April 1, 2015

SMT-2015-011
10 CFR 50.30

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

References: (1) SHINE Medical Technologies, Inc. letter to NRC, dated March 26, 2013, Part One of the SHINE Medical Technologies, Inc. Application for Construction Permit (ML130880226)
(2) SHINE Medical Technologies, Inc. letter to NRC, dated May 31, 2013, Part Two of the SHINE Medical Technologies, Inc. Application for Construction Permit (ML13172A324)
(3) NRC letter to SHINE Medical Technologies, Inc., dated September 19, 2014, SHINE Medical Technologies, Inc. – Request for Additional Information Regarding Application for Construction Permit (TAC Nos. MF2305, MF2307, and MF2308) (ML14195A159)
(4) SHINE Medical Technologies, Inc. letter to NRC, dated October 15, 2014, SHINE Medical Technologies, Inc. Application for Construction Permit, Response to Request for Additional Information (ML14296A190)
(5) SHINE Medical Technologies, Inc. letter to NRC, dated December 3, 2014, SHINE Medical Technologies, Inc. Application for Construction Permit, Response to Request for Additional Information (ML14356A528)

SHINE Medical Technologies, Inc. Application for Construction Permit
Submittal of NSA-DAC-SHN-13-02, Revision 1

Pursuant to 10 CFR 50.30, SHINE Medical Technologies, Inc. (SHINE) submitted an application for a construction permit to construct a medical isotope facility to be located in Janesville, WI (References 1 and 2). Via Reference (3), the NRC staff determined that additional information was required to enable the staff's continued review of the SHINE construction permit application. SHINE responded to the NRC staff's requests for additional information (RAIs) via References (4) and (5).

The SHINE Response to RAI 6b.3-1, provided via Reference (5), provided NSA-TR-07-08, Revision 0, as the SHINE project-specific validation report. However, SHINE should have provided NSA-DAC-SHN-13-02, Revision 1, as the SHINE project-specific validation report. Enclosure 1 provides NSA-DAC-SHN-13-02, Revision 1, supporting the SHINE Response to RAI 6b.3-1.

If you have any questions, please contact Mr. Jim Costedio, Licensing Manager, at 608/210-1730.

I declare under the penalty of perjury that the foregoing is true and correct.
Executed on April 1, 2015.

Very truly yours,

R. Vann Bynum, Ph.D.
Chief Operating Officer
SHINE Medical Technologies, Inc.
Docket No. 50-608

Enclosure

cc: Administrator, Region III, USNRC
Project Manager, USNRC
Environmental Project Manager, USNRC
Supervisor, Radioactive Materials Program, Wisconsin Division of Public Health

ENCLOSURE 1

SHINE MEDICAL TECHNOLOGIES, INC.

SHINE MEDICAL TECHNOLOGIES, INC. APPLICATION FOR CONSTRUCTION PERMIT SUBMITTAL OF NSA-DAC-SHN-13-02, REVISION 1

NSA-DAC-SHN-13-02, REVISION 1
EVALUATION OF BIAS OF URANIUM SULFATE SOLUTIONS FOR MCNP 5 AND THE ENDF/B-VI CROSS SECTION LIBRARY

12 pages follow

Revision History Log

Rev	Date	Revision Description/Reason
0		Original Issue
1		Editorial changes and clarifications based on AECOM review. - Defined ZAID in Section 1.2. - Defined ENDF/B-VI in Section 5.0. - Clarified experiment report number from Reference 1.

Table of Contents

1.0 INTRODUCTION

1.1 Background/Purpose

Nuclear criticality safety analysis is performed for all systems and operations involving the handling, storage and processing of fissile material. The nuclear criticality safety analysis establishes the nuclear criticality safety operating limits for the systems and operations. Calculation methods are used to provide an estimate of critical conditions and the margin of subcriticality for the systems and operations under evaluation. The computational methods predict the neutronic behavior of the system and operation. However, certain approximations are inherent in the computer code used including inexact neutron cross section data and statistical uncertainty.

Validation compares the computational method with documented critical experiments to determine any bias that might exist between the calculated reactivity of a given system and the actual conditions. It is a process that determines and establishes computational method applicability, adequacy, and uncertainty.

