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Oak Ridge National Laboratory Shutdown Dose Rate Code Suite

Arzu Alpan

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OAK RIDGE NATIONAL LABORATORY
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Reactor and Nuclear Systems Division

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831-6283
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ACRONYMS

ADVANTG	Automated Variance Reduction Generator
ANS	American Nuclear Society
ANSI	American National Standards Institute
CADES	Compute and Data Environment for Science
CPU	central processing unit
FENDL	Fusion Evaluated Nuclear Data Library
hdf5	Hierarchical Data Format version 5
IAEA	International Atomic Energy Agency
ITER	International Thermonuclear Experimental Reactor
MCNP	Monte Carlo N-Particle
MS-CADIS	Multi-Step Consistent Adjoint Driven Importance Sampling
NAGSS	Neutron Activation Gamma Source Sampler
ORIGEN	Oak Ridge Isotope Generator
ORNL	Oak Ridge National Laboratory
R2S	rigorous two-step
SCALE	Standardized Computer Analyses for Licensing Evaluation
SDDR	shutdown dose rate
TENDL	TALYS-based Evaluated Nuclear Data Library
TN	Transformative Neutronics
US	United States

EXECUTIVE SUMMARY

The Oak Ridge National Laboratory (ORNL) shutdown dose rate (SDDR) code suite calculates gamma dose rates at a location of interest due to activation of materials. The code suite is based on the rigorous two-step (R2S) method that involves two radiation transport calculations: (1) neutron radiation transport to determine neutron fluxes in the material for which activation calculations will be performed and (2) gamma radiation transport to determine dose rates at a location of interest, due to material activation. The ORNL SDDR code suite is used to determine an importance function that characterizes the neutron's importance to the final SDDR when the Monte Carlo radiation transport method is used.

This report demonstrates how the ORNL SDDR code suite is implemented through the following codes: Monte Carlo N-Particle (MCNP) code Version 5-1.60, Oak Ridge Isotope Generator (ORIGEN), MSX suite of utilities, Neutron Activation Gamma Source Sampler (NAGSS), and Automated Variance Reduction Generator (ADVANTG). For this demonstration, the International Thermonuclear Experimental Reactor (ITER) SDDR benchmark problem is used and the dose rate result is compared to previously published work.

ACKNOWLEDGMENTS

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1. INTRODUCTION

Shutdown dose rate (SDDR) calculations involve the determination of gammas emitted due to the decay of radionuclides in materials that become activated from operation of a nuclear system. The Oak Ridge National Laboratory (ORNL) SDDR code suite [1,2] is based on the rigorous two-step (R2S) method. The R2S method involves the following steps:

1. Performing a neutron transport calculation to generate a space- and energy-dependent neutron flux solution
2. Performing an activation calculation to generate a decay gamma source distribution in activated materials
3. Performing a gamma transport calculation using the decay gamma source distribution in Step 2 as the source, to calculate the SDDR

In the ORNL SDDR code suite, the Monte Carlo N-Particle (MCNP) code Version 5-1.60 [3] is used for neutron and gamma transport calculations with the ORNL-Transformative Neutronics (ORNL-TN) Version 1.0.0 patch [5]. The Oak Ridge Isotope Generator (ORIGEN) in the Standardized Computer Analyses for Licensing Evaluation (SCALE) code package Version 6.3.pre-b13 (branch 'cades-update' #2315dc0b on 2020AUG28) is used in activation calculations [4]. MSX Version 1.1.0, Neutron Activation Gamma Source Sampler (NAGSS) Version 1.1.0, Automated Variance Reduction Generator (ADVANTG) code Version 3.2.0 [5], and Denovo from SCALE Version 6.3.pre-b13 (branch 'cades-update' #2315dc0b on 2020AUG28) were used to accelerate the SDDR calculation.

In the R2S method, determining variance reduction parameters for the neutron transport calculation may be challenging because an importance function that characterizes the neutron importance to the final SDDR is needed. The Multi-Step Consistent Adjoint Driven Importance Sampling (MS-CADIS) method [1,2] overcomes this challenge. In the MS-CADIS method, the adjoint neutron source to be used in generating weight windows for the neutron transport calculation is computed by multiplying the gamma adjoint function with the transpose of transition matrices. The transition matrices describe the nuclear transmutations, burnup by neutron irradiation, and decay of radioactive nuclides using the irradiation history of a system [1,2].

The flowchart of the MS-CADIS method is given in Figure 1. Note that boxes that indicate “MCNP5” in the flowchart actually use the ORNL-TN upgrade to MCNP Version 5 [5]. Using MCNP5 with the ORNL-TN patch improves the scalability and performance of the MCNP5 code. ORNL-TN implements a shared memory mesh tally option for multithreaded simulations that reduces tally memory usage by a factor equal to the number of central processing unit (CPU) cores used. Also, the patch implements an option to write mesh tally output in Hierarchical Data Format version 5 (hdf5) binary format, which significantly improves input/output performance for large mesh tallies and reduces the size of output files compared to those output by MCNP.

