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TITLE: SIMULATING THE UPPER BARREN ZONE AND THE ORE ZONE TESTS
PERFORMED WITH THE EMC LOGGING TOOL

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Simulating the Upper Barren Zone and Ore Zone Tests Performed with the EMC Logging Tool.

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I. Introduction

As discussed in the previous report "Benchmarking the Monte Carlo Simulation Code MCNP" (LA-UR-94-1282)¹ the primary purpose of the Multispectral Nuclear Logging project is to assess the effectiveness of applying nuclear borehole-logging techniques to the Department of Energy's (DOE) Environmental Restoration (ER) program, adapt the technology to improve these capabilities, and transfer that technology to industry. The purpose of the Monte Carlo simulations using MCNP is to predict the minimum concentration levels for environmental contaminants that could be detected by Multispectral Logging (MSL). The Monte Carlo code used for this type of simulation, MCNP, should be benchmarked against experimental data to show that the user can accurately reproduce the proper gamma-ray spectrum. Experimental data was obtained from Westinghouse-Hanford Company using the Environmental Measurements Corp. (EMC) logging tool in the Upper Barren Zone (UBZ) and Ore Zone (OZ) calibration models at Grand Junction. This paper continues the discussion of benchmarking MCNP using the UBZ and OZ data.

II. Geometry and Material Specifications

The UBZ and OZ data were taken in the 4.5" diameter hole of the D-model at DOE/GJPO, Grand Junction, CO.² The model is illustrated in Figure 1 and consists of three regions: the upper barren zone, the ore zone, and the lower barren zone of thickness 5', 6', and 4' respectively, plus a run-pipe below the model for the logging tools. The D-Model's borehole is actually sloped at 2° to insure that the logging tools are kept eccentric in the borehole. The computer simulation used a non-sloped borehole, as shown in the figure. For simulation purposes, the interface between the different zones was sufficiently far away from the neutron generator and HPGe detector that the simulations for the UBZ and OZ were performed in separate computer runs. The material specifications for the UBZ and OZ are listed in Table 1.³ The experimental data were taken with the EMC logging tool described in LA-UR-94-1282, where the material specifications for the logging tool are also documented.

Figure 1: The D-Model, 4.5" hole, at Grand Junction.

Table 1
Material Specification by weight fraction of the
UBZ and the OZ in the D-Model at Grand Junction.

Element/Isotope	UBZ	OZ
H	0.0080	0.0105
6Li	1.394E-06	1.359E-06
7Li	1.719E-05	1.676E-05
10B	1.849E-06	2.704E-06
11B	7.441E-06	1.089E-05
O	0.5519	0.0006
Na	0.0140	0.0137
Al	0.0445	0.0434
Si	0.2606	0.2542
K	0.0165	0.0139
Ca	0.0816	0.0796
Ti	1.783E-03	1.740E-03
Fe	0.0204	0.0199
Cu	2.601E-05	2.219E-03
Ba	6.502E-04	6.795E-04
Th	5.573E-06	2.809E-05
235U	1.752E-08	4.557E-06
238U	2.398E-06	6.098E-04

III. Experimental Data

There are two sets of measurements that will be discussed in this technical note, the UBZ and OZ measurements. Each of these measurement sets contains passive, active, and activation data.^{4,5} The UBZ measurements were made with the mid-plane of the detector 2.0' below the surface of the D model and the OZ measurements were made 6.9' below the surface of the model. Table 2 lists information describing the sets of measurements that were made; the spectra used for data analysis are indicated by bold-face type.

The capture spectra from the active measurements in the UBZ and OZ are shown in Figure 2. As was seen previously in the Glass-Plate Model data, LA-UR-94-1282, the spectra are populated by many single- and double-escape peaks. Due to the small size of the HPGe detector, only the strongest capture peaks were evident in the spectra. As shown in Table 1, uranium and copper are approximately two orders-of-magnitude greater in concentration for the Ore Zone relative to the UBZ. Capture lines from uranium and copper were not observed in either set of measurements.

Table 2
Experimental Measurements with the EMC
Logging Tool in the D-Model at Grand Junction.

Computer File Name	Model/Ge Positon	Count Time	Remarks
md451.3	D/6.9'	16m47s	Passive spectrum, OZ
md451.4	D/6.9'	16m46s	Passive spectrum, OZ
md451.5	D/2.0'	16m46s	Passive spectrum, UBZ
md451.6	D/2.0'	16m49s	Passive spectrum, UBZ
md452.3	D/6.9'	16m53s	Active spectrum, OZ
md452.4	D/6.9'	16m53s	Active spectrum, OZ
md452.5	D/6.9'	16m53s	Active spectrum, OZ
md452.6	D/6.9'	16m53s	Active spectrum, OZ
md452.7	D/2.0'	16m46s	Passive, Tool activation
md452.8	D/6.9', 2.0'	5m03s	Passive, 3 min active, 14s, Tool activation
md452.9	D/2.0'	16m46s	Active spectrum, UBZ
md452.10	D/2.0'	16m46s	Active spectrum, UBZ
md452.11	D/2.0'	16m46s	Active spectrum, UBZ
md452.12	D/4.2'	16m53s	Passive after 1m delay, Tool activation

*Spectra used for data analysis indicated by **bold-face** type.*

Figure 2: OZ and UBZ Data using the EMC Logging Tool

The passive logging and tool activation data are shown in Figure 3, along with the capture spectrum from the OZ for comparison. The passive logging data were acquired in each zone before active measurements were made. The tool activation data were acquired by moving the tool to the UBZ and operating in passive mode, after making active measurements in the OZ. Since all spectra were collected for approximately the same period of time, it can be observed from Figure 3 that the strongest radioactive decay lines make a contribution to the capture spectrum at energies below $E_\gamma=2.5\text{-}3.0$ MeV, while tool activation does not seriously affect the capture data. The radioactive decay lines identified from the passive measurements are listed in Table 3. All of the radioactive decay lines are from daughters of uranium, with the exception of $E_\gamma=2.614$ from a thorium daughter.

Table 3
Identification of Radioactive Decay Lines from Uranium and Thorium

Energy (MeV)	Emitting Nuclide
0.352	Pb-214
0.609	B-214
0.666	Bi-214
0.768	Bi-214
0.786	Pb-214
0.806	Bi-214
0.934	Bi-214
1.12	Bi-214
1.155	Bi-214
1.238	Bi-214
1.281	Bi-214
1.378	Bi-214
1.402, 1.408	Bi-214
1.509	Bi-214
1.661	Bi-214
1.765	Bi-214
1.848	Bi-214
2.119	Bi-214
2.204	Bi-214
2.294	Bi-214
2.448	Bi-214
2.614	Tl-208

IV. MCNP Simulations

The computer simulations used the same variance-reduction techniques discussed in LA-UR-94-1282. The source was directionally biased such that a half-

Figure 3: Passive, Activation, and Capture Spectra taken with the EMC Logging Tool

cone of angle 30° was not sampled in the direction opposite the ray from the source to detector. Weight-windows in both space and energy were used. Six energy bins (ranges) were specified for both neutrons and photons. The neutron energy bins were 1×10^{-5} , 1×10^{-3} , 1×10^{-2} , 1.0, 10.0, and 15.0 MeV, where the bin is specified by the upper energy limit. The photon energy bins were 2.0, 4.0, 6.0, 8.0, 10.0, and 24.0 MeV, where the large upper-energy bin was used because few photons were detected by the EMC tool above 8 MeV. The MCNP input files are listed in Appendix A.

V. *Comparison of the Computer Simulations and the Experimental Data*

A. *Comparison of UBZ and OZ Computer Simulations*

A comparison of the computer simulation results, as well as for the experimental data, shows no appreciable difference between the OZ and UBZ capture spectra. While the ore zone has sufficient uranium to calibrate detectors for passive (radioactive) studies, there is not sufficient uranium to be detected using the thermal-neutron capture reaction for this instrument. Figure 4 shows the capture spectra for the two simulations. X-6, the Radiation Transport group, is considering developing a variance-reduction technique, first-order perturbation, that could be used in simulations similar to these where there is a small change in the concentration of the elements in a material.

A second simulation of the UBZ test was performed with the source biased in the +z direction only. The result indicates that the overall spectra for both neutron and photon flux in the detector volume changes with respect to the source direction biasing. Figures 5 and 6 show the comparison between the two simulations for the total neutron and capture photon flux tallies respectively, where *ubzrun* corresponds to the results for the original simulation and *ubz2run* corresponds to the second simulation. MCNP tallies the flux through the detector volume as flux per source neutron. Neutrons emitted from the source in the direction of the detector will have a higher probability of contributing toward this tally. By eliminating the neutrons emitted away from the direction of the detector, we have increased the detection probability for each neutron thereby giving a higher signal per source neutron. Figure 7 shows the photon flux through the detector volume over the energy range $E_\gamma = 5.0\text{--}6.0$ MeV. An analysis of this region indicates that an average increase by a factor of 1.5 resulted from the change in source biasing. Therefore, biasing the source directionally is a good variance-reduction technique provided that the same biasing is applied for simulations that will be compared quantitatively to one another. This will also apply for other types of variance-reduction techniques such as using a reflective surface.

Figure 4: Capture Spectra for the MCNP Simulations of the UBZ and OZ.

Figure 5: Comparison of Total Neutron Flux Spectra.

```

MCNP      4XI
02/04/94 10 32 2
TALLY=    14
N
NPS      10309693
RUNTPE = UBZ2RUN
DUMP     12
F      CELL      1
D      FLAG/DIR  1
J      USER      1
S      SEGMENT   1
M      MULT      1
C      COSINE    1
E      ENERGY   *
T      TIME      1
----- UBZ2RUN
----- UBZRUNI

```

Figure 6: Comparison of the Capture Photon Flux Spectra.

```
MCNP      4XI
02/04/94 10 32 2
TALLY=    4
P
NPS      10309693
RUNTPE = UBZ2RUN
DUMP     12
F      CELL      1
D      FLAG/DIR  1
U      USER      1
S      SEGMENT   1
M      MULT      1
C      COSINE    1
E      ENERGY   *
T      TIME      2
          UBZ2RUN
          UBZRUNE
```

Figure 7: Comparison of the Capture Photon
Flux Spectra from $E_\gamma=5.0-6.0$ MeV.

```

MCNP      4X1
02/04/94 10 32 2
TALLY=    4
P
NPS      10309693
RUNTPE = UBZ2RUN
DUMP     12
F        CELL      1
D        FLAG/DIR  1
U        USER     1
S        SEGMENT   1
M        MULT      1
C        COSINE    1
E        ENERGY   *
T        TIME      2
      _____ UBZ2RUN
      ----- UBZRUNF
  
```

B. Comparison of the Experimental Data with the Computer Simulations

As discussed in LA-UR-94-1282, it is difficult to make a direct comparison between the EMC experimental results and the computer simulation which has a perfect detector response. Table 4 identifies the capture gamma-ray lines observed in the experimental data and in the simulated results for the UBZ and OZ measurements. The capture lines also observed in the experimental data are indicated by bold-face type in the table. The results for the UBZ and OZ active measurements and simulations have been combined because there was no appreciable difference between the two. Table 4 also illustrates that the photon-production spectra for some elements/isotopes are not binned sufficiently finely to show discrete capture lines in the simulated spectra. In fact, that is the case for most elements/isotopes including chromium and nickel. The chromium and nickel lines observed in the experimental data are not observed in the simulated results because the photon-production spectra for thermal-neutron capture are binned in 250 keV wide energy bins in the cross-section libraries used by MCNP.