This report evaluates the bias associated with uranium sulfate critical experiments using the MCNP 5 computer code system. The critical experiments are modeled as reported in NEA/NCS/DOC (95)03 (Reference 1, experiment HEU-SOL-THERM-046). This report and the evaluated bias are used in conjunction with the bias evaluation for MCNP 5 in References 2 and 3.

1.2 Limits of Applicability

While the experiments used herein are from a limited area of applicability, the results are judged to be applicable to all thermal neutron systems evaluated with MCNP 5. Applications using the conclusions established for this experiment data set must use the isotopic material representations of Reference 2 and Table 2 to ensure that the default cross section library is used.

2.0 CONCLUSIONS

Uranium sulfate solution benchmark critical cases are modeled using MCNP 5 with the default cross section library. This report documents the methodology and results. The calculation results for the critical experiments chosen for code bias evaluation are summarized in Table 1. The experiments include high enriched uranium (HEU) in the thermal energy range. Though the experiment cases here are all with highly enriched uranium, this study provides evidence that the uranium complexed with sulfate solution does not introduce a significant, non-conservative bias to the calculation method compared to the benchmark studies run for other complexes at high enrichment. The code treatment of the cross sections for other materials is well-documented and demonstrated at the full range of enrichment, and is shown in Reference 2 to give a slight positive bias as do the sulfate cases; therefore, it is reasonable to conclude that the use of the sulfate complex with lower enrichment uranium will not exhibit significant, non-conservative bias. The behavior of all the solution complex materials is dominated by the neutron moderating

materials present, and the presence of the sulfur does not significantly affect the neutron spectrum or behavior.

It is concluded that the MCNP 5 calculated k_{eff} data with the use of uranium sulfate should use the same bias as with the use of uranium homogeneous systems for thermal neutron energies. These conclusions are valid for thermal systems only.

Table 1: HEU-SOL-THERM-046 Benchmark Critical Experiment Results

Case	^{235}U Enrichment	Uranium Form	Geometry	Moderator / Reflector	$H/^{235}U$	Average Neutron Energy Causing Fission (MeV)	k_{calc}	k_{normal}	σ_{calc}
HEU-SOL-THERM-046									
1	89.84	Solution UO_2SO_4	Cylinder	H_2SO_4-H_2O / BeO & Graphite	708.24	3.6434E-03	1.01689	1.01577	0.00031
2					689.09	3.7330E-03	1.01355	1.01244	0.00032
3					677.69	3.7802E-03	1.01452	1.01341	0.00032
4					661.20	3.8213E-03	1.01508	1.01396	0.00032
5					652.90	3.9008E-03	1.01373	1.01262	0.00032
6					641.15	3.9074E-03	1.01398	1.01287	0.00034
7					622.27	4.0050E-03	1.01507	1.01395	0.00033
8					600.97	4.1664E-03	1.01414	1.01303	0.00034
9					592.65	4.2028E-03	1.01392	1.01281	0.00032
10					560.50	4.3709E-03	1.01105	1.00994	0.00036
11					530.86	4.6273E-03	1.01447	1.01336	0.00035
12					487.52	4.8643E-03	1.01375	1.01264	0.00035
13					456.65	5.1567E-03	1.01377	1.01266	0.00036

3.0 REFERENCES

1. *International Handbook of Evaluated Criticality Safety Benchmark Experiments*, NEA/NCS/DOC(95)03, Organization for Economic Cooperation and Development, September 2011 Edition (experiment HEU-SOL-THERM-046).
2. *MCNP 5 and the ENDF/B-VI Cross Section Library Homogeneous Uranium Systems Validation*, NSA-TR-07-08, Rev. 0, August 20, 2007.
3. *Software Quality Assurance Implementation for MCNP Version 5 Nuclear Criticality Safety Software for the NSA Computer System*, NSA-CS-06, Rev. 1, June 2007.

4.0 ANALYSIS/PROCESS METHODOLOGY

This DAC does not model a process. See Section 8.1 for description of the models and calculation methodology.

5.0 COMPUTER CODES USED IN DAC

The MCNP 5 code provides a method of analysis for criticality and shielding analysis on workstations or personal computers (PCs). MCNP 5 is one of the codes chosen for criticality safety use. The MCNP 5 (build 1.4) code is executed on the NSA servers using the Fedor Linux operating system identified in Reference 3.

