=0 $ Outside Everything

1 so 20.1206 $ Sphere Inner Radius
2 so 20.2476 $ Sphere Outer Radius

mode n
kcode 3000 1.0 40 800
sdef pos 0.0 0.0 0.0 rad d1
sc1 Spherical Source about origin
si1 20.1205
c      Materials specified with atom densities
m1    94239. 8.4397e-05
      94240. 3.6572e-06 $ Solution
      7014. 1.0140e-03
      1001. 6.4544e-02
      8016. 3.4983e-02
      26054.  6.61685e-08
      26056.  1.02864e-06
      26057.  2.35515e-08
      26058.  3.14020e-09
mt1 lwtr.01t $S(Alpha,Beta)
m2    26054.  3.56277e-03
      26056.  5.53860e-02
      26057.  1.26811e-03
      26058.  1.69081e-04
      24050.  7.24659e-04
      24052.  1.39745e-02
      24053.  1.58441e-03
      24054.  3.94435e-04
      28058.  6.72487e-03
      28060.  2.57095e-03
      28061.  1.11310e-04
      28062.  3.53629e-04
      28064.  8.96386e-05
totnu
print
```

Appendix E

Mixed Metal Criticality Benchmark Input Decks for MCNP

==> mixmet1 <==

```
HEU REFLECTED PU SPHERE, PLANET ASSEMBLY; MIX-MET-FAST-001
1 1 0.04070346 -1 imp:n=1
2 2 0.048126 1 -2 imp:n=1
3 0 2 imp:n=0

1 so 5.0419
2 so 6.7056

c      Materials specified with atom densities
m1   94239. 0.037291
     94240. 0.0019277
     94241. 0.00012196
     31000. 0.0013628
m2   92235. 0.044892
     92238. 0.0032340
kcode 3000 1.0 40 400
totnu
ksrc 0 0 0
print
```

==> mixmet3 <==

```
HEU Reflected Pu Sphere, VNIITF: MIX-MET-FAST-003
1 0 -1 $ central cavity
2 1 4.2162e-2 1 -5 $ Pu
3 0 5 -6 12 $ crescent gap
4 0 5 -2 11 -12 $ diaphragm gap
5 2 4.74202e-2 5 -7 -10 15 $ bottom U
6 2 4.74202e-2 3 6 -8 12 16 $ top U
7 0 5 -7 -10 -15 $ bottom groove in U
8 0 6 -8 12 -16 $ top groove in U
9 0 5 10 -11 -17 $ critical gap
10 5 6.0426e-2 2 11 -12 -17 $ diaphragm
11 0 7 -10 13 -17 $ bottom void
12 0 8 12 -17 $ top void
13 4 8.2365e-2 7 -9 -13 -10 $ cup
14 3 8.1174e-2 9 -10 -14 -17 $ shaft
15 0 9 -10 -13 14 -17 $ void under cup
16 0 -3 6 -8 12 $ hole in top U
17 0 17 $ outer void

1 so 1
2 cz 5.5
3 cz 1.1
5 so 5.35
6 sz 1.225 5.35
7 so 7.55
8 sz 1.225 7.55
9 so 7.7
10 pz 0
11 pz 1.025
12 pz 1.225
```

```
13 cz 6.5
14 cz 2.5
15 cy 0.6
16 c/y 0 1.225 0.6
17 so 14

imp:n 1 15r 0
kcode 3000 1.0 40 400
ksrc 0 0 -2
totnu
c      Materials specified with atom densities
m1   94239. 3.3928-2 94240. 3.5032-3 94241. 3.9158-4
     31000. 2.2104-3 6000. 3.0224-4
     26054. 1.91886e-5
     26056. 2.98301e-4
     26057. 6.82983e-6
     26058. 9.10644e-7
     74182. 1.9576-5
     74183. 1.0581-5
     74184. 2.2747-5
     74186. 2.1191-5
     28058. 9.73940e-4
     28060. 3.72343e-4
     28061. 1.61206e-5
     28062. 5.12149e-5
     28064. 1.29821e-5
m2   92235. 4.1081-2 92238. 4.1002-3 92234. 5.2253-4
     92236. 8.8981-5 6000. 3.8650-4
     26054. 8.86593e-6
     26056. 1.37828e-4
     26057. 3.15567e-6
     26058. 4.20756e-7
     74182. 3.2573-6
     74183. 1.7606-6
     74184. 3.7850-6
     74186. 3.5261-6
     28058. 2.33244e-4
     28060. 8.91707e-5
     28061. 3.86065e-6
     28062. 1.22652e-5
     28064. 3.10902e-6
     29063. 5.09271e-4
     29065. 2.26989e-4
m3   26054. 4.78927e-3
     26056. 7.44528e-2
     26057. 1.70465e-3
     26058. 2.27287e-4
m4   29063. 5.69719e-2
     29065. 2.53931e-2
m5   13027. 5.8077-2 12000. 1.0332-3 25055. 1.8284-4
     29063. 7.83627e-4
     29065. 3.49273e-4
print
```

==> mixmet8 <==