VI. Summary

Computer simulations for the EMC measurements in the D-Model at Grand Junction have been performed. While there was no appreciable difference between the simulated spectra for the UBZ and OZ measurements, the simulations illustrate that MCNP can adequately reproduce these types of measurements. Since MCNP simulates a perfect detector response, the simulations show far more discrete capture lines than the experimental data for most elements. These simulations indicated that the same constraints identified in LA-UR-94-1282 apply to all simulations of this type; cross-sections must be obtained for all elements/isotopes in the given problem, the photon production cross-sections for some elements/isotopes will obscure the underlying gamma-ray lines, and no contribution from radioactive isotopes can be easily included in a simulation. For future data analysis and comparison with simulated spectra, the contribution from radioactive and tool activation should be removed from the experimental measurements. Improvements in the two key areas of cross-section availability and quality of photon-production data from thermal-neutron capture will significantly improve the capability to apply MCNP to these types of simulations.

One other area to pursue for improving the capability of using MCNP to address multispectral logging problems is to obtain a post-processing code that will translate the results from the perfect detector response of MCNP into the results for the detector

Table 4

Identification of Capture Gamma-ray Lines

Listed below are the gamma-rays identified in the MCNP simulation and the EMC experimental data over the energy range from 0.0 to 10.0 MeV. The gamma-ray energies highlighted by BOLD type are those peaks observed in the experimental data from EMC, while the observed gamma-rays from MCNP are indicated in the left-hand column. The same capture spectra were observed for both the UBZ and OZ measurements.

MCNP Gamma-ray Energy (MeV)	Actual Gamma-ray Energy (MeV)	Single Escape Peak Energy (MeV)	Double Escape Peak Energy (MeV)	Identification of Target Nucleus
0.375	0.352, 0.367			Fe
0.4775	0.472, 0.478			Na, B-delayed pair prod.
0.5125	0.511			Ga
	0.575			Fe
0.675	0.692			
	0.690			
	0.708			Ga
0.7525	0.752 (0.749)			Si (Cr)
0.7675	0.770			K
	0.835			Cr
0.8525	0.844			K
	0.868			Ga
0.8675	0.871			Na
	0.900			
0.9825	0.984			F, Al
0.9975	-			K
	1.150			
	1.200			
1.275	1.261	0.750	0.239	Fe
1.2725	1.273	0.762	0.251	Si
1.5275	1.526	1.015	0.504	Al
1.6175	1.623	1.112	0.601	K
1.625	1.613	1.102	0.591	Fe
1.725	1.725	1.214	0.703	Fe
1.7875				K
1.9425	1.942	1.431	0.920	Ca
2.0025	2.001	1.490	0.979	Ca
2.0225	2.027	1.516	1.005	Na
2.0675	2.069, 2.074	1.558, 1.563	1.047, 1.052	K
2.0925	2.093	1.582	1.071	Si
2.125	2.000	1.489	0.978	Fe
2.2075	2.210	1.699	1.188	Na

MCNP Gamma-ray Energy (MeV)	Actual Gamma-ray Energy (MeV)	Single Escape Peak Energy (MeV)	Double Escape Peak Energy (MeV)	Identification of Target Nucleus
2.0925	2.093	1.582	1.071	Si
2.125	2.000	1.489	0.978	Fe
2.2075	2.210	1.699	1.188	Na
2.2225	2.223	1.712	1.201	H
2.2325	2.235	1.724	1.213	Si
2.2825	2.286	1.775	1.264	Al
2.3425	2.346	1.835	1.324	K
2.3825	2.380	1.869	1.358	S
2.4125	2.415	1.904	1.393	Na
2.4275	2.426	1.915	1.404	Si
2.5175	2.518	2.007	1.496	Na
2.595	2.590	2.079	1.568	Al
2.7125	2.710, 2.704	2.199, 2.193	1.688, 1.682	Al, K
2.725	2.721	2.210	1.699	Fe
2.8125	2.821	2.310	1.799	Al
2.8225	2.863	2.352	1.841	Na
2.9625	2.960	2.449	1.938	Al
2.9825	2.982	2.471	1.960	Na
2.9975	2.995, 3.001	2.484, 2.490	1.973, 1.979	Cl
3.0375	3.034	2.523	2.012	Al
3.0525	3.054	2.543	2.032	Si
3.1025	3.102	2.591	2.080	Si, Na
3.275	3.413	2.902	2.391	Fe
3.3825	3.382, 3.384	2.871, 2.873	2.360, 2.362	K
3.3975	3.399, 3.412	2.888, 2.901	2.377, 2.390	S, Na
3.425	3.436	2.925	2.414	Fe
3.4625	3.465	2.954	2.443	Al
3.5325	3.539	3.028	2.517	Si
3.5575	3.55-3.57			Cl, K
3.5925	3.588-3.591			Na, Al, K
3.610	3.610	3.099	2.588	Ca
3.6325	3.630-3.635			F, K
3.6625	3.661	3.150	2.639	Si
3.760	3.760	3.249	2.738	Ca
3.8475	3.849	3.338	2.827	Al
3.8675	3.865	3.354	2.843	Si
3.8775	3.878, 3.876	3.367, 3.365	2.856, 2.584	Na, Al
3.9525	3.955	3.444	2.933	Si
3.9825	3.982	3.471	2.960	Na
4.0025	4.003	3.492	2.981	K
4.1325	4.133	3.622	3.111	Al
4.225	4.218	3.707	3.196	Fe
4.2625	4.260	3.749	3.238	Al
4.3875	4.386	3.875	3.364	K
4.425	4.406	3.895	3.384	Fe
4.4175	4.419	3.908	3.397	Ca

MCNP Gamma-ray Energy (MeV)	Actual Gamma-ray Energy (MeV)	Single Escape Peak Energy (MeV)	Double Escape Peak Energy (MeV)	Identification of Target Nucleus
4.6575	4.660	4.149	3.638	Al
4.6925	4.691	4.180	3.669	Al
4.7375	4.734	4.223	3.712	Al
4.7675	4.755, 4.765	4.244, 4.254	3.733, 3.743	Al
4.850	4.810	4.299	3.788	Fe
4.9075	4.903	4.392	3.881	Al
4.9325	4.934	4.423	3.912	Si
4.965	4.964	4.453	3.942	Ca
5.0175	5.014	4.503	3.992	K
5.0575	5.04-5.07			K
5.1075	5.107	4.596	4.085	Si
5.1375	5.134	4.623	4.112	Al
5.1775	5.174	4.663	4.152	K
5.2725	5.271	4.760	4.249	Ca
5.3875	5.381	4.870	4.359	K
5.4125	5.411	4.900	4.389	Al
5.5075	5.510	4.999	4.488	K
5.5675	5.518	5.007	4.496	Cl
5.6175	5.617	5.106	4.595	Na
5.7475	5.752	5.241	4.730	K
5.9025	5.901	5.390	4.879	Ca
5.925	5.920	5.409	4.898	Fe
6.025	6.018	5.507	4.996	Fe
6.0475	6.046	5.535	5.024	Si
6.3175	6.316	5.805	5.294	Al
6.3825	6.381	5.870	5.359	Si
6.3975	6.395	5.884	5.373	Na
6.42	6.420	5.909	5.398	Ca
6.7125	6.710	6.199	5.688	Al
6.7475	6.743, 6.747	6.232, 6.236	5.721, 5.725	Si
7.0025	7.000, 7.005	6.489, 6.494	5.978, 5.983	K, B
7.2025	7.201	6.690	6.179	Si
7.275	7.279	6.768	6.257	Fe
7.625	7.631, 7.645	7.120, 7.134	6.609, 6.623	Fe
7.6975	7.693	7.182	6.671	Al
7.7275	7.723	7.212	6.701	Al
7.7675	7.770	7.259	6.748	K
8.3575				
8.3725	8.372	7.861	7.350	Si
8.4725	8.473	7.962	7.451	Si
	8.884	8.373	7.862	Cr
	8.999	8.488	7.977	Ni
9.275	9.298	8.787	8.276	Fe
9.3925				K
	9.718	9.208	8.697	Cr

used for the measurements. In lieu of obtaining such a detector response code, simulating a number of experimental measurements for a specific detector would allow the user to infer a detector response as a function of energy. This response function can then be applied to simulated results for that detector for which no experimental data exist.

References

1. "Benchmarking the Monte Carlo Simulation Code MCNP", S. Frankle, LA-UR-94-1282.
2. Communication from R. Wilson, RUST Geotech, Nov. 1, 1993.
3. *Benchmark Data* communication from R. Wilson, RUST Geotech, Nov. 1, 1993.
4. *MSL Tool Project* communication from R. Wilson, RUST Geotech, Nov. 18, 1993.
5. *EMC raw data files* communication from R. Wilson, RUST Geotech, Nov. 12, 1993.

Appendix A

MCNP input files for the UBZ and OZ simulations.

MCNP input file for the UBZ simulation.

ubzinp

```

logger2-9> cat ubzinp
c      This is the MCNP input file for the EMC tool geometry
c      Overall geometry is Neutron Generator (NG) is at the
c      bottom of the borehole and the detector is at the top.
c
c      Borehole specification: GJ 4.5" airfilled, upper barren zone
c
c      cell cards
c
c      EMC tool geometry
1      5      -8.98      -5 68 -73      $Cu cold fing. in Freon
2      2      -1.52      -1 72 -74 #1      $Freon cryogen
3      5      -8.98      1 -2 72 -74      $Cu cryo inner vessel
4      9      -0.00129      2 -3 72 -74      $air gap in cryo
5      1      -7.95      3 -4 72 -74      $SS cryo outer vessel
6      0      -7.95      4 -7 71 -74      $vacuum around cryo
7      1      -7.95      5 -3 71 -72      $cryo bottom
8      1      -7.95      7 -8 60 -74      $outer SS detector housing
9      1      -7.95      -8 -60 59      $top of SS det. housing
10     1      -7.95      -6 -59 57      $SS det. casing, port, assumed solid
11     1      -7.95      3 -4 -72 63      $heat shield, assumed SS
12     1      -7.95      -4 -63 62      $heat shield bottom
13     0      (-3 63 -71) #1 #14 #15 #16 #17 #18
14     5      -8.98      5 -6 70 -71      $extra Cu around cold finger
15     3      -2.70      5 -6 -70 69      $Al ring around cold finger
16     3      -2.70      67 -68 -5      $Al cold finger conn., assumed size
c 17     4      -5.32      65 -66 -9      $Ge detector
17     0      -5.32      65 -66 -9      $Ge detector as a void
18     3      -2.70      64 -67 -10 #17      $Ge detector casing
19     0      (4 -7 62 -71):(60 -62 -7) $vacuum in SS housing
20     9      -0.00129      59 -74 8 -19      $around around SS housing
21     11     -0.497      (27 -26 55 -59 +11 6 -14):(55 -57 27 -26 -6) $wire-filled s
lot in poly
22     6      -1.4      ((58 -59 6 -13):(56 -58 6 -14):(55 -56 6 -13)) #21 $polycarb
onate
23     9      -0.00129      (55 -59 -19) #10 #21 #22      $air
24     1      -7.95      6 -12 54 -55      $SS part of wire connector
c 25     10     -5.53      -6 53 -52      $epoxy wire conn.
25     10     -5.53      -6 53 -52      $epoxy wire conn., polycarb. substituted
26     1      -7.95      12 -19 53 -55      $assumed SS around 24 and 25
27     9      -0.00129      -18 -55 52 #24 #26      $air gaps
28     9      -0.00129      -18 -53 28 #24 #26      $air gap
29     11     -1.789      (29 -28 -17 16 25 -24):(-29 30 -19 16 25 -24) $1/2 wire-fille
d SS shield slot
30     1      -7.95      ((-17 29 -28):(30 -29 -19))#29      $SS shield plug
31     1      -7.95      (18 -19 29 -54):(54 -53 12 -19) $outer connection piece
32     9      -0.00129      -18 29 -28 #29 #30      $air between plug and conn.piece
33     1      -7.95      -30 31 -15      $SS shield plug threads
34     7      -1.62      (-30 31 15 -23):(32 -31 -22):(-32 33 -22 6) $celcon conn. piece
35     1      -7.95      75 -31 22 -23      $NG outer housing, assumed SS
36     1      -7.95      75 -34 21 -22      $NG inner housing, assumed SS
37     10     -5.53      -6 -33 34      $epoxy wire conn.
38     9      -0.00129      -6 -32 33      $air gap
39     9      -0.00129      -22 -33 34 6      $air gap
40     8      -0.0412      75 -34 -21 5      $pressurized sulfur hexafluoride
41     0      -0.0412      75 -34 -5      $evacuated neutron tube (??)
42     9      -0.00129      -30 75 23 -19      $air around NG
43     1      -7.95      19 -20 75 -34      $EMC tool housing, assumed density
44     1      -7.95      19 -20 34 -29
45     1      -7.95      19 -20 29 -53
46     1      -7.95      19 -20 53 -58
47     1      -7.95      19 -20 58 -62
48     1      -7.95      19 -20 62 -69
49     1      -7.95      19 -20 69 -74
c 44     0      20:74:-75      $outside world
c