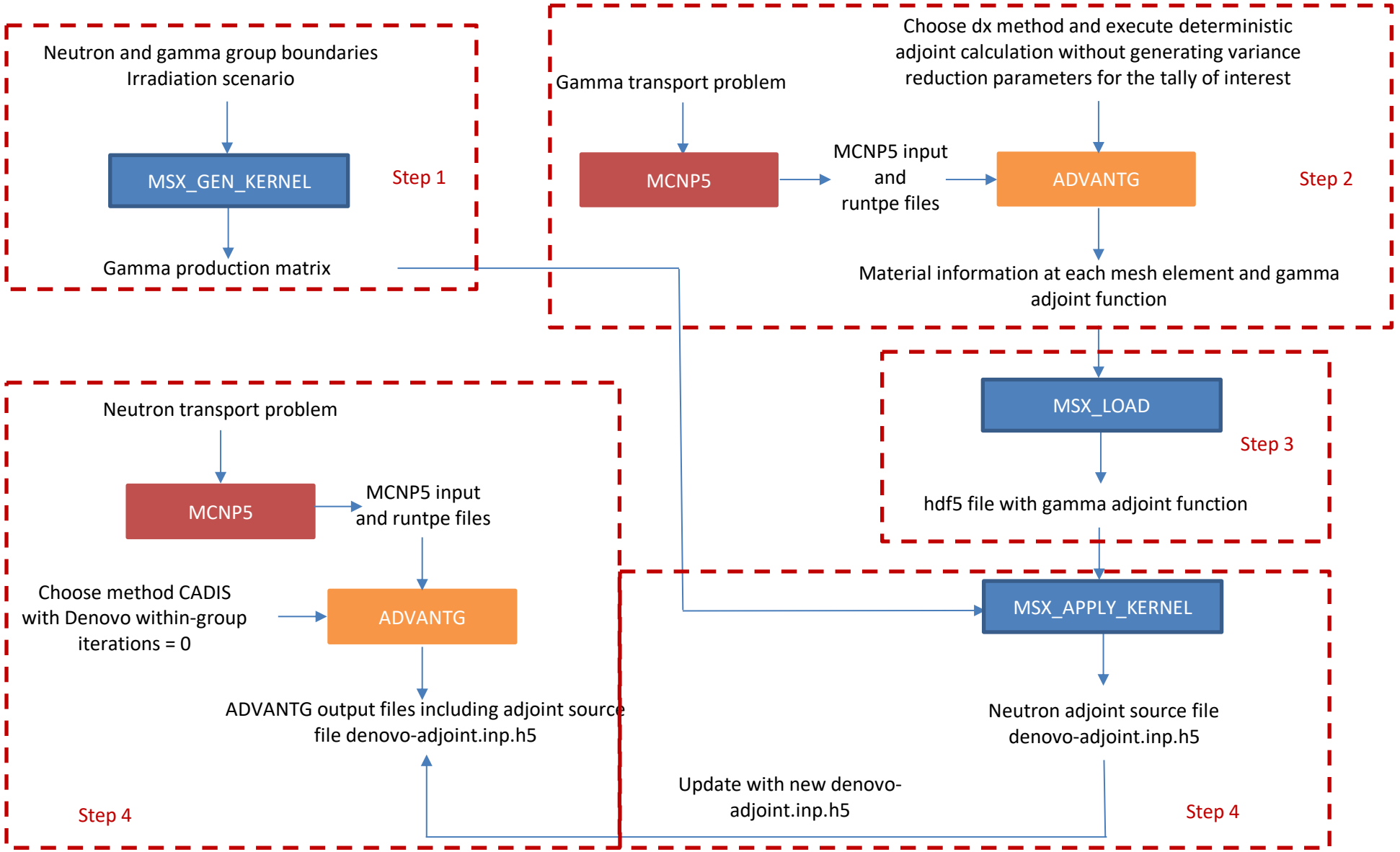

Figure 1. ORNL shutdown dose rate code suite flowchart.

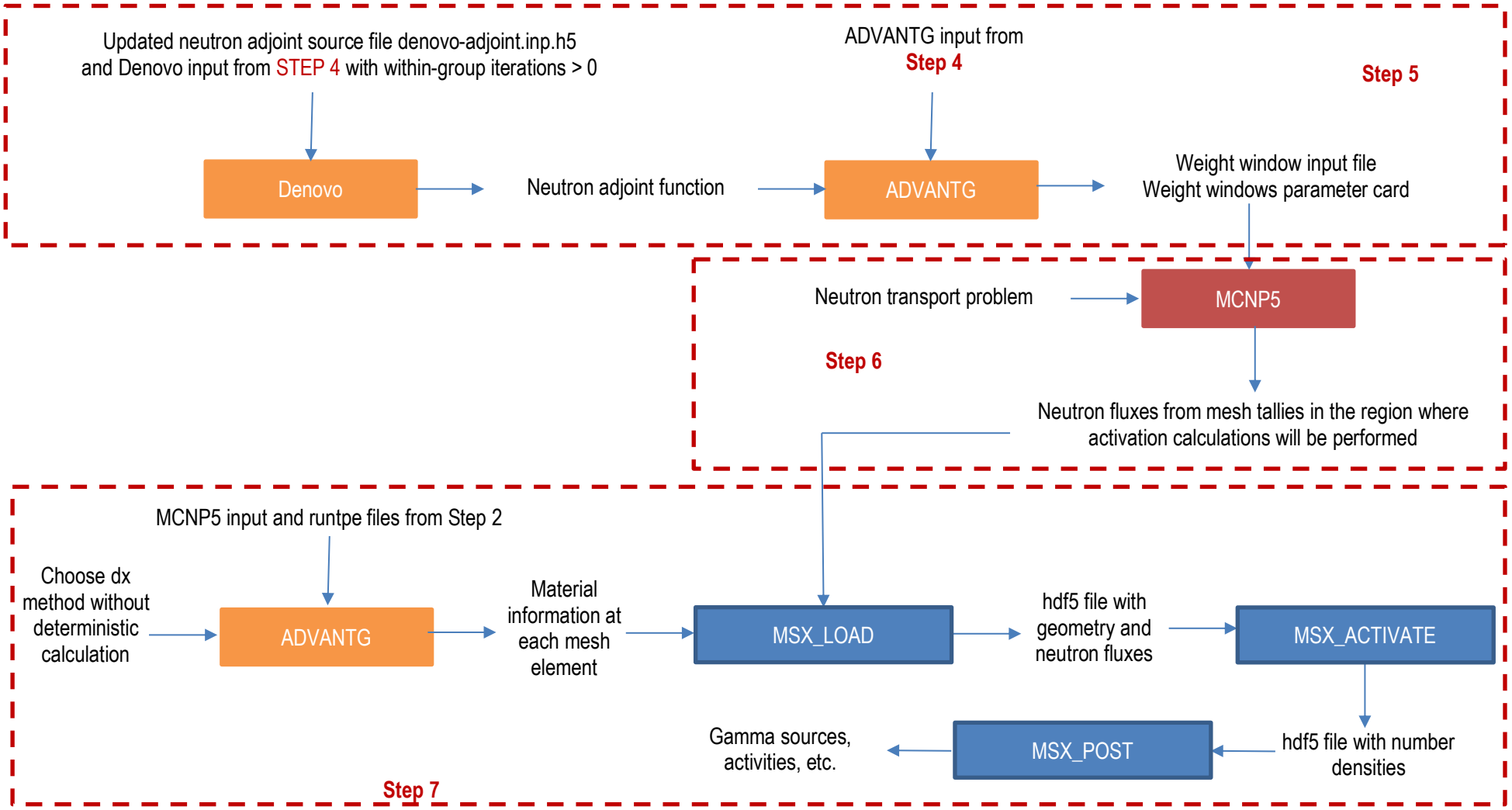

Figure 1. ORNL shutdown dose rate code suite flowchart (continued).