The default library is used for the critical experiment calculations. This is primarily the Evaluated Neutron Data File B-VI (ENDF/B-VI) library which contains data for all nuclides (more than 300). Table 2 lists the specific elements used in this evaluation. Where the default library does not contain a "natural" mixture of isotopes, the isotopic fractions are included. The light water (lwtr.60t), beryllium oxide (beo.60t) and graphite (grph.60t) s(α,β) corrections are used.

Table 2. Default Library Definitions for Various Elements

Element	ZAID*	Isotopic Fraction	Element	ZAID	Isotopic Fraction
Hydrogen	1001		Nickel	28058	0.682737
Beryllium	4009			28060	0.261053
Boron	5010	0.199		28061	0.011263
	5011	0.801		28062	0.035895
Carbon	6000			28064	0.009053
Nitrogen	7014		Copper	29063	0.6917
Oxygen	8016			29065	0.3083
Fluorine	9019		Zirconium	40000	
Sodium	11023		Molybdenum	42000	
Magnesium	12000		Silver	47107	0.5184
Aluminum	13027			47109	0.4816
Silicon	14000		Cadmium	48106	0.0125
Sulfur	16032			48108	0.0089
Chlorine	17000			48110	0.1249
Calcium	20000			48111	0.128
Titanium	22000			48112	0.2413
Vanadium	23000			48113	0.1222
Chromium	24050	0.043474		48114	0.2873
	24052	0.837895		48116	0.0749
	24053	0.095000	Tin	50000	
	24054	0.023632	Samarium 149	62149	
Manganese	25055		Lead	82206	0.2444
Iron	26054	0.059006		82207	0.2241
	26056	0.917181		82208	0.5314
	26057	0.021007	Uranium	92234	0.0077
	26058	0.002806		92235	0.8984
				92236	0.0018
				92238	0.0920

* ZAID notation for MCNP material input: Z = Atomic number; A = mass number

6.0 ASSUMPTIONS & OPEN ITEMS

6.1 Assumptions

The modeling assumptions made for the critical experiments are consistent with those described in Reference 1.

6.2 Open Items

There are no open items.

7.0 ACCEPTANCE CRITERIA

7.1 Biases and Uncertainties

The code methodology benchmark bias and bias uncertainties are not used to determine a process limit or margin of safety in this analysis and are not used in this analysis. This analysis provides justification that the presence of uranium sulfate does not adversely affect the bias and bias uncertainties determined in Reference 2.

7.2 Area of Applicability (AoA)

This DAC extends the AoA derived in Reference 2 to include uranium sulfate solution as discussed in Section 8.0. The AoA derived in Reference 2 includes most of the materials in this study (with exception of the uranium sulfate addressed in this DAC), including uranium enrichment, elements and materials modeled, and average energy of neutrons causing fission. Based on the previous work and the results of this DAC, it is judged that the models of this study are within the AoA of the code validation.

8.0 CALCULATIONS

8.1 Method Discussion

Materials validation is, in effect, the evaluation of how well the use of the cross section libraries estimates the actual neutron interactions for the isotopes making up the material. An observable difference between calculated and measured k_{eff} for the benchmark experiments would indicate a possible bias due to the system materials. The evaluation herein examines the k_{eff} results for selected benchmark experiments in Reference 1 (experiment HEU-SOL-THERM-046) containing uranium sulfate solution. A summary of the experiment information is listed in Table 3. The calculated k_{eff} for these benchmark experiments are then compared with similar ^{235}U systems to estimate the possible change in the bias.

Table 3. HEU-SOL-THERM-046 Benchmark Critical Experiment Summary

Case	^{235}U Enrichment	Uranium Form	Geometry	Moderator / Reflector	$H/^{235}U$	Other Materials	k_{exp} [a]	σ_{exp}
HEU-SOL-THERM-046								
1	89.84	Solution UO_2SO_4	Cylinder	H_2SO_4-H_2O / BeO & Graphite	708.24	Zircalloy, Al alloy	1.0011	0.0029
2					689.09		1.0011	0.0029
3					677.69		1.0011	0.0029
4					661.20		1.0011	0.0029
5					652.90		1.0011	0.0030
6					641.15		1.0011	0.0029
7					622.27		1.0011	0.0031
8					600.97		1.0011	0.0032
9					592.65		1.0011	0.0037
10					560.50		1.0011	0.0029
11					530.86		1.0011	0.0028
12					487.52		1.0011	0.0029
13					456.65		1.0011	0.0030

[a] Reference 1, Table 37.