```

```

c      borehole geometry:cells
c
50  9  -0.00129   20 -105 -74 73  $air-filled borehole,section
51  9  -0.00129   20 -105 -73 69
52  9  -0.00129   20 -105 -69 62
53  9  -0.00129   20 -105 -62 58
54  9  -0.00129   20 -105 -58 53
55  9  -0.00129   20 -105 -53 29
56  9  -0.00129   20 -105 -29 32
57  9  -0.00129   20 -105 -32 34
58  9  -0.00129   20 -105 -34 120
59  9  -0.00129   20 -105 -120 75
60  13 -2.390     105 -106 -74 73  $casing of borehole,section
61  13 -2.390     105 -106 -73 69
62  13 -2.390     105 -106 -69 62
63  13 -2.390     105 -106 -62 58
64  13 -2.390     105 -106 -58 53
65  13 -2.390     105 -106 -53 29
66  13 -2.390     105 -106 -29 32
67  13 -2.390     105 -106 -32 34
68  13 -2.390     105 -106 -34 120
69  13 -2.390     105 -106 -120 75
70  13 -2.39      106 -107 -74 73  $cement of borehole,section
71  13 -2.39      106 -107 -73 69
72  13 -2.39      106 -107 -69 62
73  13 -2.39      106 -107 -62 58
74  13 -2.39      106 -107 -58 53
75  13 -2.39      106 -107 -53 29
76  13 -2.39      106 -107 -29 32
77  13 -2.39      106 -107 -32 34
78  13 -2.39      106 -107 -34 120
79  13 -2.39      106 -107 -120 75
80  13 -2.3900    107 -108 -74 73  $$SiO2 , H2O of borehole,section
81  13 -2.3900    107 -108 -73 69
82  13 -2.3900    107 -108 -69 62
83  13 -2.3900    107 -108 -62 58
84  13 -2.3900    107 -108 -58 53
85  13 -2.3900    107 -108 -53 29
86  13 -2.3900    107 -108 -29 32
87  13 -2.3900    107 -108 -32 34
88  13 -2.3900    107 -108 -34 120
89  13 -2.3900    107 -108 -120 75
90  13 -2.3900    108 -109 -74 73  $$SiO2 , H2O of borehole,section
91  13 -2.3900    108 -109 -73 69
92  13 -2.3900    108 -109 -69 62
93  13 -2.3900    108 -109 -62 58
94  13 -2.3900    108 -109 -58 53
95  13 -2.3900    108 -109 -53 29
96  13 -2.3900    108 -109 -29 32
97  13 -2.3900    108 -109 -32 34
98  13 -2.3900    108 -109 -34 120
99  13 -2.3900    108 -109 -120 75
100 13 -2.3900    109 -110 -74 73  $$SiO2 , H2O of borehole,section
101 13 -2.3900    109 -110 -73 69
102 13 -2.3900    109 -110 -69 62
103 13 -2.3900    109 -110 -62 58
104 13 -2.3900    109 -110 -58 53
105 13 -2.3900    109 -110 -53 29
106 13 -2.3900    109 -110 -29 32
107 13 -2.3900    109 -110 -32 34
108 13 -2.3900    109 -110 -34 120
109 13 -2.3900    109 -110 -120 75
c      outside world as void
110 0      110:74:-75

c      surface cards