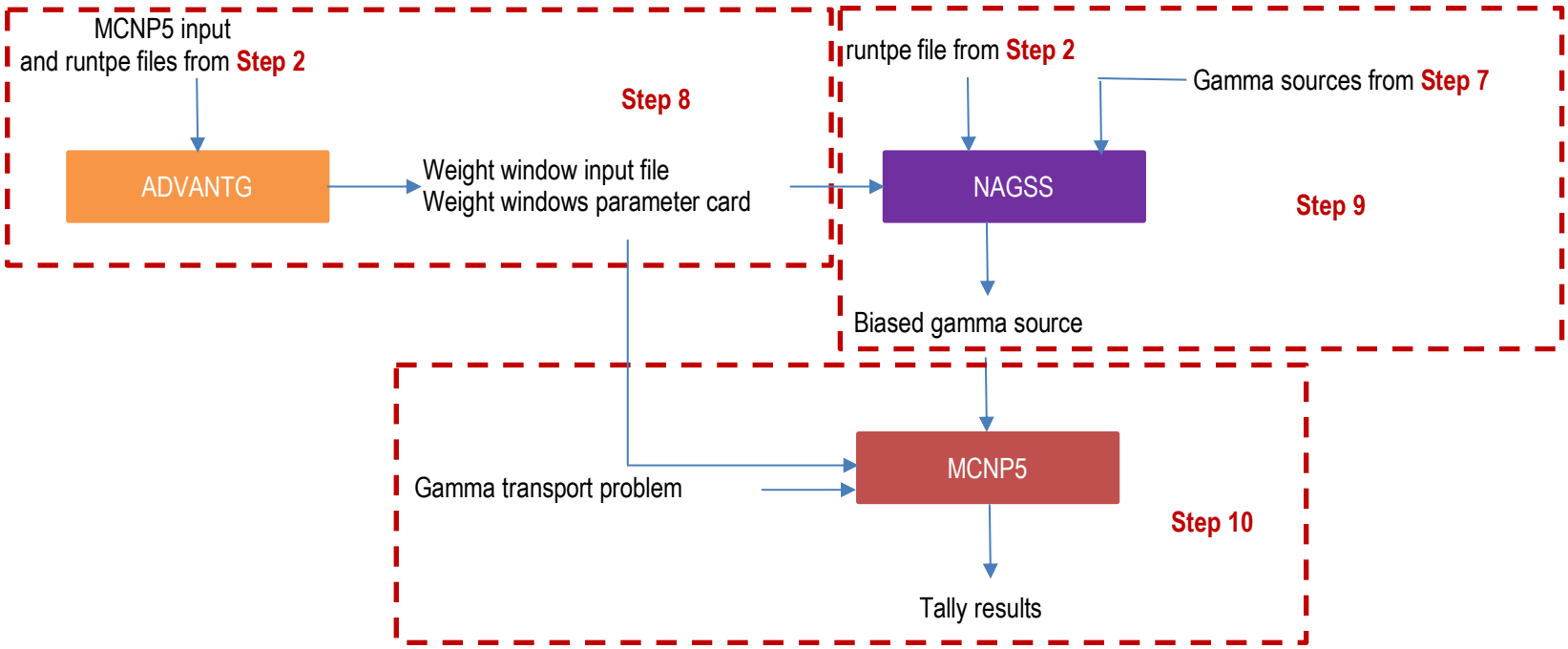

Figure 1. ORNL shutdown dose rate code suite flowchart (continued).

2. APPLICATION OF THE MS-CADIS METHOD TO THE INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR SHUTDOWN DOSE RATE BENCHMARK PROBLEM

The ITER SDDR benchmark was selected to demonstrate the application of the MS-CADIS R2S method. This benchmark, which simulates an ITER upper port plug, has been presented in several papers [1,2,6,7,8,9].

2.1 BENCHMARK PROBLEM

The geometry of the benchmark problem is shown in Figure 3 of [1], Figure 2 of [2], Figure 2 of [6], Figure 10 of [7], Figure 7 of [8], Figure 1 of [9] and Figure 2 of this report. The geometry includes a steel cylindrical ring with an outer radius of 100 cm, an inner radius of 50 cm, and a length of 550 cm [2,7]. There is a 15 cm thick steel plate at one end of this cylindrical ring and tally cells are placed 30 cm away from that steel plate. At the other end, inside the steel cylindrical ring, there is a steel and water cylindrical ring with an inner radius of 7.5 cm, an outer radius of 48 cm, and a length of 210 cm. There is a 2 cm gap between the steel cylindrical ring and the steel/water cylindrical ring. There is also a 2 cm gap between the top and bottom of the steel plate and the steel cylindrical ring.

There is an isotropic neutron source cell that is 10 cm thick and 100 cm away from the end that includes the steel/water region, as shown in Figure 2. This source emits 14 MeV neutrons, which is uniformly distributed within the source cell. The irradiation history is given in Table 1 [1,2,6,7]. The steel and steel/water material compositions are given in Table 2 [6].

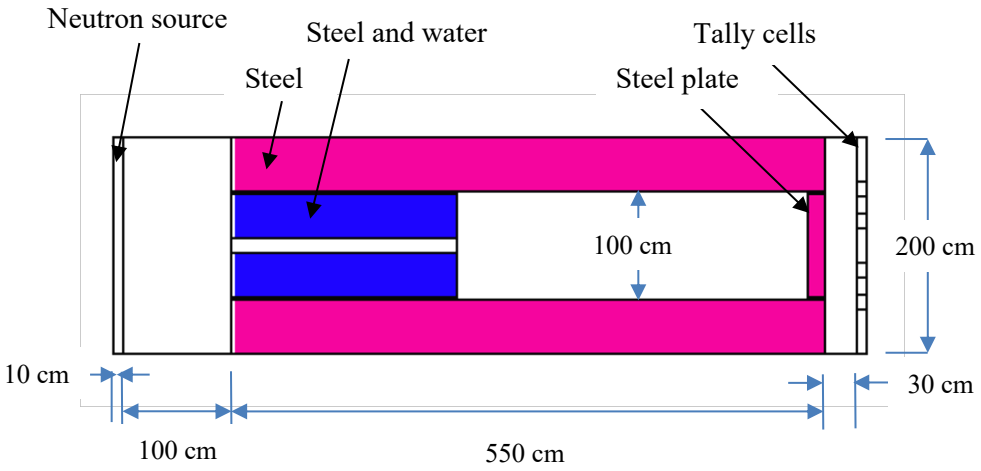

Figure 2. ITER shutdown dose rate benchmark geometry.