```
c Cylindrical Graphite Reflected Pu, ZEBRA 8A/2:  MIX-MET-FAST-008 Case 1
c
c Pu pellet
1 1 4.086069e-02 4 -5 -9 10 -17 18 imp:n=1
c Can
2 2 6.750202e-02 3 -6 12 -11 20 -19 (-4:5:9:-10:17:-18) imp:n=1
c U nat
3 3 4.713345e-02 1 -2 12 -11 20 -19 imp:n=1
c U nat
33 3 4.713345e-02 7 -8 12 -11 20 -19 imp:n=1
c Graphite
4 4 8.106395e-02 2 -3 12 -11 20 -19 imp:n=1
c Graphite
44 4 8.106395e-02 6 -7 12 -11 20 -19 imp:n=1
c void
5 0 1 -8 -13 14 -21 22 (11:-12:19:-20) imp:n=1
c Sheath
6 5 8.567983e-02 1 -8 -15 16 -23 24 (13:-14:21:-22) imp:n=1
c supercell
7 0 -1:8:15:-16:23:-24 imp:n=0

1 -8 pz 0
2 pz 1.5875
3 pz 3.7939
4 pz 3.8447
5 pz 4.0606
6 pz 4.1114
7 pz 6.6330
8 -1 pz 7.5855
c
9 px 2.3355 $ Pu pellet
10 px -2.3355 $ Pu pellet
11 px 2.5335 $ Can and other pellets
12 px -2.5335 $ Can and other pellets
13 px 2.5510 $ Air gap
14 px -2.5510 $ Air gap
15 -16 px 2.6272 $ Sheath
16 -15 px -2.6272 $ Sheath
c
17 py 2.3355 $ Pu pellet
18 py -2.3355 $ Pu pellet
19 py 2.5335 $ Can and other pellets
20 py -2.5335 $ Can and other pellets
21 py 2.5510 $ Air gap
22 py -2.5510 $ Air gap
*23 py 2.6272 $ Sheath
*24 py -2.6272 $ Sheath

kcode 3000 1.0 40 400
ksrc 0 0 3.95
totnu
print
c      Materials specified with atom densities
m1   94239. 3.6094e-2
     94240. 1.8693e-3
     94241. 1.1174e-4
```

```
      93237. 1.2404e-5
      95241. 3.4897e-5
      31000. 2.3470e-3
      6000. 1.0431e-4
      26054. 1.32361e-6
      26056. 2.05765e-5
      26057. 4.71114e-7
      26058. 6.28152e-8
      28058. 1.45736e-5
      28060. 5.57157e-6
      28061. 2.41221e-7
      28062. 7.66357e-7
      28064. 1.94258e-7
      13027. 4.6434e-5
      14000. 4.4609e-5
      1001. 1.5221e-4
m2    6000. 1.6451e-4
      26054. 2.12512e-3
      26056. 3.30366e-2
      26057. 7.56399e-4
      26058. 1.00853e-4
      24050. 4.27900e-4
      24052. 8.25172e-3
      24053. 9.35570e-4
      24054. 2.32908e-4
      28058. 3.02422e-3
      28060. 1.15618e-3
      28061. 5.00567e-5
      28062. 1.59030e-4
      28064. 4.03112e-5
      25055. 4.8299e-4
      29063. 1.11820e-2
      29065. 4.98398e-3
      14000. 3.4173e-4
      1001. 1.4064e-5
      15031. 1.8227e-5
      16032. 1.7604e-5
m3    92235. 3.3316e-4
      92238. 4.5948e-2
      6000. 4.9205e-4
      26054. 6.24397e-6
      26056. 9.70673e-5
      26057. 2.22243e-6
      26058. 2.96324e-7
      14000. 2.1043e-4
      1001. 4.3978e-5
m4    6000. 8.0604e-2
      26054. 4.08805e-7
      26056. 6.35519e-6
      26057. 1.45507e-7
      26058. 1.94009e-8
      25055. 2.7091e-7
      13027. 1.7927e-6
      29063. 2.10602e-7
      29065. 9.38681e-8
      14000. 6.8889e-6
      23000. 1.8990e-7
      1001. 2.9798e-4
```

```
     16032. 1.5779e-7
     8016. 1.4037e-4
     11023. 2.9132e-6
     5010. 1.4864e-7
     5011. 5.4074e-7
     20000. 1.4668e-6
mt4  grph.01t
m5   6000. 7.7829e-4
     26054. 3.34082e-3
     26056. 5.19355e-2
     26057. 1.18910e-3
     26058. 1.58547e-4
     24050. 6.99849e-4
     24052. 1.34961e-2
     24053. 1.53017e-3
     24054. 3.80931e-4
     28058. 6.14710e-3
     28060. 2.35007e-3
     28061. 1.01746e-4
     28062. 3.23247e-4
     28064. 8.19373e-5
     42000. 1.4635e-4
     25055. 1.1918e-3
     13027. 3.4646e-4
     29063. 5.10841e-5
     29065. 2.27689e-5
     22000. 2.9326e-4
     14000. 9.9988e-4
     23000. 9.2127e-5
     1001. 2.2714e-5
```

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