```

```

c
c      EMC tool surfaces
c      cylindrical surfaces;exluding surfaces 11 and 16
1      cz 1.7145      $cryostat: inner Cu vessel radius
2      cz 2.2225      $cryostat: outer Cu radius
3      cz 2.7305      $cryostat: inner SS radius
4      cz 2.8575      $cryostat: outer SS radius
5      cz 0.9525      $CU coldfinger / Al ring inner rad
6      cz 1.5875      $CU coldfinger / Al ring outer rad
7      cz 3.4091      $Detector SS vessel, inner rad
8      cz 3.658       $Detector SS vessel, outer rad
c      8a      cz 2.8575      $heat shield for detector, outer rad
c      8b      cz 2.7305      $heat shield for detector, inner rad
9      cz 2.3368      $Detector casing, inner rad (detector rad)
10     cz 2.5273      $Detector casing, outer rad
c      10a     cz 1.27       $Ge detector well radius
11     py 1.57        $inner surf. polycarbonate slot
12     cz 3.683       $Poly upper connection piece, outer
13     cz 3.7846      $Poly lower connection piece, outer
14     cz 2.654       $Poly mid-1 connection piece
15     cz 1.04        $SS shield plug, inner
16     py 1.11        $inner surf. SS slot
17     cz 2.064       $SS shield plug, outer
18     cz 2.144       $inner wall connection
19     cz 3.81        $inner rad of tool casing
20     cz 4.445       $outer rad of tool casing
21     cz 1.435       $inner rad of neutron generator casing
22     cz 1.702       $middle rad of neutron generator casing
23     cz 2.1425      $outer rad of neutron generator casing
c      planar surfaces
24     px 0.6350      $SS slot (centered on y-axis)
25     px -0.6250     $SS slot (centered on y-axis)
26     px 1.270       $polycarbonate slot
27     px -1.270      $polycarbonate slot
c      surface perpendicular to z axis, z=0 is top of steel shield plug
28     pz 0.0         $top of steel shield plug main body
29     pz -12.7        $bot. core steel plug and connector piece
30     pz -13.97       $bot. plug flange, top celcon piece
31     pz -16.205      $bot. plug threads, top of outer NG casing
32     pz -18.796      $top of NG innards
33     pz -20.068      $top of wire connector
34     pz -27.212      $bottom of wire conn.
c      pz -34.036      $NG source location
52     pz 13.784       $top of wire connector
53     pz 6.64         $bottom of wire connector
54     pz 4.973        $bottom of steel around wire conn.
55     pz 14.769       $bottom of polycarbonate/top of steel around wire conn.
56     pz 15.404       $mid-1 polycarbonate
57     pz 16.039       $bottom of steel det casing port
58     pz 17.944       $mid-2 polycarbonate
59     pz 18.579       $bot steel det casing-outer
60     pz 18.828       $bottom steel casing-inner
c      61     pz 19.849      $top of polycarbonate
62     pz 27.889       $bottom of outer detector heat shield
63     pz 29.00        $bottom of inner detector heat shield
64     pz 30.2         $bottom of outer detector
65     pz 30.3911      $bottom of inner detector
c      65a     pz          $detector well bottom
66     pz 37.6936      $top of inner detector
67     pz 38.2524      $top of outer detector
68     pz 40.7924      $top of detector cold finger/bot of Cu
69     pz 43.3324      $bottom of Al ring
70     pz 44.0944      $top of Al ring, bottom extra Cu
71     pz 52.0192      $bottom of freon casing/ top of extra Cu
72     pz 54.559       $top of heat shield, mid-1 freon
73     pz 57.099       $top of Cu cold finger

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74 pz 75.0          $stop of problem cutoff
75 pz -60.0         $bottom of problem cutoff

c
c      borehole surface definitions
c
c 101 py 0.0          $radial dividings
c 102 p 0.707 0.707 0.0 0.0
c 103 px 0.0
c 104 p 0.707 -0.707 0.0 0.0
105 c/z -1.27 0.0 5.75      $cylindrical dividings
106 c/z -1.27 0.0 8.
107 c/z -1.27 0.0 10.0
108 c/z -1.27 0.0 20.0
109 c/z -1.27 0.0 40.0
110 c/z -1.27 0.0 60.0
c
120 pz -40          ,extra plane for vertical dividings

c      physics specifications
c
mode      n p
phys:p    100 1 0
cut:p     1+8 0.01
phys:n    15. 0.0
cut:n     1+8 0.0

c
c      Source specification
c
sdef      pos=0 0 -34.036 erg=14.1 tme=d1 vec=0 0 1 dir=d2
si1       0 1000
sp1       0 1
si2       -0.866 1.0
sp2       -21 1.

c
c      Computer time/# of particles started
c
c nps      5500000
ctme      13000

c
c      tallies
c
prdmpr    -4000 -2000 1 2
print     10 20 40 60 120
f4:p      17
f14:n     17
e4        0.015 2796i 14.0
t4        1+3 1+8
e14       0.02 723i 14.5
t14       1+3 1+8

c
c      Importances and weight-window generation
c imp:n    1 108r 0
c imp:p    1 108r 0
c
c      Weight windows
c
wwg        4 41 0. 0. 0. 34.04 1
wwge:n     1-5 1-3 1-1 1. 15.
wwge:p     1. 3. 8. 12. 24.

c
wwp:n      5 3 5
wwe:n      1.0000E-05 1.0000E-03 1.0000E-01 1.0000E+00 1.5000E+01
wnw1:n     4.6232E-03 1.0000E+00 5.7988E-02 3.3852E-02 3.9487E-02
           1.4460E-02 1.3976E-02 3.6787E-03 8.2901E-03 9.2427E-03
           2.8898E-03 2.9731E-03 2.9187E-03 3.6656E-03 4.2935E-03
           2.6092E-03 2.6606E-03 2.7767E-03 3.6091E-03 3.6228E-03

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	1.1231E-02	1.5845E-02	1.4398E-02	5.1124E-02	4.0833E-02
	4.9760E-02	1.2744E-02	1.7920E-01	2.6880E-01	7.5681E-01
	4.5615E-01	7.0457E-01	6.9110E-01	4.6294E-01	2.7563E+00
	4.0889E+00	1.2380E+00	9.0766E-01	2.0034E+00	2.3966E+00
	2.3480E+00	1.9709E+00	4.2520E+00	1.3637E+00	4.1377E-01
	3.8203E-02	8.4089E-03	3.0884E-03	8.9100E-03	3.8989E-02
	6.8197E-03	3.2413E-03	6.9853E-03	2.3936E-02	1.5341E-01
	3.7922E-01	9.5773E-01	2.1473E+00	3.7671E+00	3.0171E-02
	1.3995E-02	4.7335E-03	1.0497E-02	4.1982E-02	2.8423E-01
	1.0244E+00	1.8181E+00	2.6691E+00	3.9836E+00	2.7267E-02
	1.6747E-02	6.2234E-03	1.3045E-02	4.7688E-02	2.9678E-01
	9.3704E-01	1.8862E+00	3.7177E+00	5.9839E+00	7.8913E-02
	2.4735E-02	1.1101E-02	1.9494E-02	5.7170E-02	2.1986E-01
	1.1049E+00	1.9256E+00	4.7077E+00	4.0529E+00	1.2160E-01
	9.5827E-02	4.6737E-02	7.5412E-02	1.7145E-01	4.8023E-01
	1.7965E+00	3.3420E+00	3.7192E+00	1.1058E+00	1.2021E-01
	4.2926E-01	3.4297E-01	3.5705E-01	5.4637E-01	1.8906E+00
	4.2058E+00	5.4846E+00	1.1658E+00	4.4829E+00	-1.0000E+00
wwn2:n	8.6405E-03	4.9620E-03	1.9137E-02	2.3490E-02	2.9186E-02
	1.9628E-02	5.3016E-03	1.0665E-02	1.0139E-02	5.1780E-03
	7.7213E-03	6.9129E-03	8.1416E-03	8.9445E-03	1.0000E+00
	1.0000E+00	8.9626E-03	8.0756E-03	8.7007E-03	1.0443E-02
	9.1086E-03	8.9546E-03	9.8729E-03	4.2782E-02	2.1470E-02
	3.6289E-02	9.2758E-03	5.6041E-02	3.5313E-01	2.6370E-01
	1.7705E-01	2.4580E-01	1.0808E-01	4.3454E-01	1.6464E+00
	3.9734E+00	1.3156E+00	1.0000E+00	1.3989E+00	2.4855E+00
	2.1579E+00	1.2454E+00	3.0869E+00	7.2851E-01	1.7823E-01
	2.8156E-02	1.2944E-02	7.6047E-03	1.8841E-02	1.0000E+00
	1.0961E-02	7.9647E-03	1.2146E-02	2.4882E-02	1.0429E-01
	2.4841E-01	5.3035E-01	1.4203E+00	4.4206E+00	7.3034E-02
	1.1520E-02	8.2203E-03	1.2809E-02	3.2872E-02	1.9394E-01
	5.9639E-01	1.1060E+00	3.8157E+00	5.4838E+00	2.5234E-02
	1.2555E-02	9.0650E-03	1.3466E-02	3.8552E-02	2.4268E-01
	6.7404E-01	1.6082E+00	2.8699E+00	2.2968E+00	5.7628E-02
	1.9248E-02	1.3751E-02	1.9258E-02	4.2319E-02	2.5646E-01
	8.2548E-01	1.6889E+00	2.7713E+00	2.1835E+00	8.9430E-02
	8.1554E-02	4.3955E-02	6.0953E-02	1.3353E-01	4.0512E-01
	1.1640E+00	1.8631E+00	2.1183E+00	2.0277E+00	1.0000E+00
	8.6239E-02	1.8165E-01	2.5562E-01	7.1445E-01	9.5942E-01
	2.6958E+00	2.6494E+00	2.2544E+00	1.9131E+00	-1.0000E+00
wwn3:n	4.7685E-03	1.7187E-03	9.1706E-03	1.3722E-02	6.9457E-03
	1.2324E-02	4.0902E-03	1.1454E-02	1.2773E-02	6.1662E-03
	8.5768E-03	8.0689E-03	8.7348E-03	4.8901E-03	9.5671E-04
	2.8939E-03	9.5478E-03	8.7773E-03	1.1410E-02	1.3070E-02
	8.8764E-03	1.2279E-02	1.3532E-02	3.6819E-02	1.9208E-02
	3.6803E-02	5.1451E-03	5.5604E-02	1.2772E-01	2.4428E-01
	1.5246E-01	1.7396E-01	2.0487E-01	4.3593E-01	1.4087E+00
	1.7694E+00	1.1083E+00	3.4758E-01	1.1220E+00	1.3486E+00
	1.0285E+00	8.7560E-01	1.8017E+00	7.0559E-01	1.7712E-01
	3.0069E-02	1.1858E-02	1.1854E-02	1.2598E-02	3.5416E-02
	8.3490E-03	1.0400E-02	1.3533E-02	2.7693E-02	1.3535E-01
	3.0294E-01	8.1261E-01	1.8887E+00	3.9314E+00	2.2818E-02
	1.4705E-02	1.1430E-02	1.3164E-02	3.6580E-02	2.1331E-01
	4.7399E-01	1.0165E+00	2.6094E+00	2.9336E+00	1.5570E-02
	1.3725E-02	1.1159E-02	1.6405E-02	3.9985E-02	2.0299E-01
	7.6799E-01	1.1044E+00	2.8839E+00	3.4189E+00	2.0284E-02
	2.0360E-02	1.4009E-02	1.8727E-02	5.2639E-02	2.1839E-01
	8.3994E-01	1.3946E+00	2.7174E+00	3.7817E+00	3.5436E-02
	6.9911E-02	3.4309E-02	6.1216E-02	1.2986E-01	3.8604E-01
	1.2659E+00	1.8294E+00	3.6205E+00	3.0870E+00	1.0585E-01
	8.0469E-02	3.7476E-01	3.4945E-01	5.1379E-01	6.9261E-01
	1.9691E+00	2.1808E+00	3.6221E+00	1.2500E+00	-1.0000E+00
wwn4:n	1.2726E-02	1.0730E-02	1.8733E-02	1.8731E-02	2.0681E-02
	1.5163E-02	5.6832E-03	1.6681E-02	2.5325E-02	9.4528E-03
	1.1094E-02	1.1548E-02	1.0382E-02	7.8268E-03	1.0000E+00
	2.8203E-03	8.8839E-03	9.9202E-03	1.8098E-02	1.3051E-02

	1.1890E-02	1.9114E-02	1.8940E-02	3.8523E-02	3.4821E-02
	3.0688E-02	1.8134E-02	4.6392E-02	8.8049E-02	1.7378E-01
	1.2751E-01	1.1384E-01	1.8097E-01	4.7170E-01	9.2640E-01
	2.0602E+00	1.1496E+00	4.4815E-01	7.3276E-01	1.7070E+00
	1.8280E+00	6.3935E-01	1.1898E+00	4.8415E-01	1.2233E-01
	3.2795E-02	1.2330E-02	1.3098E-02	1.5986E-02	1.9846E-02
	1.2407E-02	1.3361E-02	1.7205E-02	3.0359E-02	9.8555E-02
	2.1912E-01	4.4976E-01	1.0125E+00	1.8874E+00	1.3791E-02
	1.4393E-02	1.1837E-02	1.9502E-02	3.9130E-02	1.4081E-01
	4.3969E-01	8.0911E-01	1.7205E+00	2.0464E+00	2.7417E-02