Table 1. ITER shutdown dose rate benchmark irradiation history

Neutron source strength (n/s)	Duration	Repetition
1.0714E+17	2 y	Once
8.25E+17	10 y	Once
0	0.667 y	Once
1.6607E+18	1.33 y	Once
0	3,920 s	17 times
2.0E+19	400 s	
0	3,920 s	4 times
2.8E+19	400 s	

Table 2. ITER shutdown dose rate benchmark material compositions

Element	Atom fractions		Element	Atom fractions	
	Steel and water	Steel		Steel and water	Steel
H	1.46E-01	-	Mn	1.42E-02	1.82E-02
B	4.02E-05	5.14E-05	Fe	5.03E-01	6.44E-01
C	8.14E-04	1.04E-03	Co	3.68E-04	4.71E-04
N	2.17E-03	2.78E-03	Ni	9.06E-02	1.16E-01
O	7.29E-02	6.95E-05	Cu	2.05E-03	2.62E-03
Al	8.04E-04	1.03E-03	Zr	9.52E-06	1.22E-05
Si	7.73E-03	9.89E-03	Nb	4.67E-05	5.98E-05
P	3.50E-04	4.48E-04	Mo	1.13E-02	1.45E-02
S	1.02E-04	1.30E-04	Sn	7.31E-06	9.36E-06
K	5.55E-06	7.10E-06	Ta	2.40E-05	3.07E-05
Ti	1.36E-03	1.74E-03	W	2.36E-06	3.02E-06
V	3.41E-05	4.36E-05	Pb	1.68E-06	2.14E-06
Cr	1.46E-01	1.87E-01	Bi	1.66E-06	2.13E-06

2.2 CALCULATIONS

The MCNP neutron transport calculations were based on Fusion Evaluated Nuclear Data Library (FENDL) 2.1 or FENDL 3.1b. Note that due to a processing error in the ^{39}K data in the FENDL 3.1b distribution, this isotope was processed at ORNL with the TALYS-based Evaluated Nuclear Data Library (TENDL) 2012 data. The MCNP gamma transport calculations were based on MCPLIB04 [3].

Isotope abundances of each element used in the material card in the MCNP inputs were taken from the International Atomic Energy Agency (IAEA) Live Chart of Nuclides [10]. These data are provided in Table 3.

Table 3. Isotope abundances from the IAEA live chart of nuclides

Element	Isotope	Abundance (%)	Element	Isotope	Abundance (%)	Element	Isotope	Abundance (%)
H	^{1}H-1	99.9885	Mn	^{55}Mn	100	Sn	^{118}Sn	24.22
	^{2}H	0.0115	Fe	^{54}Fe	5.845		^{119}Sn	8.59
B	^{10}B	19.9		^{56}Fe	91.754		^{120}Sn	32.58
	^{11}B	80.1		^{57}Fe	2.119		^{122}Sn	4.63
C	^{12}C	100		^{58}Fe	0.282		^{124}Sn	5.79
N	^{14}N	99.636	Co	^{59}Co	100	Ta	^{181}Ta	100
	^{15}N	0.364	Ni	^{58}Ni	68.077	W	^{180}W	0.12
O	^{16}O	100		^{60}Ni	26.223		^{182}W	26.5
Al	^{27}Al	100		^{61}Ni	1.1399		^{183}W	14.31
Si	^{14}Si	92.223		^{62}Ni	3.6346		^{184}W	30.64
	^{15}Si	4.685		^{64}Ni	0.9255		^{186}W	28.43
	^{16}Si	3.092	Cu	^{63}Cu	69.15	Pb	^{204}Pb	1.4
P	^{31}P	100		^{65}Cu	30.85		^{206}Pb	24.1
S	^{32}S	94.99	Zr	^{90}Zr	51.45		^{207}Pb	22.1
	^{33}S	0.75		^{91}Zr	11.22		^{208}Pb	52.4
	^{34}S	4.25		^{92}Zr	17.15	Bi	^{209}Bi	100
	^{36}S	0.01		^{94}Zr	17.38			
K	^{39}K	93.2581		^{96}Zr	2.8			
	^{40}K	0.0117	Nb	^{93}Nb	100			
	^{41}K	6.7302	Mo	^{92}Mo	14.53			
Ti	^{46}Ti	8.25		^{94}Mo	9.15			
	^{47}Ti	7.44		^{95}Mo	15.84			
	^{48}Ti	73.72		^{96}Mo	16.67			
	^{49}Ti	5.41		^{97}Mo	9.6			
	^{50}Ti	5.18		^{98}Mo	24.39			
V	^{50}V	0.25		^{100}Mo	9.82			
	^{51}V	99.75	Sn	^{112}Sn	0.97			
Cr	^{50}Cr	4.345		^{114}Sn	0.66			
	^{52}Cr	83.789		^{115}Sn	0.34			
	^{53}Cr	9.501		^{116}Sn	14.54			
	^{54}Cr	2.365		^{117}Sn	7.68			

The multigroup structures that were used for the ITER SDDR benchmark were as follows:

1. **Coupled 46-neutron- and 21-gamma-group library.** The group boundaries consist of a subset of the VITAMIN-J library [11,12]. This group structure is used in MSX_GEN_KERNEL in Step 1 and ADVANTG to generate a gamma adjoint function in Step 2, a neutron adjoint source in Step 4, neutron weight windows in Step 5, and gamma weight windows in Step 8.
2. **175-neutron-group VITAMIN-J structure.** This group structure is used for mesh tallies in the MCNP input of Step 6.

3. **54-gamma-group structure.** This group structure is a modified version of the 42-gamma-group VITAMIN-J structure. The development of the 54-gamma groups was needed to effectively capture the important gamma emission lines. If a decay energy lies at the edge of an energy group, then the decay energy is shifted up or down. If the group is wide to accommodate an important decay energy, then this can also affect the solution. Therefore, the 54-gamma-group structure has finely spaced groups near the important gamma emission lines. This group structure is used in MSX_POST in Step 7.

The American National Standards Institute (ANSI)/American Nuclear Society (ANS)-6.1.1 [13] flux-to-dose rate conversion factors were used to calculate responses at the SDDR location in the ITER benchmark.

The script that was used to generate SDDRs for the ITER benchmark was developed for scalable high-performance computing using Compute and Data Environment for Science (CADES) at ORNL*. A simplified version of this script that is not CADES-specific—iter.bash—is given in Appendix A. The MCNP input decks used in the script—mcnp_inp_G, mcnp_inp_G_adv, mcnp_inp_N, mcnp_inp_N_adv, config (for ORNL-TN), and config_G (for ORNL-TN)—are given in Appendix B.* This script was divided into ten steps as outlined in Figure 1. The ten steps are described below.