8.2 Input

All input is obtained from Reference 1, experiment HEU-SOL-THERM-046.

Beryllium Oxide and Graphite Reflected Uranyl Sulfate (HEU-SOL_THERM-046)
Thirteen experiments involved a beryllium oxide- and graphite-reflected tank of uranyl sulfate (UO_2SO_4). The core was comprised of the fissile solution inside a cylindrical tank of Zircaloy-2. The inner tank was 25 cm in diameter and 30 cm in height, with a conical bottom, surrounded by an outer aluminum-alloy tank, and reflected by a minimum of 27.5 cm of beryllium oxide followed by a layer of at least 50 cm of graphite. The reflectors contained structural plates of aluminum alloy, as well as several penetrations throughout to accommodate the fill tube, experimental channels, control rods, safety rods, etc. The range of the uranium ^{235}U concentration was 36.588 to 56.51 g/liter.

8.3 Evaluations, Analysis, and Detailed Calculations

The evaluation herein seeks to estimate the potential bias for systems of uranium sulfate systems. While several benchmark experiments are available for other uranium mixtures and solutions, there is only a limited set of uranium sulfate experiments. Therefore, only limited conclusions are possible.

Note: *A second experiment series involving uranium sulfate solution is included in Reference 1 (IEU-SOL-THERM-001) but was judged unusable due to unacceptable k_{eff} results that are not explained by the evaluators / authors of the benchmark discussion and model.*

The MCNP 5 (build 1.40) code is executed on the NSA servers using the Fedor Linux operating system identified in Reference 2. Each case was run for sufficient neutron generations and neutrons per generation to achieve a calculation uncertainty (σ_{calc}) less than 0.001. The

calculation results are recorded in Table 1. As not all experiments are exactly critical the calculated k_{eff} is normalized to the estimated experiment k_{eff}: $k_{normal} = k_{calc}/k_{exp}$; k_{exp} is listed in Table 1. The data are plotted as k_{normal} vs H/^{235}U, k_{normal} vs ANECF (average neutron energy causing fission) in Figures 1 and 2.