	1.6649E-02	1.4058E-02	1.7657E-02	4.1770E-02	1.6349E-01
	5.3220E-01	9.4637E-01	2.3754E+00	3.1580E+00	3.6069E-02
	2.5792E-02	1.7871E-02	2.4781E-02	5.2860E-02	2.4802E-01
	6.9360E-01	1.3921E+00	2.5713E+00	4.3606E+00	3.3946E-02
	5.0921E-02	3.9386E-02	5.4442E-02	1.0895E-01	3.7640E-01
	1.0250E+00	2.2535E+00	3.4501E+00	3.2085E+00	2.5002E-02
	3.9540E-02	1.8210E-01	1.4628E-01	3.0298E-01	8.1305E-01
	1.2504E+00	3.1684E+00	2.2529E+00	2.4953E+00	-1.0000E+00
wnn5:n	5.8868E-03	7.5417E-03	1.4123E-02	1.9531E-02	6.5178E-02
	4.4952E-02	7.8170E-03	5.9875E-03	7.4013E-03	7.5306E-03
	5.0284E-03	3.9844E-03	4.4544E-03	5.2139E-03	6.9490E-03
	5.7654E-03	4.4182E-03	3.7279E-03	5.8037E-03	5.8054E-03
	7.4877E-03	1.1183E-02	1.0985E-02	3.0453E-02	3.2165E-02
	2.1186E-02	7.9272E-03	4.1961E-02	1.4455E-01	1.9684E-01
	1.4805E-01	1.6678E-01	2.8301E-01	3.2359E-01	4.3607E-01
	5.0556E-01	3.7057E-01	2.8209E-01	2.3310E-01	4.9062E-01
	5.0000E-01	3.7406E-01	6.2242E-01	3.1396E-01	1.0824E-01
	2.1130E-02	7.1892E-03	4.8591E-03	9.2190E-03	1.0000E+00
	7.4426E-03	5.8258E-03	9.0567E-03	1.7495E-02	7.9038E-02
	1.4705E-01	3.1763E-01	5.3796E-01	1.4510E+00	4.6435E-01
	1.9519E-02	7.2952E-03	1.1871E-02	2.4671E-02	1.0460E-01
	2.2283E-01	3.9994E-01	8.6030E-01	3.3650E+00	5.8014E-02
	1.3780E-02	8.8162E-03	1.3839E-02	3.2021E-02	1.1541E-01
	2.5927E-01	4.1103E-01	1.0908E+00	1.9516E+00	4.2443E-02
	2.5975E-02	1.7472E-02	2.4287E-02	4.6820E-02	1.4764E-01
	3.0368E-01	5.8147E-01	1.5636E+00	2.0724E+00	3.4175E-02
	5.2868E-02	5.3621E-02	5.2378E-02	9.3495E-02	2.8380E-01
	4.4281E-01	8.4476E-01	2.1283E+00	2.9136E+00	1.4755E-01
	4.6292E-02	9.3860E-02	1.8000E-01	2.4400E-01	6.7496E-01
	1.2459E+00	2.4506E+00	1.7424E+00	2.3370E+00	-1.0000E+00
wwp:p 5 3 5					
wwe:p	1.0000E+00	3.0000E+00	8.0000E+00	1.2000E+01	2.4000E+01
wnn1:p	1.7477E-03	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	4.4536E-04	2.2174E-03	7.5039E-03
	1.7566E-04	3.6358E-04	1.5118E-04	8.1297E-03	7.9872E-04
	2.2424E-04	1.1081E-04	1.2167E-04	3.6875E-04	4.4662E-04
	8.2605E-03	4.0096E-03	4.2447E-03	1.1290E-01	1.3835E-01
	6.0014E-02	1.1162E-02	3.3180E-01	1.0000E+00	1.0000E+00
	4.2396E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.8053E+00
	1.1450E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.5360E+00	1.5682E+00	4.4558E+00	2.3461E+00
	3.7883E-02	3.6350E-03	6.1620E-04	9.3387E-03	3.3323E-02
	1.2142E-02	8.2987E-04	4.1595E-03	2.4798E-02	3.4414E-01
	9.0896E-01	2.2824E+00	3.9406E+00	1.0878E+00	1.8286E-01
	3.8665E-02	1.7802E-03	6.6648E-03	5.0571E-02	6.4278E-01
	3.5445E+00	4.4462E+00	1.9899E+00	1.0000E+00	1.0000E+00
	3.0308E-02	3.4576E-03	8.7786E-03	7.3568E-02	9.9557E-01
	5.9608E+00	2.5033E+00	3.3885E+00	1.0000E+00	1.0000E+00
	1.6355E-01	2.3042E-02	5.0291E-02	2.6236E-01	4.2256E+00
	1.3557E+00	1.3430E+00	1.0000E+00	1.0000E+00	1.0000E+00
	9.4777E-01	3.7359E-01	7.2802E-01	1.4231E+00	2.1912E+00
	4.3833E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn2:p	2.7207E-03	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	3.2897E-03	3.3287E-03	4.0118E-04	1.1467E-03	2.7927E-03

	1.5678E-04	2.3680E-04	1.4935E-04	6.0518E-03	5.8321E-04
	4.5757E-04	1.1198E-04	1.2015E-04	3.8217E-04	3.9710E-04
	2.8401E-03	1.4983E-03	1.5911E-03	1.2407E-02	1.9119E-02
	6.2293E-03	3.9492E-03	3.8919E-02	3.9244E-01	5.5504E-01
	3.1047E-01	3.4591E-01	6.2527E+00	2.5446E+00	1.4119E+00
	3.0070E+00	2.4387E+00	1.2421E+00	9.0327E-01	5.3982E+00
	1.5134E+00	1.3448E+00	2.9142E+00	1.0642E+00	1.3434E-01
	5.6272E-03	1.0691E-03	2.9405E-04	1.0662E-02	1.0000E+00
	1.0532E-02	4.4901E-04	1.4227E-03	5.2230E-03	5.6167E-02
	1.9222E-01	4.8945E-01	9.8923E-01	5.7867E+00	1.0000E+00
	3.7156E-03	6.6814E-04	1.9860E-03	7.0368E-03	6.6135E-02
	2.8383E-01	8.0857E-01	2.1062E+00	2.6194E+00	1.0000E+00
	2.4247E-03	1.0196E-03	2.4971E-03	8.8608E-03	8.1347E-02
	4.1982E-01	9.6654E-01	6.0238E+00	1.0000E+00	1.2511E-01
	1.0632E-02	4.0413E-03	7.9645E-03	2.3841E-02	1.4350E-01
	4.5320E-01	7.7086E-01	2.0555E+00	1.9476E+00	1.0000E+00
	5.3669E-02	2.4753E-02	4.6202E-02	9.3596E-02	3.1640E-01
	7.6163E-01	1.2688E+00	5.3282E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	2.0372E-01	2.4419E-01	1.9273E+00
	1.0000E+00	1.9011E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn3:p	3.8954E-03	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	3.2663E-03	1.0000E+00	4.4405E-04	1.1274E-03	2.7061E-03
	1.7865E-04	2.5087E-04	1.7445E-04	2.0861E-03	6.1122E-04
	3.3567E-04	1.2825E-04	1.3721E-04	4.3234E-04	4.4583E-04
	2.1901E-03	1.8908E-03	1.9186E-03	1.3143E-02	1.1897E-02
	7.4076E-03	2.4046E-03	3.0681E-02	1.1350E-01	2.6142E-01
	2.1504E-01	1.5186E-01	2.9211E-01	2.1420E-01	8.3290E-01
	1.3602E+00	4.9438E-01	1.7841E-01	5.1762E-01	1.0309E+00
	1.0895E+00	6.7919E-01	1.4791E+00	6.8266E-01	1.3579E-01
	6.0020E-03	1.1316E-03	3.3222E-04	4.1410E-03	1.0000E+00
	4.5482E-03	4.8660E-04	1.6074E-03	5.5151E-03	5.2926E-02
	1.5373E-01	4.0261E-01	6.0586E-01	1.9251E+00	1.0000E+00
	2.3778E-03	6.8533E-04	2.0744E-03	7.6470E-03	4.9541E-02
	1.4487E-01	4.0620E-01	8.1034E-01	4.2582E+00	1.0000E+00
	2.4874E-03	1.0480E-03	2.4411E-03	8.8931E-03	5.0624E-02
	1.8023E-01	3.0980E-01	7.4898E-01	1.8806E+00	1.0000E+00
	7.4339E-03	3.6391E-03	6.0939E-03	1.5225E-02	7.0668E-02
	1.6169E-01	2.9121E-01	8.1814E-01	3.0826E+00	1.0000E+00
	3.5863E-02	2.0047E-02	2.3545E-02	3.7955E-02	1.3455E-01
	2.4581E-01	4.1703E-01	1.6152E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	7.7772E-02	1.2243E-01	5.8710E-01
	1.0835E+00	1.0035E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn4:p	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	5.0475E-04	1.2820E-03	2.4510E-03
	2.2822E-04	3.1275E-04	2.3580E-04	1.0000E+00	1.0000E+00
	1.0000E+00	1.4250E-04	1.6128E-04	4.9831E-04	5.1245E-04
	6.2109E-03	1.5992E-03	1.9117E-03	1.1558E-02	6.0732E-02
	5.8178E-03	1.4947E-02	5.7928E-02	1.0000E+00	1.0206E-01
	5.5801E-02	1.0000E+00	1.0000E+00	5.6176E-02	5.7920E-01
	1.0000E+00	1.0000E+00	4.2974E-02	1.0000E+00	1.0000E+00
	1.0000E+00	2.9214E-01	7.1001E-01	6.1559E-01	5.6323E-02
	8.9631E-03	1.6566E-03	5.0963E-04	1.0000E+00	1.0000E+00
	7.8321E-03	7.7099E-04	2.0969E-03	8.2787E-03	4.6660E-02
	4.7162E-01	4.7206E-01	1.4110E+00	1.0000E+00	1.0000E+00
	1.6110E-02	8.3030E-04	4.0599E-03	1.0179E-02	6.6050E-02
	1.5259E-01	4.7287E-01	3.4611E+00	1.0000E+00	1.0000E+00
	1.0000E+00	9.5155E-04	4.1017E-03	1.1937E-02	1.1542E-01
	1.8382E-01	3.0707E-01	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	3.6977E-03	8.3545E-03	1.8987E-02	9.0161E-02
	3.1626E-01	4.5678E-01	1.1847E+00	1.9005E-00	1.0000E+00
	9.8974E-02	8.9754E-03	1.2678E-02	1.5980E-01	2.1100E-01
	1.3063E-01	2.4049E-01	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn5:p	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	4.0302E-04	1.0000E+00	1.0000E+00

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4.0302E-04  1.0000E+00  4.0302E-04  1.0000E+00  1.0000E+00
1.0000E+00  8.0987E-04  8.0987E-04  4.0302E-04  4.0302E-04
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  4.0302E-04  4.0302E-04  1.0000E+00
4.0302E-04  8.0604E-04  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
8.0741E-04  5.3852E-04  3.2253E-03  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
8.0741E-04  4.0302E-04  3.6790E-03  1.1855E-02  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  6.6478E-03  2.0230E-03  1.1278E-02  1.0000E+00
5.2028E-02  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00  -1.0000E+00
c  Materials list for EMC tool
c  M1      303 stainless (SS) at 7.95 g/cc, specified for various parts &
c          assumed for Neutron Generator Casing, also used in place of
c          17-4 PH SS
c  M2      freon-12, 1.52 g/cc (CCl2F2)
c  M3      Aluminum, nat., 2.70 g/cc
c  M4      Germanium, 5.32 g/cc
c  M5      Copper, nat.(8.96 g/cc)
c  M6      polycarbonate, 1.4 g/cc
c  M7      Celcon 25% GF, 1.62 g/cc
c  M8      Sulfur Hexafluoride, 100 psi or 0.0412 g/cc
c  M9      air, sea level 0.00129 and LA altitude 0.000935 g/cc
c  M10     Epoxy connector plus Cu wire, 5.53 g/cc (polycarb substituted)
c  M11     Cu wire with teflon coating, various densities
m1      6000.50c -0.0015  14000.50c -0.01  15031.50c -0.002
        16032.50c -0.00015  24000.50c -0.18  25055.50c -0.02
        26000.55c -0.69635  28000.50c -0.09
m2      6000.50c -0.0993  17000.50c -0.3142  9019.50c -0.5865
m3      13027.50c -1.0
c m4     natural Ge
m5      29000.50c -1.0
m6      1001.50c -0.10  6000.50c -0.61  8016.50c -0.29
mt6     poly.01t
m7      1001.50c -0.0495  6000.50c -0.3038  8016.50c -0.5299
        14000.50c -0.1168
mt7     poly.01t
m8      9019.50c -0.7805  16032.50c -0.2195
m9      7014.50c -0.765  8016.50c -0.235
m10     1001.50c -0.0726  6000.50c -0.4427  8016.50c -0.2104
        29000.50c -0.2743
mt10    poly.01t
m11     6000.50c -0.1790  9019.50c -0.5677  29000.50c -0.2533
c
c  Material specification for borehole formation.
c  Air-filled borehole, upper barren zone at GJ, no casing.
c  drybulk density 2.22 g/cc with 0.17 g/cc water =2.39 g/cc
c  M9      air, sea level 0.00129 and LA altitude 0.000935 g/cc
c
c  M12     casing
c  M13     formation
m13     1001.50c -7.959-3  3006.50c -1.394-6  3007.55c -1.719-5
        5010.50c -1.8485-6  5011.55c -7.4405-6  8016.50c -0.55185
        11023.50c -0.01403  13027.50c -0.0445  14000.50c -0.26064
        19000.50c -0.01653  20000.50c -0.0816  22000.50c -1.7834-3
        26000.55c -0.0204  29000.50c -2.601-5  56138.50c -6.502-4
        90232.50c -5.5732-6  92235.50c -1.7521-8  92238.50c -2.3975-6