Step 1

Gamma sources from nuclide decay are calculated with MSX_GEN_KERNEL using the 173 nuclides in the FENDL3 library. The multigroup library contains coupled 46-neutron and 21-gamma groups and is based on FENDL-3.1b. The energy group boundaries and irradiation history are given as input.

Step 2

The MCNP code uses mcnp_inp_G_adv to calculate a runtpe file to be used in ADVANTG for the benchmark problem. This MCNP input file is for gamma transport. The MCNP material card includes identification numbers of nuclides for neutron interactions from an xsdir file based on FENDL-2.1 (nuclide identification with extension 21c) and FENDL-3.1 (nuclide identification with extension 31c). The atom fractions given in Table 2 were input into the material cards for each nuclide. Isotope abundances of each element were taken from the IAEA Live Chart of Nuclides as given in Table 3. The input gamma source is arbitrary. Tally cells, which are located 30 cm away from the 15 cm steel plate and are the locations of interest for the final dose rate calculation, are modified using ANSI/ANS-6.1.1-1977 flux-to-dose-rate conversion factors.

In the ADVANTG input input_photon_adjoint, the dx method is selected to discretize the transport model and execute a deterministic adjoint calculation. The adjoint source corresponds to the cell flux tallies at the final dose rate location as modified by ANSI/ANS-6.1.1-1977 flux-to-dose rate conversion factors. Spatial discretization of the Denovo parallel discrete ordinates solver model includes 5 cm meshes in the x, y, and z directions. The model is executed with P_3 order of Legendre expansion and a quadruple range quadrature set with 8 polar directions. The FENDL-3.1b 46-neutron- and 21-gamma-group cross-section library is used.

*Files are modified versions of those that were generated by Stephen C. Wilson (Los Alamos National Laboratory).

Step 3

The MSX_LOAD code is executed to load material data (spatial mesh, material composition, material mixing table, and material map) and photon adjoint function from the Step 2 ADVANTG outputs.

Step 4

The MCNP code uses mcnp_inp_N_adv to calculate a runtpe file to be used in ADVANTG. This MCNP input file is for neutron transport. The MCNP material card includes identification numbers of nuclides for neutron interactions from an xsdir file based on FENDL-2.1 (nuclide identification with extension 21c) and FENDL-3.1 (nuclide identification with extension 31c). The atom fractions given in Table 2 were input into the material cards for each nuclide. Isotope abundances of each element were taken from the IAEA Live Chart of Nuclides as given in Table 3. The input neutron source is arbitrary. Mesh tallies are set up within the large steel cylinder (outer radius of 100 cm and length of 550 cm), having x, y, and z mesh lengths of 5 cm. The 175-neutron-group structure of VITAMIN-J is given in the mesh tally input.

In the ADVANTG input input_advantg_n_v1, the CADIS method is selected, but a deterministic calculation is not executed. The adjoint source corresponds to the mesh tallies within the large cylinder (outer radius of 100 cm and length of 550 cm). Spatial discretization of the Denovo parallel discrete ordinates solver model includes 5 cm meshes in the x, y, and z directions. The model is set up with P_3 order of Legendre expansion and a quadruple range quadrature set with 8 polar directions. The FENDL-3.1b 46-neutron-, 21-gamma-group cross-section library is specified.

The MSX_APPLY_KERNEL code is executed to calculate the MS-CADIS adjoint neutron source using the outputs of Steps 1 and 3. The same irradiation history in Step 1 is used in MSX_APPLY_KERNEL. The adjoint neutron source file from the ADVANTG run (see previous paragraph) is updated by the new adjoint source generated by MSX_APPLY_KERNEL.

Step 5

Using the adjoint neutron source in Step 4, the Denovo input from Step 4 is executed by setting the within-group iterations to 100. A neutron adjoint function is generated. Using this adjoint function with the ADVANTG input input_advantg_n_v1, a neutron weight window file and parameter card are generated.

Step 6

The MCNP input file mcnp_inp_N is executed with the weight windows generated in Step 5. This MCNP input file is for neutron transport. The MCNP material card includes identification numbers of nuclides for neutron interactions from an xsdir file based on FENDL-2.1 (nuclide identification with extension 21c) and FENDL-3.1 (nuclide identification with extension 31c). The atom fractions given in Table 2 were input into the material cards for each nuclide. Isotope abundances of each element were taken from the IAEA Live Chart of Nuclides as given in Table 3. The source definition is provided as 14 MeV neutrons emitted from the 100 cm radius 10 cm height cylinder region shown in Figure 3 of [1]. Mesh tallies are set up within the large cylinder (outer radius of 100 cm and length of 550 cm) having x, y, and z mesh lengths of 5 cm. The 175-neutron-group structure of VITAMIN-J is given in the mesh tally input.

Step 7

The ADVANTG input input_dx is created that uses the dx method to discretize the MCNP input from Step 2 (mcnp_inp_G_adv) without executing a deterministic calculation. In the ADVANTG input, the x,

y, and z dimensions of the benchmark problem are discretized into 5 cm meshes. The VITAMIN-J library with 175 neutron and 42 gamma groups is specified. Spatial mesh, material compositions, the material mixing table, and the material map are loaded from the ADVANTG output, as well as the mesh tally file generated in Step 6, using the code MSX_LOAD. The output file msx_activate_NAGSS.h5 is generated by MSX_LOAD. This output file is used as input to MSX_ACTIVATE to perform activation calculations in each mesh voxel and generate nuclide number densities. The input for MSX_ACTIVATE, input_msx_activate_NAGSS, includes the same irradiation history specified in Step 1. The number densities generated by MSX_ACTIVATE are used by MSX_POST to generate problem-dependent gamma sources and activities in an hdf5 file in a 54-gamma-group structure.

Step 8

The MCNP runtpe and input files from Step 2 are used as input to the ADVANTG code. Method CADIS, FENDL 3.1b 46-neutron-, 21-gamma group library, P_3 Legendre order of scattering, and quadruple range quadrature set with 8 polar directions are selected in ADVANTG. The MCNP tally number for which variance reduction parameters/adjoint sources are generated corresponds to the location where dose rates are to be calculated. The benchmark problem x, y, and z dimensions are discretized into 5 cm length meshes. A gamma weight windows and parameter card file is produced by ADVANTG.

Step 9

The NAGSS code is used to generate a biased gamma source for the final gamma transport MCNP calculation. The weight windows file from Step 8, the runtpe file from Step 2, and the gamma sources from Step 7 are used as input.