Figure 1: k_{normal} vs H/^{235}U

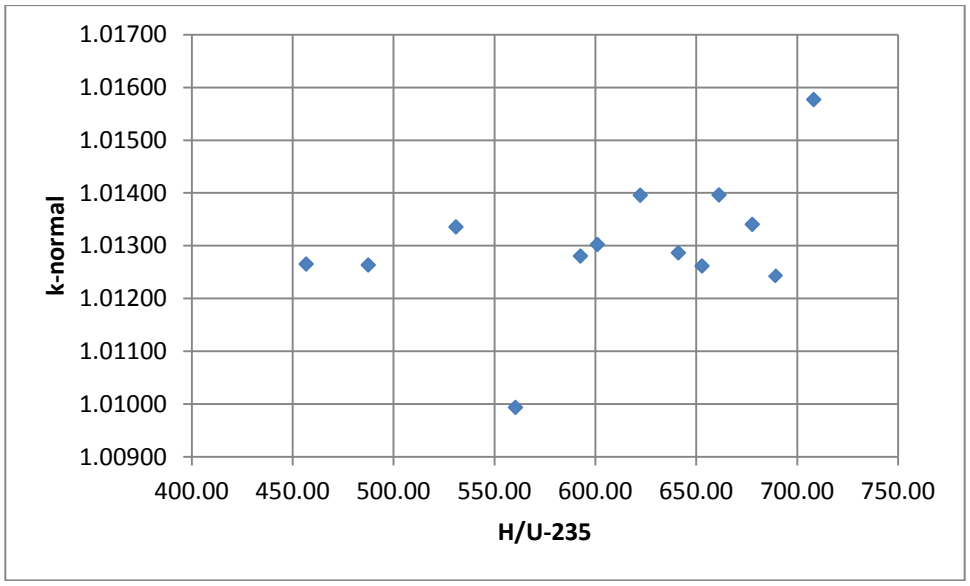
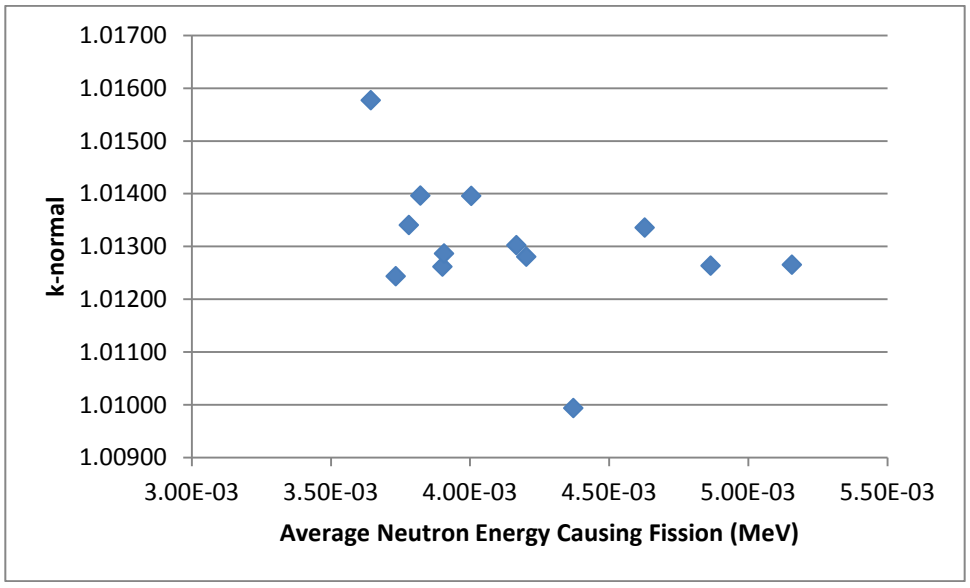


Figure 2: k_{normal} vs Average Neutron Energy Causing Fission



The uranium sulfate solutions are nearly pure ^{235}U and are therefore most appropriately compared with the highly enriched ^{235}U (HEU) solution systems from Reference 2. As shown in Table 4 the UO_2SO_4 solutions exhibit a slight positive bias (tendency to over

predict k_{eff}), however as the average total uncertainty (σ_{total}) herein is 0.00033 there is no statistically significant bias. Additionally, a positive bias is conservative for criticality safety. Therefore, it is concluded that no additional AOA margin is required with the use of homogeneous uranium sulfate solutions.

Table 4: Average Value Comparison

Group	Ave k_{normal}
	MCNP
Uranium Sulfate Solutions	1.0130
Ref. 2 LEU Homogeneous Solids	1.0046
Ref. 2 LEU Homogeneous Solutions	1.0001
Ref. 2 HEU Homogeneous Solutions	1.0003