```

MCNP input file for the OZ simulation
ozinp

```

logger2-8> cat ozinp
c      This is the MCNP input file for the EMC tool geometry
c      Overall geometry is Neutron Generator (NG) is at the
c      bottom of the borehole and the detector is at the top.
c
c      Borehole specification: GJ 4.5" airfilled, ore zone
c
c      cell cards
c
c      EMC tool geometry
1      5      -8.98      -5 68 -73      $Cu cold fing. in Freon
2      2      -1.52      -1 72 -74 #1      $Freon cryogen
3      5      -8.98      1 -2 72 -74      $Cu cryo inner vessel
4      9      -0.00129      2 -3 72 -74      $air gap in cryo
5      1      -7.95      3 -4 72 -74      $SS cryo outer vessel
6      0      4 -7 71 -74      $vacuum around cryo
7      1      -7.95      5 -3 71 -72      $cryo bottom
8      1      -7.95      7 -8 60 -74      $outer SS detector housing
9      1      -7.95      -8 -60 59      $top of SS det. housing
10     1      -7.95      -6 -59 57      $SS det. casing, port, assumed solid
11     1      -7.95      3 -4 -72 63      $heat shield, assumed SS
12     1      -7.95      -4 -63 62      $heat shield bottom
13     0      (-3 63 -71) #1 #14 #15 #16 #17 #18
14     5      -8.98      5 -6 70 -71      $extra Cu around cold finger
15     3      -2.70      5 -6 -70 69      $Al ring around cold finger
16     3      -2.70      67 -68 -5      $Al cold finger conn., assumed size
c 17     4      -5.32      65 -66 -9      $Ge detector
17     0      65 -66 -9      $Ge detector as a void
18     3      -2.70      64 -67 -10 #17      $Ge detector casing
19     0      (4 -7 62 -71):(60 -62 -7) $vacuum in SS housing
20     9      -0.00129      59 -74 8 -19      $around around SS housing
21     11     -0.497      (27 -26 55 -59 +11 6 -14):(55 -57 27 -26 -6) $wire-filled s
lot in poly
22     6      -1.4      ((58 -59 6 -13):(56 -58 6 -14):(55 -56 6 -13)) #21 $polycarb
onate
23     9      -0.00129      (55 -59 -19) #10 #21 #22      $air
24     1      -7.95      6 -12 54 -55      $SS part of wire connector
c 25     10     -5.53      -6 53 -52      $epoxy wire conn.
25     10     -5.53      -6 53 -52      $epoxy wire conn., polycarb. substituted
26     1      -7.95      12 -19 53 -55      $assumed SS around 24 and 25
27     9      -0.00129      -18 -55 52 #24 #26      $air gaps
28     9      -0.00129      -18 -53 28 #24 #26      $air gap
29     11     -1.789      (29 -28 -17 16 25 -24):(-29 30 -19 16 25 -24) $1/2 wire-fille
d SS shield slot
30     1      -7.95      ((-17 29 -28):(30 -29 -19))#29      $SS shield plug
31     1      -7.95      (18 -19 29 -54):(54 -53 12 -19) $outer connection piece
32     9      -0.00129      -18 29 -28 #29 #30      $air between plug and conn.piece
33     1      -7.95      -30 31 -15      $SS shield plug threads
34     7      -1.62      (-30 31 15 -23):(32 -31 -22):(-32 33 -22 6) $celcon conn. piece
35     1      -7.95      75 -31 22 -23      $NG outer housing, assumed SS
36     1      -7.95      75 -34 21 -22      $NG inner housing, assumed SS
37     10     -5.53      -6 -33 34      $epoxy wire conn.
38     9      -0.00129      -6 -32 33      $air gap
39     9      -0.00129      -22 -33 34 6      $air gap
40     8      -0.0412      75 -34 -21 5      $pressurized sulfur hexafluoride
41     0      75 -34 -5      $evacuated neutron tube (??)
42     9      -0.00129      -30 75 23 -19      $air around NG
43     1      -7.95      19 -20 75 -34      $EMC tool housing, assumed density
44     1      -7.95      19 -20 34 -29
45     1      -7.95      19 -20 29 -53
46     1      -7.95      19 -20 53 -58
47     1      -7.95      19 -20 58 -62
48     1      -7.95      19 -20 62 -69
49     1      -7.95      19 -20 69 -74
c 44     0      20:74:-75      $outside world
c

```

```

c      borehole geometry:cells
c
50  9  -0.00129    20 -105 -74 73  $air-filled borehole,section
51  9  -0.00129    20 -105 -73 69
52  9  -0.00129    20 -105 -69 62
53  9  -0.00129    20 -105 -62 58
54  9  -0.00129    20 -105 -58 53
55  9  -0.00129    20 -105 -53 29
56  9  -0.00129    20 -105 -29 32
57  9  -0.00129    20 -105 -32 34
58  9  -0.00129    20 -105 -34 120
59  9  -0.00129    20 -105 -120 75
60  13 -2.340      105 -106 -74 73  $casing of borehole,section
61  13 -2.340      105 -106 -73 69
62  13 -2.340      105 -106 -69 62
63  13 -2.340      105 -106 -62 58
64  13 -2.340      105 -106 -58 53
65  13 -2.340      105 -106 -53 29
66  13 -2.340      105 -106 -29 32
67  13 -2.340      105 -106 -32 34
68  13 -2.340      105 -106 -34 120
69  13 -2.340      105 -106 -120 75
70  13 -2.34       106 -107 -74 73  $cement of borehole,section
71  13 -2.34       106 -107 -73 69
72  13 -2.34       106 -107 -69 62
73  13 -2.34       106 -107 -62 58
74  13 -2.34       106 -107 -58 53
75  13 -2.34       106 -107 -53 29
76  13 -2.34       106 -107 -29 32
77  13 -2.34       106 -107 -32 34
78  13 -2.34       106 -107 -34 120
79  13 -2.34       106 -107 -120 75
80  13 -2.3400     107 -108 -74 73  $SiO2 , H2O of borehole,section
81  13 -2.3400     107 -108 -73 69
82  13 -2.3400     107 -108 -69 62
83  13 -2.3400     107 -108 -62 58
84  13 -2.3400     107 -108 -58 53
85  13 -2.3400     107 -108 -53 29
86  13 -2.3400     107 -108 -29 32
87  13 -2.3400     107 -108 -32 34
88  13 -2.3400     107 -108 -34 120
89  13 -2.3400     107 -108 -120 75
90  13 -2.3400     108 -109 -74 73  $SiO2 , H2O of borehole,section
91  13 -2.3400     108 -109 -73 69
92  13 -2.3400     108 -109 -69 62
93  13 -2.3400     108 -109 -62 58
94  13 -2.3400     108 -109 -58 53
95  13 -2.3400     108 -109 -53 29
96  13 -2.3400     108 -109 -29 32
97  13 -2.3400     108 -109 -32 34
98  13 -2.3400     108 -109 -34 120
99  13 -2.3400     108 -109 -120 75
100 13 -2.3400     109 -110 -74 73  $SiO2 , H2O of borehole,section
101 13 -2.3400     109 -110 -73 69
102 13 -2.3400     109 -110 -69 62
103 13 -2.3400     109 -110 -62 58
104 13 -2.3400     109 -110 -58 53
105 13 -2.3400     109 -110 -53 29
106 13 -2.3400     109 -110 -29 32
107 13 -2.3400     109 -110 -32 34
108 13 -2.3400     109 -110 -34 120
109 13 -2.3400     109 -110 -120 75
c      outside world as void
110 0      110:74:-75

c      surface cards