Step 10

This step uses the mcnp_inp_G MCNP input for gamma transport, gamma weight windows and the parameter card from Step 8, and the biased gamma source generated in Step 9 to calculate dose rates at the tally location. The mcnp_inp_G input deck is similar to mcnp_inp_G_adv, with the main difference being the description of the source and use of weight windows / weight window card in mcnp_inp_G.

2.3 RESULTS

In Table 4, the column labeled “Current analysis” provides photon dose rates for the ITER SDDR benchmark calculation. MSX-CADIS was used for the four tally cells shown in Figure 2 with the script and input files provided in Appendices A and B, respectively. Tallies 1, 2, 3, and 4 are tallied over the 0 to 15 cm, 15 to 30 cm, 30 to 45 cm, and 45 to 60 cm radial extent of the target, respectively [1]. Results from Wilson et al. [1] are also given in Table 4; these results correspond to the case that performed MSX/NAGSS calculations with a cubic mesh having a side length of 5 cm, which is consistent with the current analysis. Additionally, input parameters used by Wilson et al. [1] were utilized here to recalculate photon dose rates in Tallies 1, 2, 3, and 4. These results are listed in the Table 4 column labeled “Current analysis with parameters from Wilson et al. [1].” Relative errors were all less than 1% for all the tallied photon dose rates included in Table 4.

Table 4. ITER shutdown dose rate benchmark results

Tally	Photon dose rate (Sv/h)		
	Current analysis	Wilson et al. [1]	Current analysis with parameters from Wilson et al. [1]
1	2.659E-02	2.086E-02	2.104E-02
2	2.252E-02	1.765E-02	1.778E-02
3	1.722E-02	1.350E-02	1.358E-02
4	1.236E-02	9.708E-03	9.747E-03

The photon dose rates under "Current analysis" in Table 4 were calculated by extracting the total biased source from the file nagss_log.out, dividing this value by two, multiplying with each of the tally outputs (1 through 4) below "vals" in the file MCTALMRG, and applying a multiplication factor of 1.0E-05 (to convert mrem/h to Sv/h). The division by two is a fixed number that must be applied to the total biased source from the NAGSS execution.

The photon dose rates under "Current analysis with parameters from Wilson et al. [1]" in Table 4 were calculated by extracting the total biased source from the file nagss_log.out, dividing this value by two, multiplying with each of the tally outputs (1 through 4) below "vals" in the file MCTALMRG, and applying a multiplication factor of 1.0E-02 (to convert rem/h to Sv/h).

Previously published results for the ITER SDDR benchmark dose rates with MSX-CADIS by Wilson et al. in [1] were reproduced within 1% relative differences, as given in Table 4. This small discrepancy is attributed to different computer code versions that might have been used between the two calculations.

A comparison of the dose rate results from the current analysis and those from the analysis of Wilson et al. [1] show relative differences of ~28%. This discrepancy is mainly due to the different flux-to-dose-rate conversion factors used. Other differences that are expected to have a smaller contribution to differences are (1) the format in which the irradiation history was entered (2) the use of different FENDL versions for S, K, V, Zr, and Sn for neutron interactions in the MCNP material cards, (3) inclusion of ^{204}Pb in the MCNP material cards in the current analysis, (4) isotopic abundances in determining atomic fractions of nuclides in the MCNP material cards, and (5) quadrature set used in ADVANTG.