APPENDIX 1: REPRESENTATIVE INPUT FILES

HEU-SOL-THERM-046

```
Proserpine case1, 36.588g U235/L (Table 1)
c Benchmark HEU-SOL-THERM-046, h(crit) = surface 1 = Table 1 & 32
c Dimensions & materials from HEU-SOL-THERM-046 sections 3.1 - 3.3
1   1 0.100174   -2 -1           imp:n=1  $ solution in cylindrical part of tank
2   1 0.100174   -3              imp:n=1  $ solution in tapered base of tank
3   1 0.100174   -4              imp:n=1  $ solution in drain tube
4   2 4.3243E-02  3 -5  7        imp:n=1  $ Zircaloy-2 tapered base of tank
5   2 4.3243E-02  2  3 -6 8 14   imp:n=1  $ Zircaloy-2 cylindrical part of tank
6   2 4.3243E-02  4 -7           imp:n=1  $ Zircaloy-2 drain tube
7   3 5.3248E-05 -8  1           imp:n=1  $ air above solution
8   3 5.3248E-05 -9  6 5 10      imp:n=1  $ air around Zircaloy-2 tank
9   3 5.3248E-05 -10 5 7         imp:n=1  $ air around Zircaloy-2 tube
10  4 5.9544E-02 -11 9 12        imp:n=1  $ Al-alloy tank
11  4 5.9544E-02 -12 10          imp:n=1  $ Al-alloy tube
12  4 5.9544E-02 -13 11          imp:n=1  $ Al-alloy tank lip
13  2 4.3243E-02 -14 8           imp:n=1  $ Zircaloy-2 tank lip
14  5 7.7673E-02 -15 8           imp:n=1  $ Teflon gasket/tank lip
15  4 5.9544E-02 -16 17 19 21    imp:n=1  $ Al-alloy tank cover
16  4 5.9544E-02 -17 18          imp:n=1  $ Al-alloy center top tube (#1)
17  4 5.9544E-02 -19 20          imp:n=1  $ Al-alloy center top tube (#2)
18  4 5.9544E-02 -21 22          imp:n=1  $ Al-alloy center top tube (#3)
19  3 5.3248E-05 -18             imp:n=1  $ air in tube #1
20  3 5.3248E-05 -20             imp:n=1  $ air in tube #2
21  3 5.3248E-05 -22             imp:n=1  $ air in tube #3
30  6 1.4204E-01 -30 11 12 13 14 15 16 17 19 21
                  41 43 47 49 50 51  imp:n=1  $ BeO section #1
31  6 1.4204E-01 -31 30 12 17 19 21
                  41 43 47 49    imp:n=1  $ BeO section #2
32  6 1.4204E-01 -32 31 41 43    imp:n=1  $ BeO section #3
33  6 1.4204E-01 -33 17 19 21    imp:n=1  $ BeO top section #4
34  4 5.9544E-02 -34 17 19 21    imp:n=1  $ Al-alloy BeO cover
35  7 8.2737E-02 -35 12 17 19 21 30 31 32 33 34
      41 43 44 45 47 49 50 51 52 53  imp:n=1  $ Graphite
40  3 5.3248E-05 -40             imp:n=1  $ air, reflector channel #1
41  4 5.9544E-02 -41 40          imp:n=1  $ Al-alloy, reflector channel #1
42  3 5.3248E-05 -42             imp:n=1  $ air, reflector channel #2
43  4 5.9544E-02 -43 42          imp:n=1  $ Al-alloy, reflector channel #2
44  3 5.3248E-05 -44             imp:n=1  $ air, reflector channel #3
45  3 5.3248E-05 -45             imp:n=1  $ air, reflector channel #4
46  3 5.3248E-05 -46             imp:n=1  $ air, reflector channel #5
47  4 5.9544E-02 -47 46          imp:n=1  $ Al-alloy, reflector channel #5
48  3 5.3248E-05 -48             imp:n=1  $ air, reflector channel #6
49  4 5.9544E-02 -49 48          imp:n=1  $ Al-alloy, reflector channel #6
50  3 5.3248E-05 -50 11          imp:n=1  $ air, reflector channel #7
51  3 5.3248E-05 -51 11          imp:n=1  $ air, reflector channel #8
52  3 5.3248E-05 -52             imp:n=1  $ air, reflector channel #9
53  3 5.3248E-05 -53             imp:n=1  $ air, reflector channel #10
99  0             35             imp:n=0  $ outside world

1   pz  23.875                             $ critical h of solution from base of tapered base