```



```

c
c      EMC tool surfaces
c      cylindrical surfaces;exluding surfaces 11 and 16
1      cz 1.7145      $cryostat: inner Cu vessel radius
2      cz 2.2225      $cryostat: outer Cu radius
3      cz 2.7305      $cryostat: inner SS radius
4      cz 2.8575      $cryostat: outer SS radius
5      cz 0.9525      $CU coldfinger / Al ring inner rad
6      cz 1.5875      $CU coldfinger / Al ring outer rad
7      cz 3.4091      $Detector SS vessel, inner rad
8      cz 3.658       $Detector SS vessel, outer rad
c      8a      cz 2.8575      $heat shield for detector, outer rad
c      8b      cz 2.7305      $heat shield for detector, inner rad
9      cz 2.3368      $Detector casing, inner rad (detector rad)
10     cz 2.5273      $Detector casing, outer rad
c      10a     cz 1.27       $Ge detector well radius
11     py 1.57        $inner surf. polycarbonate slot
12     cz 3.683       $Poly upper connection piece, outer
13     cz 3.7846      $Poly lower connection piece, outer
14     cz 2.654       $Poly mid-1 connection piece
15     cz 1.04        $SS shield plug, inner
16     py 1.11        $inner surf. SS slot
17     cz 2.064       $SS shield plug, outer
18     cz 2.144       $inner wall connection
19     cz 3.81        $inner rad of tool casing
20     cz 4.445       $outer rad of tool casing
21     cz 1.435       $inner rad of neutron generator casing
22     cz 1.702       $middle rad of neutron generator casing
23     cz 2.1425      $outer rad of neutron generator casing
c      planar surfaces
24     px 0.6350      $SS slot (centered on y-axis)
25     px -0.6250     $SS slot (centered on y-axis)
26     px 1.270       $polycarbonate slot
27     px -1.270      $polycarbonate slot
c      surface perpendicular to z axis, z=0 is top of steel shield plug
28     pz 0.0         $top of steel shield plug main body
29     pz -12.7       $bot. core steel plug and connector piece
30     pz -13.97      $bot. plug flange, top celcon piece
31     pz -16.205     $bot. plug threads, top of outer NG casing
32     pz -18.796     $top of NG innards
33     pz -20.068     $top of wire connector
34     pz -27.212     $bottom of wire conn.
c      pz -34.036     $NG source location
52     pz 13.784      $top of wire connector
53     pz 6.64        $bottom of wire connector
54     pz 4.973       $bottom of steel around wire conn.
55     pz 14.769      $bottom of polycarbonate/top of steel around wire conn.
56     pz 15.404      $mid-1 polycarbonate
57     pz 16.039      $bottom of steel det casing port
58     pz 17.944      $mid-2 polycarbonate
59     pz 18.579      $bot steel det casing-outer
60     pz 18.828      $bottom steel casing-inner
c      61     pz 19.849      $top of polycarbonate
62     pz 27.889      $bottom of outer detector heat shield
63     pz 29.00       $bottom of inner detector heat shield
64     pz 30.2        $bottom of outer detector
65     pz 30.3911     $bottom of inner detector
c      65a     pz          $detector well bottom
66     pz 37.6936     $top of inner detector
67     pz 38.2524     $top of outer detector
68     pz 40.7924     $top of detector cold finger/bot of Cu
69     pz 43.3324     $bottom of Al ring
70     pz 44.0944     $top of Al ring, bottom extra Cu
71     pz 52.0192     $bottom of freon casing/ top of extra Cu
72     pz 54.559      $top of heat shield, mid-1 freon
73     pz 57.099      $top of Cu cold finger

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74 pz 75.0 $stop of problem cutoff
75 pz -60.0 $bottom of problem cutoff

c
c borehole surface definitions
c
c 101 py 0.0 $radial dividings
c 102 p 0.707 0.707 0.0 0.0
c 103 px 0.0
c 104 p 0.707 -0.707 0.0 0.0
105 c/z -1.27 0.0 5.75 $cylindrical dividings
106 c/z -1.27 0.0 8.
107 c/z -1.27 0.0 10.0
108 c/z -1.27 0.0 20.0
109 c/z -1.27 0.0 40.0
110 c/z -1.27 0.0 60.0
c
120 pz -40 $extra plane for vertical dividings

c physics specifications
c
mode n p
phys:p 100 1 0
cut:p 1+8 0.01
phys:n 15. 0.0
cut:n 1+8 0.0
c
c Source specification
c
sdef pos=0 0 -34.036 erg=14.1 tme=d1 vec=0 0 1 dir=d2
si1 0 1000
sp1 0 1
si2 -0.866 1.0
sp2 -21 1.
c
c Computer time/# of particles started
c
c nps 5500000
ctme 13000
c
c tallies
c
prdmp -4000 -2000 1 2
print 10 20 40 60 120
f4:p 17
f14:n 17
e4 0.015 2796i 14.0
t4 1+3 1+8
e14 0.02 723i 14.5
t14 1+3 1+8
c
c Importances and weight-window generation
c imp:n 1 108r 0
c imp:p 1 108r 0
c
c Weight windows
c
wwg 4 41 0. 0. 0. 34.04 1
wwge:n 1-5 1-3 1-1 1. 15.
wwge:p 1. 3. 8. 12. 24.
c
wwp:n 5 3 5
wwe:n 1.0000E-05 1.0000E-03 1.0000E-01 1.0000E+00 1.5000E+01
wnl:n 4.6232E-03 1.0000E+00 5.7988E-02 3.3852E-02 3.9487E-02
1.4460E-02 1.3976E-02 3.6787E-03 8.2901E-03 9.2427E-03
2.8898E-03 2.9731E-03 2.9187E-03 3.6656E-03 4.2935E-03
2.6092E-03 2.6606E-03 2.7767E-03 3.6091E-03 3.6228E-03

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1.1231E-02 1.5845E-02 1.4398E-02 5.1124E-02 4.0833E-02
4.9760E-02 1.2744E-02 1.7920E-01 2.6880E-01 7.5681E-01
4.5615E-01 7.0457E-01 6.9110E-01 4.6294E-01 2.7563E+00
4.0889E+00 1.2380E+00 9.0766E-01 2.0034E+00 2.3966E+00
2.3480E+00 1.9709E+00 4.2520E+00 1.3637E+00 4.1377E-01
3.8203E-02 8.4089E-03 3.0884E-03 8.9100E-03 3.8989E-02
6.8197E-03 3.2413E-03 6.9853E-03 2.3936E-02 1.5341E-01
3.7922E-01 9.5773E-01 2.1473E+00 3.7671E+00 3.0171E-02
1.3995E-02 4.7335E-03 1.0497E-02 4.1982E-02 2.8423E-01
1.0244E+00 1.8181E+00 2.6691E+00 3.9836E+00 2.7267E-02
1.6747E-02 6.2234E-03 1.3045E-02 4.7688E-02 2.9678E-01
9.3704E-01 1.8862E+00 3.7177E+00 5.9839E+00 7.8913E-02
2.4735E-02 1.1101E-02 1.9494E-02 5.7170E-02 2.1986E-01
1.1049E+00 1.9256E+00 4.7077E+00 4.0529E+00 1.2160E-01
9.5827E-02 4.6737E-02 7.5412E-02 1.7145E-01 4.8023E-01
1.7965E+00 3.3420E+00 3.7192E+00 1.1058E+00 1.2021E-01
4.2926E-01 3.4297E-01 3.5705E-01 5.4637E-01 1.8906E+00
4.2058E+00 5.4846E+00 1.1658E+00 4.4829E+00 -1.0000E+00
wnn2:n 8.6405E-03 4.9620E-03 1.9137E-02 2.3490E-02 2.9186E-02
1.9628E-02 5.3016E-03 1.0665E-02 1.0139E-02 5.1780E-03
7.7213E-03 6.9129E-03 8.1416E-03 8.9445E-03 1.0000E+00
1.0000E+00 8.9626E-03 8.0756E-03 8.7007E-03 1.0443E-02
9.1086E-03 8.9546E-03 9.8729E-03 4.2782E-02 2.1470E-02
3.6289E-02 9.2758E-03 5.6041E-02 3.5313E-01 2.6370E-01
1.7705E-01 2.4580E-01 1.0808E-01 4.3454E-01 1.6464E+00
3.9734E+00 1.3156E+00 1.0000E+00 1.3989E+00 2.4855E+00
2.1579E+00 1.2454E+00 3.0869E+00 7.2851E-01 1.7823E-01
2.8156E-02 1.2944E-02 7.6047E-03 1.8841E-02 1.0000E+00
1.0961E-02 7.9647E-03 1.2146E-02 2.4882E-02 1.0429E-01
2.4841E-01 5.3035E-01 1.4203E+00 4.4206E+00 7.3034E-02
1.1520E-02 8.2203E-03 1.2809E-02 3.2872E-02 1.9394E-01
5.9639E-01 1.1060E+00 3.8157E+00 5.4838E+00 2.5234E-02
1.2555E-02 9.0650E-03 1.3466E-02 3.8552E-02 2.4268E-01
6.7404E-01 1.6082E+00 2.8699E+00 2.2968E+00 5.7628E-02
1.9248E-02 1.3751E-02 1.9258E-02 4.2319E-02 2.5646E-01
8.2548E-01 1.6889E+00 2.7713E+00 2.1835E+00 8.9430E-02
8.1554E-02 4.3955E-02 6.0953E-02 1.3353E-01 4.0512E-01
1.1640E+00 1.8631E+00 2.1183E+00 2.0277E+00 1.0000E+00
8.6239E-02 1.8165E-01 2.5562E-01 7.1445E-01 9.5942E-01
2.6958E+00 2.6494E+00 2.2544E+00 1.9131E+00 -1.0000E+00
wnn3:n 4.7685E-03 1.7187E-03 9.1706E-03 1.3722E-02 6.9457E-03
1.2324E-02 4.0902E-03 1.1454E-02 1.2773E-02 6.1662E-03
8.5768E-03 8.0689E-03 8.7348E-03 4.8901E-03 9.5671E-04
2.8939E-03 9.5478E-03 8.7773E-03 1.1410E-02 1.3070E-02
8.8764E-03 1.2279E-02 1.3532E-02 3.6819E-02 1.9208E-02
3.6803E-02 5.1451E-03 5.5604E-02 1.2772E-01 2.4428E-01
1.5246E-01 1.7396E-01 2.0487E-01 4.3593E-01 1.4087E+00
1.7694E+00 1.1083E+00 3.4758E-01 1.1220E+00 1.3486E+00
1.0285E+00 8.7560E-01 1.8017E+00 7.0559E-01 1.7712E-01
3.0069E-02 1.1858E-02 1.1854E-02 1.2598E-02 3.5416E-02
8.3490E-03 1.0400E-02 1.3533E-02 2.7693E-02 1.3535E-01
3.0294E-01 8.1261E-01 1.8887E+00 3.9314E+00 2.2818E-02
1.4705E-02 1.1430E-02 1.3164E-02 3.6580E-02 2.1331E-01
4.7399E-01 1.0165E+00 2.6094E+00 2.9336E+00 1.5570E-02
1.3725E-02 1.1159E-02 1.6405E-02 3.9985E-02 2.0299E-01
7.6799E-01 1.1044E+00 2.8839E+00 3.4189E+00 2.0284E-02
2.0360E-02 1.4009E-02 1.8727E-02 5.2639E-02 2.1839E-01
8.3994E-01 1.3946E+00 2.7174E+00 3.7817E+00 3.5436E-02
6.9911E-02 3.4309E-02 6.1216E-02 1.2986E-01 3.8604E-01
1.2659E+00 1.8294E+00 3.6205E+00 3.0870E+00 1.0585E-01
8.0469E-02 3.7476E-01 3.4945E-01 5.1379E-01 6.9261E-01
1.9691E+00 2.1808E+00 3.6221E+00 1.2500E+00 -1.0000E+00
wnn4:n 1.2726E-02 1.0730E-02 1.8733E-02 1.8731E-02 2.0681E-02
1.5163E-02 5.6832E-03 1.6681E-02 2.5325E-02 9.4528E-03
1.1094E-02 1.1548E-02 1.0382E-02 7.8268E-03 1.0000E+00
2.8203E-03 8.8839E-03 9.9202E-03 1.8098E-02 1.3051E-02

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1.1890E-02 1.9114E-02 1.8940E-02 3.8523E-02 3.4821E-02
3.0688E-02 1.8134E-02 4.6392E-02 8.8049E-02 1.7378E-01
1.2751E-01 1.1384E-01 1.8097E-01 4.7170E-01 9.2640E-01
2.0602E+00 1.1496E+00 4.4815E-01 7.3276E-01 1.7070E+00
1.8280E+00 6.3935E-01 1.1898E+00 4.8415E-01 1.2233E-01
3.2795E-02 1.2330E-02 1.3098E-02 1.5986E-02 1.9846E-02
1.2407E-02 1.3361E-02 1.7205E-02 3.0359E-02 9.8555E-02
2.1912E-01 4.4976E-01 1.0125E+00 1.8874E+00 1.3791E-02
1.4393E-02 1.1837E-02 1.9502E-02 3.9130E-02 1.4081E-01
4.3969E-01 8.0911E-01 1.7205E+00 2.0464E+00 2.7417E-02
1.6649E-02 1.4058E-02 1.7657E-02 4.1770E-02 1.6349E-01
5.3220E-01 9.4637E-01 2.3754E+00 3.1580E+00 3.6069E-02