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APPENDIX A. BASH SCRIPT

APPENDIX A. ITER.BASH

```
#! /bin/bash
#
## This script is designed to run on 8 nodes / 32 processors per node
#
# NAGSS (runs 16 copies of the program on each node on shared memory)
export NAGSS='mpiexec -np 16 --npersocket 1 nagss'

# ADVANTG with threading
export ADVANTG='advantg -t 32 -v -f'

# MSX Utilities
export MSX_LOAD='msx_load'
export MSX_ACTIVATE='mpiexec -np 256 -bind-to core -cpus-per-proc 1 msx_activate'
export MSX_GEN_KERNEL='mpiexec -np 256 -bind-to core -cpus-per-proc 1 msx_gen_kernel'
export MSX_APPLY_KERNEL='mpiexec -np 256 -bind-to core -cpus-per-proc 1 msx_apply_kernel'
export MSX_POST='msx_post'

# MCNP5 with ORNL-TN
export MCNP5BASEN='mcnp5 '

# MCNP5 with ORNL-TN and NAGSS source routine
export MCNP5BASEG='mcnp5_nagss '

#
# step descriptions:
# step 1: msx_gen_kernel - generate activation kernel
# step 2: advantg - generate photon adjoints with advantg/denovo
# step 3: msx_load - load material data and photon adjoints from advantg output
# step 4: advantg / msx_apply_kernel: calculate neutron adjoint source using steps 1 & 3, place it
in advantg directory
# step 5: advantg - generate a neutron wwinp file
# step 6: mcnp - use wwinp from step 5 & generate neutron fluxes in a meshtal file
# step 7: MSX steps to generate a gamma activation source
```

```
# step 7a: msx_load - load material data and neutron fluxes from the mcnp meshtal file
# step 7b: msx_activate - activation calculation; calculate number densities
# step 7c: msx_post - calculate gamma sources
# step 8: advantg - generate gamma weight windows
# step 9: nagss -  generate MCNP source
# step 10: mcnp - generate gamma results
#
# switches to control step execution
step1exec=true
step2exec=true
step3exec=true
step4exec=true
step5exec=true
step6exec=true
step7exec=true
step8exec=true
step9exec=true
step10exec=true
# substeps inside step 7
step7aexec=true
step7bexec=true
step7cexec=true
#
#
# NOTE: need 4 inputs (neutron transport, photon transport, neutron advantg,
#    photon advandtg) plus any optional items (like quadrature files for Denovo)
#
export EXECDIR='/path/to/execdir'
export SRCDIR='/path/to/srcdir'
#
cd $EXECDIR
echo Copying $SRCDIR files to $EXECDIR...
cp $SRCDIR/* .
#
# ***************************************************************************
# step 1: generate the kernel
# NOTE: neutron energy descending in eV
```

```
#       gamma energy descending in MeV
#

if [ "$step1exec" = true ]
then
echo Beginning Step 1

cat << eof > input_gen_kernel

neutron_group_bounds=(1.4191E+07,1.3499E+07,1.2214E+07,1.1052E+07,1.0000E+07,
9.0484E+06,8.1873E+06,7.4082E+06,6.7032E+06,6.0653E+06,
5.4881E+06,4.9659E+06,4.4933E+06,4.0657E+06,3.6788E+06,
3.3287E+06,3.0119E+06,2.7253E+06,2.4660E+06,1.8268E+06,
1.3534E+06,1.0026E+06,7.4274E+05,5.5023E+05,4.0762E+05,
3.0197E+05,2.2371E+05,1.6573E+05,1.2277E+05,6.7379E+04,
3.1828E+04,1.5034E+04,7.1017E+03,3.3546E+03,1.5846E+03,
7.4852E+02,3.5358E+02,1.6702E+02,7.8893E+01,3.7267E+01,
1.7603E+01,8.3153E+00,3.9279E+00,1.8554E+00,8.7642E-01,
4.1399E-01,1.0000E-05)

gamma_group_bounds=(1.4000E+01,1.2000E+01,1.0000E+01,8.0000E+00,7.5000E+00,
7.0000E+00,6.5000E+00,6.0000E+00,5.5000E+00,5.0000E+00,
4.5000E+00,4.0000E+00,3.5000E+00,3.0000E+00,2.5000E+00,
2.0000E+00,1.5000E+00,1.0000E+00,4.0000E-01,2.0000E-01,
1.0000E-01,1.0000E-02)

# ITER Irradiation Scenario
# NOTE: ITER benchmark indicates 4 700 MW pulses at the end
#       of the irradiation scenario.

time_step_factor = 1  # conversion factor to secs
time_steps = (
   63115200,  #  2 y
  315576000,  # 10 y
   21048919,  #  0.667 y
   41813820,  #  1.325 y
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,  # 17x 400 s pulses
```

```
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 1000000)    #  4x 400 s pulses

flux_factor = 1.0
flux_step_factors = (
  1.0714e+17,
    8.25e+17,
           0,
  1.6607e+18,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,   # 17 pulses
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19,
            0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0)            #  4 pulses


eof
$MSX_GEN_KERNEL input_gen_kernel

fi
# ****************************************************************************
# step 2: generate photon adjoint

if [ "$step2exec" = true ]
then
echo Beginning Step 2

# Setup and run ADVANTG
cat << eof2 > input_photon_adjoint

method                      dx

dx_adjoint  True
dx_forward  False
```

```
anisn_library  FENDL31_46n21g

mcnp_input     mcnp_inp_G_adv
mcnp_sb_type     none
mcnp_tallies   4

mcnp_min_source_samples 1e6
mcnp_max_source_samples 1e8
mcnp_target_source_density 1e5

mcnp_min_rays_per_face 100

mesh_x                 -100.0 100.0
mesh_x_ints            40

mesh_y                  -100.0 100.0
mesh_y_ints            40

mesh_z                  -110.0 590.0
mesh_z_ints             140

denovo_quadrature      qr
denovo_quad_num_azi_vec  1 2 3 4 5 6 7 8
denovo_quad_num_polar  8

denovo_pn_order     3
denovo_tolerance    1E-5

denovo_transport_correction   cesaro

denovo_x_blocks   16
denovo_y_blocks   16

eof2

$ADVANTG input_photon_adjoint
```

```
fi
# ************************************************************************
# step 3: execute msx_load on the ADVANTG output
if [ "$step3exec" = true ]
then
echo Beginning Step 3

cat << eof3 > input_msx_load_adv.py

SetHDF5File("msx_adjoint.h5")

SetAdvantgRunDirectory("./")

LoadAdvantgMatls()

LoadAdvantgFlux("adj","p")

eof3

$MSX_LOAD input_msx_load_adv.py

fi
# ************************************************************************
# step 4: apply kernel to generate adjoint neutron source
if [ "$step4exec" = true ]
then
echo Beginning Step 4

if [ ! -d advantg_neutron ]
then
  mkdir advantg_neutron
fi

cd advantg_neutron
ln -s ../mcnp_inp_N_adv .
ln -s ../config .
```

```
cat << eof5 > input_advantg_n_v1
method                      cadis

fwcadis_spatial_treatment    pathlength

anisn_library  FENDL31_46n21g
mcnp_input      mcnp_inp_N_adv
mcnp_sb_type     none
mcnp_tallies   204

mcnp_min_source_samples 1e6
mcnp_max_source_samples 1e8
mcnp_target_source_density 1e5

mcnp_min_rays_per_face 100

mesh_x                 -100.0 100.0
mesh_x_ints            40

mesh_y                  -100.0 100.0
mesh_y_ints            40

mesh_z                  -110.0 590.0
mesh_z_ints             140

denovo_quadrature      qr
denovo_quad_num_azi_vec  1 2 3 4 5 6 7 8
denovo_quad_num_polar  8

denovo_pn_order     3
denovo_tolerance    1E-4
denovo_max_iterations 0

denovo_transport_correction   cesaro

denovo_x_blocks   16
denovo_y_blocks   16
```

```
mcnp_lost_rays  1000

eof5

# run the first ADVANTG execution
$ADVANTG input_advantg_n_v1

# Back up to main execdir
cd ..

cat << eof4 > input_apply_kernel

hdf5_input = "./msx_adjoint.h5"

kernel_input = "./msx_kernel.dat"