2   rcc 0 0 0.87     0 0 23.005     12.5  $ solution in cylindrical part of tank (max critical h)
3   trc 0 0 0        0 0  0.87  0.3 12.5  $ solution in tapered base
4   rcc 0 0 0        0 0 -80.5       0.3  $ solution in drain tube
5   trc 0 0 -0.0931  0 0  0.87  0.4 12.6  $ Zircaloy-2 tank tapered base
6   rcc 0 0 0.7769   0 0 29.0       12.6  $ Zircaloy-2 cylindrical tank
7   rcc 0 0 0        0 0 -80.5       0.4  $ Zircaloy-2 drain tube
8   rcc 0 0 30.7     0 0 -15.16     12.5  $ air above solution (min critical h)
9   rcc 0 0 -0.3     0 0 30.0       12.9  $ air around Zircaloy-2 tank
10  rcc 0 0 0        0 0 -80.5       0.7  $ air around Zircaloy-2 drain tube
11  rcc 0 0 -0.5     0 0 30.2       13.1  $ Al-alloy tank
12  rcc 0 0 -0.3     0 0 -80.2       0.9  $ Al-alloy drain tube
13  rpp  -15 15  -15 15  29.5 29.7        $ Al-alloy tank lip
14  rpp  -15 15  -15 15  29.7 29.8        $ Zircaloy-2 tank lip
15  rpp  -15 15  -15 15  29.8 30.7        $ Teflon gasket/tank lip
```

```
16  rpp  -15 15  -15 15  30.7 33.5        $ Al-alloy tank cover
17  rcc    0  0  30.7    0 0 80    1.0    $ Al-alloy center top tube #1 OD
18  rcc    0  0  30.7    0 0 80    0.9    $ Al-alloy center top tube #1 ID
19  rcc   10  0  30.7    0 0 80    1.0    $ Al-alloy 2nd 2cmOD top tube #2
20  rcc   10  0  30.7    0 0 80    0.9    $ Al-alloy 2nd 2cmOD top tube #2 ID
21  rcc  -10  0  30.7    0 0 80    0.5    $ Al-alloy 1cmOD top tube #3
22  rcc  -10  0  30.7    0 0 80    0.4    $ Al-alloy 1cmOD top tube #3 ID
30  rpp  -40 40  -25 25  -20.5  50.7      $ BeO reflector section #1
31  rpp  -30 30  -35 35  -30.5  60.7      $ BeO reflector section #2
32  rpp  -20 20  -40 40  -30.5  60.7      $ BeO reflector section #3
33  rpp  -15 15  -15 15   60.7  63.2      $ BeO reflector section #4 (top/cover)
34  rpp  -20 20  -20 20   63.2  65.2      $ Al-alloy BeO reflector top/cover
35  rpp  -90 90  -90 90  -80.5 110.7      $ Graphite reflector
40  rcc   15 -90   4.5   0 180 0   1.5    $ air, y-axis channel #1 ID
41  rcc   15 -90   4.5   0 180 0   1.7    $ Al-alloy tube, y-axis channel #1 OD
42  rcc  -15 -90   4.5   0 180 0   1.5    $ air, y-axis channel #2 ID
43  rcc  -15 -90   4.5   0 180 0   1.7    $ Al-alloy tube, y-axis channel #2 OD
44  rcc   50 -90   4.5   0 180 0   2.5    $ air, y-axis channel #3 ID
45  rcc  -50 -90   4.5   0 180 0   2.5    $ air, y-axis channel #4 ID
46  rcc   25 -90  14.5   0 180 0   0.6    $ air, y-axis channel #5 ID
47  rcc   25 -90  14.5   0 180 0   0.8    $ Al-alloy tube, y-axis channel #5 OD
48  rcc  -25 -90  14.5   0 180 0   0.6    $ air, y-axis channel #6 ID
49  rcc  -25 -90  14.5   0 180 0   0.8    $ Al-alloy tube, y-axis channel #6 OD
50  rcc  -90   0   9.5   180 0 0   0.9    $ air, x-axis channel #7 ID
51  rcc  -90   0  19.5   180 0 0   0.6    $ air, x-axis channel #8 ID
52  rcc  -90  50   9.5   180 0 0   2.5    $ air, x-axis channel #9 ID (assumed z, dimension not
shown)
53  rcc  -90 -50   9.5   180 0 0   2.5    $ air, x-axis channel #10 ID (assumed z, dimension not
shown)

c UO2SO4 solution (mass density = 1.05607 g/cc)
m1    92234.60c   8.0385E-07
      92235.60c   9.3399E-05
      92236.60c   1.8632E-07
      92238.60c   9.4426E-06
       1001.60c   6.6149E-02
       8016.60c   3.3787E-02
      16032.60c   1.3383E-04
mt1 lwtr.60t
c
c Zircaloy-2 (mass density = 6.56 g/cc)