2.5792E-02 1.7871E-02 2.4781E-02 5.2860E-02 2.4802E-01
6.9360E-01 1.3921E+00 2.5713E+00 4.3606E+00 3.3946E-02
5.0921E-02 3.9386E-02 5.4442E-02 1.0895E-01 3.7640E-01
1.0250E+00 2.2535E+00 3.4501E+00 3.2085E+00 2.5002E-02
3.9540E-02 1.8210E-01 1.4628E-01 3.0298E-01 8.1305E-01
1.2504E+00 3.1684E+00 2.2529E+00 2.4953E+00 -1.0000E+00
wnn5:n 5.8868E-03 7.5417E-03 1.4123E-02 1.9531E-02 6.5178E-02
4.4952E-02 7.8170E-03 5.9875E-03 7.4013E-03 7.5306E-03
5.0284E-03 3.9844E-03 4.4544E-03 5.2139E-03 6.9490E-03
5.7654E-03 4.4182E-03 3.7279E-03 5.8037E-03 5.8054E-03
7.4877E-03 1.1183E-02 1.0985E-02 3.0453E-02 3.2165E-02
2.1186E-02 7.9272E-03 4.1961E-02 1.4455E-01 1.9684E-01
1.4805E-01 1.6678E-01 2.8301E-01 3.2359E-01 4.3607E-01
5.0556E-01 3.7057E-01 2.8209E-01 2.3310E-01 4.9062E-01
5.0000E-01 3.7406E-01 6.2242E-01 3.1396E-01 1.0824E-01
2.1130E-02 7.1892E-03 4.8591E-03 9.2190E-03 1.0000E+00
7.4426E-03 5.8258E-03 9.0567E-03 1.7495E-02 7.9038E-02
1.4705E-01 3.1763E-01 5.3796E-01 1.4510E+00 4.6435E-01
1.9519E-02 7.2952E-03 1.1871E-02 2.4671E-02 1.0460E-01
2.2283E-01 3.9994E-01 8.6030E-01 3.3650E+00 5.8014E-02
1.3780E-02 8.8162E-03 1.3839E-02 3.2021E-02 1.1541E-01
2.5927E-01 4.1103E-01 1.0908E+00 1.9516E+00 4.2443E-02
2.5975E-02 1.7472E-02 2.4287E-02 4.6820E-02 1.4764E-01
3.0368E-01 5.8147E-01 1.5636E+00 2.0724E+00 3.4175E-02
5.2868E-02 5.3621E-02 5.2378E-02 9.3495E-02 2.8380E-01
4.4281E-01 8.4476E-01 2.1283E+00 2.9136E+00 1.4755E-01
4.6292E-02 9.3860E-02 1.8000E-01 2.4400E-01 6.7496E-01
1.2459E+00 2.4506E+00 1.7424E+00 2.3370E+00 -1.0000E+00
wvp:p 5 3 5
wve:p 1.0000E+00 3.0000E+00 8.0000E+00 1.2000E+01 2.4000E+01
wnn1:p 1.7477E-03 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 4.4536E-04 2.2174E-03 7.5039E-03
1.7566E-04 3.6358E-04 1.5118E-04 8.1297E-03 7.9872E-04
2.2424E-04 1.1081E-04 1.2167E-04 3.6875E-04 4.4662E-04
8.2605E-03 4.0096E-03 4.2447E-03 1.1290E-01 1.3835E-01
6.0014E-02 1.1162E-02 3.3180E-01 1.0000E+00 1.0000E+00
4.2396E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.8053E+00
1.1450E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.5360E+00 1.5682E+00 4.4558E+00 2.3461E+00
3.7883E-02 3.6350E-03 6.1620E-04 9.3387E-03 3.3323E-02
1.2142E-02 8.2987E-04 4.1595E-03 2.4798E-02 3.4414E-01
9.0896E-01 2.2824E+00 3.9406E+00 1.0878E+00 1.8286E-01
3.8665E-02 1.7802E-03 6.6648E-03 5.0571E-02 6.4278E-01
3.5445E+00 4.4462E+00 1.9899E+00 1.0000E+00 1.0000E+00
3.0308E-02 3.4576E-03 8.7786E-03 7.3568E-02 9.9557E-01
5.9608E+00 2.5033E+00 3.3885E+00 1.0000E+00 1.0000E+00
1.6355E-01 2.3042E-02 5.0291E-02 2.6236E-01 4.2256E+00
1.3557E+00 1.3430E+00 1.0000E+00 1.0000E+00 1.0000E+00
9.4777E-01 3.7359E-01 7.2802E-01 1.4231E+00 2.1912E+00
4.3833E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 -1.0000E+00
wnn2:p 2.7207E-03 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
3.2897E-03 3.3287E-03 4.0118E-04 1.1467E-03 2.7927E-03

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	1.5678E-04	2.3680E-04	1.4935E-04	6.0518E-03	5.8321E-04
	4.5757E-04	1.1198E-04	1.2015E-04	3.8217E-04	3.9710E-04
	2.8401E-03	1.4983E-03	1.5911E-03	1.2407E-02	1.9119E-02
	6.2293E-03	3.9492E-03	3.8919E-02	3.9244E-01	5.5504E-01
	3.1047E-01	3.4591E-01	6.2527E+00	2.5446E+00	1.4119E+00
	3.0070E+00	2.4387E+00	1.2421E+00	9.0327E-01	5.3982E+00
	1.5134E+00	1.3448E+00	2.9142E+00	1.0642E+00	1.3434E-01
	5.6272E-03	1.0691E-03	2.9405E-04	1.0662E-02	1.0000E+00
	1.0532E-02	4.4901E-04	1.4227E-03	5.2230E-03	5.6167E-02
	1.9222E-01	4.8945E-01	9.8923E-01	5.7867E+00	1.0000E+00
	3.7156E-03	6.6814E-04	1.9860E-03	7.0368E-03	6.6135E-02
	2.8383E-01	8.0857E-01	2.1062E+00	2.6194E+00	1.0000E+00
	2.4247E-03	1.0196E-03	2.4971E-03	8.8608E-03	8.1347E-02
	4.1982E-01	9.6654E-01	6.0238E+00	1.0000E+00	1.2511E-01
	1.0632E-02	4.0413E-03	7.9645E-03	2.3841E-02	1.4350E-01
	4.5320E-01	7.7086E-01	2.0555E+00	1.9476E+00	1.0000E+00
	5.3669E-02	2.4753E-02	4.6202E-02	9.3596E-02	3.1640E-01
	7.6163E-01	1.2688E+00	5.3282E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	2.0372E-01	2.4419E-01	1.9273E+00
	1.0000E+00	1.9011E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn3:p	3.8954E-03	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	3.2663E-03	1.0000E+00	4.4405E-04	1.1274E-03	2.7061E-03
	1.7865E-04	2.5087E-04	1.7445E-04	2.0861E-03	6.1122E-04
	3.3567E-04	1.2825E-04	1.3721E-04	4.3234E-04	4.4583E-04
	2.1901E-03	1.8908E-03	1.9186E-03	1.3143E-02	1.1897E-02
	7.4076E-03	2.4046E-03	3.0681E-02	1.1350E-01	2.6142E-01
	2.1504E-01	1.5186E-01	2.9211E-01	2.1420E-01	8.3290E-01
	1.3602E+00	4.9438E-01	1.7841E-01	5.1762E-01	1.0309E+00
	1.0895E+00	6.7919E-01	1.4791E+00	6.8266E-01	1.3579E-01
	6.0020E-03	1.1316E-03	3.3222E-04	4.1410E-03	1.0000E+00
	4.5482E-03	4.8660E-04	1.6074E-03	5.5151E-03	5.2926E-02
	1.5373E-01	4.0261E-01	6.0586E-01	1.9251E+00	1.0000E+00
	2.3778E-03	6.8533E-04	2.0744E-03	7.6470E-03	4.9541E-02
	1.4487E-01	4.0620E-01	8.1034E-01	4.2582E+00	1.0000E+00
	2.4874E-03	1.0480E-03	2.4411E-03	8.8931E-03	5.0624E-02
	1.8023E-01	3.0980E-01	7.4898E-01	1.8806E+00	1.0000E+00
	7.4339E-03	3.6391E-03	6.0939E-03	1.5225E-02	7.0668E-02
	1.6169E-01	2.9121E-01	8.1814E-01	3.0826E+00	1.0000E+00
	3.5863E-02	2.0047E-02	2.3545E-02	3.7955E-02	1.3455E-01
	2.4581E-01	4.1703E-01	1.6152E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	7.7772E-02	1.2243E-01	5.8710E-01
	1.0835E+00	1.0035E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn4:p	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	5.0475E-04	1.2820E-03	2.4510E-03
	2.2822E-04	3.1275E-04	2.3580E-04	1.0000E+00	1.0000E+00
	1.0000E+00	1.4250E-04	1.6128E-04	4.9831E-04	5.1245E-04
	6.2109E-03	1.5992E-03	1.9117E-03	1.1558E-02	6.0732E-02
	5.8178E-03	1.4947E-02	5.7928E-02	1.0000E+00	1.0206E-01
	5.5801E-02	1.0000E+00	1.0000E+00	5.6176E-02	5.7920E-01
	1.0000E+00	1.0000E+00	4.2974E-02	1.0000E+00	1.0000E+00
	1.0000E+00	2.9214E-01	7.1001E-01	6.1559E-01	5.6323E-02
	8.9631E-03	1.6566E-03	5.0963E-04	1.0000E+00	1.0000E+00
	7.8321E-03	7.7099E-04	2.0969E-03	8.2787E-03	4.6660E-02
	4.7162E-01	4.7206E-01	1.4110E+00	1.0000E+00	1.0000E+00
	1.6110E-02	8.3030E-04	4.0599E-03	1.0179E-02	6.6050E-02
	1.5259E-01	4.7287E-01	3.4611E+00	1.0000E+00	1.0000E+00
	1.0000E+00	9.5155E-04	4.1017E-03	1.1937E-02	1.1542E-01
	1.8382E-01	3.0707E-01	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	3.6977E-03	8.3545E-03	1.8987E-02	9.0161E-02
	3.1626E-01	4.5678E-01	1.1847E+00	1.9005E-00	1.0000E+00
	9.8974E-02	8.9754E-03	1.2678E-02	1.5980E-01	2.1100E-01
	1.3063E-01	2.4049E-01	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	-1.0000E+00
wnn5:p	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
	1.0000E+00	1.0000E+00	4.0302E-04	1.0000E+00	1.0000E+00

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4.0302E-04 1.0000E+00 4.0302E-04 1.0000E+00 1.0000E+00
1.0000E+00 8.0987E-04 8.0987E-04 4.0302E-04 4.0302E-04
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
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1.0000E+00 1.0000E+00 4.0302E-04 4.0302E-04 1.0000E+00
4.0302E-04 8.0604E-04 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
8.0741E-04 5.3852E-04 3.2253E-03 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
8.0741E-04 4.0302E-04 3.6790E-03 1.1855E-02 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 6.6478E-03 2.0230E-03 1.1278E-02 1.0000E+00
5.2028E-02 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00
1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 -1.0000E+00
c Materials list for EMC tool
c M1 303 stainless (SS) at 7.95 g/cc, specified for various parts &
c assumed for Neutron Generator Casing, also used in place of
c 17-4 PH SS
c M2 freon-12, 1.52 g/cc (CC12F2)
c M3 Aluminum, nat., 2.70 g/cc
c M4 Germanium, 5.32 g/cc
c M5 Copper, nat.(8.96 g/cc)
c M6 polycarbonate, 1.4 g/cc
c M7 Celcon 25% GF, 1.62 g/cc
c M8 Sulfur Hexafluoride, 100 psi or 0.0412 g/cc
c M9 air, sea level 0.00129 and LA altitude 0.000935 g/cc
c M10 Epoxy connector plus Cu wire, 5.53 g/cc (polycarb substituted)
c M11 Cu wire with teflon coating, various densities
m1 6000.50c -0.0015 14000.50c -0.01 15031.50c -0.002
16032.50c -0.00015 24000.50c -0.18 25055.50c -0.02
26000.55c -0.69635 28000.50c -0.09
m2 6000.50c -0.0993 17000.50c -0.3142 9019.50c -0.5865
m3 13027.50c -1.0
c m4 natural Ge
m5 29000.50c -1.0
m6 1001.50c -0.10 6000.50c -0.61 8016.50c -0.29
mt6 poly.01t
m7 1001.50c -0.0495 6000.50c -0.3038 8016.50c -0.5299
14000.50c -0.1168
mt7 poly.01t
m8 9019.50c -0.7805 16032.50c -0.2195
m9 7014.50c -0.765 8016.50c -0.235
m10 1001.50c -0.0726 6000.50c -0.4427 8016.50c -0.2104
29000.50c -0.2743
mt10 poly.01t
m11 6000.50c -0.1790 9019.50c -0.5677 29000.50c -0.2533
c
c Material specification for borehole formation.
c Air-filled borehole, ore zone at GJ, no casing.
c drybulk density 2.12 g/cc with 0.22 g/cc water =2.34 g/cc
c M9 air, sea level 0.00129 and LA altitude 0.000935 g/cc
c
c M12 casing
c M13 formation
m13 1001.50c -0.01052 3006.50c -1.359-6 3007.55c -1.676-5
5010.50c -2.7044-6 5011.55c -1.0886-5 8016.50c -0.55953
11023.50c -0.01368 13027.50c -0.0434 14000.50c -0.2542
19000.50c -0.01386 20000.50c -0.07959 22000.50c -1.7395-3
26000.55c -0.0199 29000.50c -2.2187-3 56138.50c -6.795-4
90232.50c -2.8085-5 92235.50c -4.4557-6 92238.50c -6.0979-4

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