m2    40000.60c   4.2552E-02 $ zirconium
      50000       4.8254E-04 $ tin
      26054.60c   5.8429E-06 $ iron
      26056.60c   9.0833E-05 $ iron
      26057.60c   2.0797E-06 $ iron
      26058.60c   2.7729E-07 $ iron
      24050.60c   3.3012E-06 $ chromium
      24052.60c   6.3661E-05 $ chromium
      24053.60c   7.2178E-06 $ chromium
      24054.60c   1.7969E-06 $ chromium
      28058.60c   2.2977E-05 $ nickel
      28060.60c   8.7842E-06 $ nickel
      28061.60c   3.8031E-07 $ nickel
      28062.60c   1.2083E-06 $ nickel
      28064.60c   3.0627E-07 $ nickel
c
c air
m3     7014.60c   4.1985E-5  $ nitrogen
       8016.60c   1.1263E-5  $ oxygen
c
c AL-alloy (mass density = 2.66 g/cc)
m4    13027.60c   5.7529E-02 $ aluminum
      12000.60c   1.9772E-03 $ magnesium
      26054.60c   6.0080E-07 $ iron
      26056.60c   9.3398E-06 $ iron
      26057.60c   2.1384E-07 $ iron
      26058.60c   2.8512E-08 $ iron
      14000.60c   1.9962E-05 $ silicon
      22000.60c   2.0074E-06 $ titanium
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      25055.60c   8.7474E-07 $ manganese
      23000.60c   9.4337E-07 $ vanadium
      29000       4.2870E-06 $ Cu substituted for Zn
c
c Teflon (mass density = 2.15 g/cc)
m5     6000.60c   2.5891E-02 $ carbon
       9019.60c   5.1782E-02 $ fluorine
c
c BeO (mass density = 2.95 g/cc)
m6     4009.60c   7.0937E-02 $ beryllium
       8016.60c   7.0937E-02 $ oxygen
      13027.60c   9.8763E-06 $ aluminum
      26054.60c   9.3840E-08 $ iron
      26056.60c   1.4588E-06 $ iron
      26057.60c   3.3401E-08 $ iron
      26058.60c   4.4534E-09 $ iron
      14000.60c   3.1627E-06 $ silicon
      12000.60c   3.6546E-07 $ magnesium
      25055.60c   3.2337E-08 $ manganese
      48106.66c   5.9265E-11 $ cadmium
      48108.66c   4.2197E-11 $ cadmium
      48110.66c   5.9218E-10 $ cadmium
      48111.66c   6.0687E-10 $ cadmium
      48112.66c   1.1441E-09 $ cadmium
      48113.66c   5.7937E-10 $ cadmium
      48114.66c   1.3621E-09 $ cadmium
      48116.66c   3.5512E-10 $ cadmium
      47107.60c   4.2281E-09 $ silver
      47109.60c   3.9282E-09 $ silver
      29063.60c   1.9337E-07 $ copper
      29065.60c   8.6188E-08 $ copper
      82206.60c   6.2865E-09 $ lead
      82207.60c   5.7643E-09 $ lead
      82208.60c   1.3669E-08 $ lead
      28058.60c   6.1995E-08 $ nickel
      28060.60c   2.3701E-08 $ nickel
      28061.60c   1.0261E-09 $ nickel
      28062.60c   3.2600E-09 $ nickel
      28064.60c   8.2636E-10 $ nickel
       6000.60c   1.4791E-04 $ carbon
       5010.60c   9.8103E-09 $ boron
       5011.60c   3.9488E-08 $ boron
mt6  beo.60t
c
c Graphite (mass density = 1.65 g/cc)
m7     6000.60c   8.2718E-02 $ carbon
       5010.60c   3.6580E-09 $ boron
       5011.60c   1.4724E-08 $ boron
       1001.60c   1.6267E-05 $ hydrogen
      11023.60c   8.2120E-07 $ sodium
      20000.60c   7.4378E-07 $ calcium
      62149.66c   1.1343E-10 $ samarium 149
      22000.60c   1.0376E-07 $ titanium
      26054.60c   2.0995E-09 $ iron
      26056.60c   3.2639E-08 $ iron
      26057.60c   7.4729E-10 $ iron
      26058.60c   9.9638E-11 $ iron
      42000.60c   1.0470E-07 $ molybdenum
      23000.60c   6.2418E-07 $ vanadium
      17000.60c   9.8095E-08 $ chlorine
mt7  grph.60t
c
kcode  10000 1.0 15 500
ksrc   0 0 5
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