transpose = true

denovo_hdf5_input = "./advantg_neutron/adj_solution/denovo-adjoint.inp.h5"

denovo_hdf5_output = "denovo-adjoint.inp.h5"

# NOTE: ITER benchmark indicates 4 700 MW pulses at the end
#       of the irradiation scenario.

time_step_factor = 1  # conversion factor to secs
time_steps = (
   63115200,  #  2 y
  315576000,  # 10 y
   21048919,  #  0.667 y
   41813820,  #  1.325 y
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,  # 17x 400 s pulses
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 1000000)    #  4x 400 s pulses
```

```
flux_factor = 1.0
flux_step_factors = (
  1.0714e+17,
    8.25e+17,
           0,
  1.6607e+18,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,   # 17 pulses
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19,
            0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0)            #  4 pulses


eof4

echo Applying kernel
$MSX_APPLY_KERNEL input_apply_kernel

cp denovo-adjoint.inp.h5 ./advantg_neutron/adj_solution/denovo-adjoint.inp.h5

fi
# ****************************************************************************************
# step 5: make a neutron wwinp file
if [ "$step5exec" = true ]
then
echo Beginning Step 5

cd advantg_neutron

# go into adj_solution
cd adj_solution

# replace max_iterations 0 in omnibus.inp.omn
perl -pi -e 's/max_iterations 0/max_iterations 100/g;' omnibus.inp.omn
perl -pi -e 's/\"max_itr\" type=\"int\" value=\"0\"/\"max_itr\" type=\"int\" value=\"100\"/g;'
omnibus.inp.xml
```

```
perl -pi -e 's/\<Parameter name=\"scale_rev\"/\<Parameter name=\"num_threads\" type=\"int\"
value=\"1\" \/\>\<Parameter name=\"scale_rev\"/g;' omnibus.inp.xml

# run Denovo with the kernel sources
mpiexec -np 256 /software/user_tools/current/cades-nsed-exnihilo/Exnihilo/bin/omnibus
omnibus.inp.xml

# back up to the advantg run directory
cd ..

# force ADVANTG to run with the new adj_solution
$ADVANTG input_advantg_n_v1

# back up to main exec directory
cd ..

fi
#
********************************************************************************************
# step 6: run MCNP to generate neutron meshtal
# NOTE: run exterior script for this step
if [ "$step6exec" = true ]
then
echo Beginning Step 6

if [ ! -d mcnp_neutron ]
then
  mkdir mcnp_neutron
fi

cd mcnp_neutron

cp ../mcnp_inp_N .
cp ../config .
cat ../advantg_neutron/output/inp_edits.txt >> mcnp_inp_N

ln -s ../advantg_neutron/output/wwinp wwinp_mscadis_neutron
```

```
# create N independent decks
NBERT=16
for ((ibert=0;ibert<NBERT;ibert++)); do

  ((qbert=ibert*2+1))
  cp mcnp_inp_N mcnp_inp_N_$ibert
  echo RAND GEN=2 SEED=$qbert STRIDE=30239789 > card_$ibert
  cat card_$ibert >> mcnp_inp_N_$ibert

done

# create OpenMPI stage and launch script

  rm launch.bash

  echo '#! /bin/bash' >> launch.bash
  echo '#' >> launch.bash
  echo 'echo Executing on rank $OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'rm -r temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'mkdir temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'cd temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo $SRCORNLTN >> launch.bash
  echo 'unset OMP_PLACES' >> launch.bash
  echo 'export OMP_PROC_BIND=true' >> launch.bash
  echo 'export DATAPATH='$DATAPATH >> launch.bash
  echo 'ln -s '$EXECDIR'/mcnp_neutron/wwinp_mscadis_neutron .' >> launch.bash
  echo 'ln -s '$EXECDIR'/mcnp_neutron/config .' >> launch.bash
  echo 'mv '$EXECDIR'/mcnp_neutron/mcnp_inp_N_$OMPI_COMM_WORLD_RANK .' >> launch.bash
  echo $MCNP5BASEN' inp=mcnp_inp_N_$OMPI_COMM_WORLD_RANK outp=out_$OMPI_COMM_WORLD_RANK
runtpe=trash wwinp=wwinp_mscadis_neutron tasks 15' >> launch.bash
  echo 'mv meshtal.h5 '$EXECDIR'/mcnp_neutron/meshtal_n_$OMPI_COMM_WORLD_RANK.h5' >> launch.bash
  echo 'cd '$EXECDIR'/mcnp_neutron' >> launch.bash
  echo 'sleep 100' >> launch.bash

  chmod u+rx launch.bash
```

```
# mpiexec the launch script
mpiexec -np $NBERT --npersocket 1 launch.bash

# recombine the meshtals
ls -1 meshtal_n*.h5 > mergelist.txt
cat mergelist.txt | merge-meshtal-hdf5 -o merged_meshtal.h5 -

cd ..

fi
#
********************************************************************************
# step 7: run MSX (load, activate, post) to generate activation gamma sources
if [ "$step7exec" = true ]
then

if [ "$step7aexec" = true ]
then
echo Beginning Step 7a

if [ ! -d advantg_source ]
then
  mkdir advantg_source
fi

cd advantg_source

cp -p ../mcnp_inp_G_adv .
ln -s /lustre/hydra/cades-nsed/proj-shared/iter_data/FENDL31_175n42g* .

mkdir model
cp ../model/runtpe model/

cat << eof20 > input_dx

method                      dx
```

```
dx_adjoint  False
dx_forward  False

anisn_library  FENDL31_175n42g

mcnp_input     mcnp_inp_G_adv

mcnp_sb_type     none

mcnp_tallies   4

mcnp_min_source_samples 1e7
mcnp_max_source_samples 1e9
mcnp_target_source_density 1e6

mcnp_min_rays_per_face 100

mesh_x                 -100.0 100.0
mesh_x_ints            40

mesh_y                  -100.0 100.0
mesh_y_ints            40

mesh_z                  0.0 550.0
mesh_z_ints             110

# mcnp_unfolding_origin 600.0 10.0 60.0
# mcnp_unfolding_safe  True

denovo_quadrature      qr
denovo_quad_num_azi_vec  1 2 3 4 5 6 7 8
denovo_quad_num_polar  8

denovo_pn_order     3
denovo_tolerance    1E-4

denovo_transport_correction   cesaro
```

```
denovo_x_blocks   16
denovo_y_blocks   16

eof20

$ADVANTG -v input_dx

cd ..

cat << eof7a > input_msx_load_NAGSS.py

SetHDF5File("msx_activate_NAGSS.h5")

SetAdvantgRunDirectory("./advantg_source/")

LoadAdvantgMatls()

SetMeshtalFile("./mcnp_neutron/merged_meshtal.h5")

LoadMeshtalFlux(204)

eof7a

$MSX_LOAD input_msx_load_NAGSS.py
fi

if [ "$step7bexec" = true ]
then
echo Beginning Step 7b

cat << eof7b > input_msx_activate_NAGSS

hdf5_input = "msx_activate_NAGSS.h5"

hdf5_output = "numdens_NAGSS.h5"
```

```
# NOTE: ITER benchmark indicates 4 700 MW pulses at the end
#       of the irradiation scenario.

time_step_factor = 1  # conversion factor to secs
time_steps = (
   63115200,  #  2 y
  315576000,  # 10 y
   21048919,  #  0.667 y
   41813820,  #  1.325 y
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,  # 17x 400 s pulses
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 3920, 400,
       3920, 400, 3920, 400,
       3920, 400, 3920, 400, 3920, 400, 3920, 400, 1000000)    #  4x 400 s pulses

flux_factor = 1.0
flux_step_factors = (
  1.0714e+17,
    8.25e+17,
           0,
  1.6607e+18,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,   # 17 pulses
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19, 0, 2.0e+19 ,0, 2.0e+19,
            0, 2.0e+19, 0, 2.0e+19,
            0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0, 2.8e+19, 0)            #  4 pulses


min_number_density = 1.0e-30

eof7b

$MSX_ACTIVATE input_msx_activate_NAGSS
fi

if [ "$step7cexec" = true ]
then
```

```
echo Beginning Step 7c

cat << eof7c > input_msx_post_NAGSS.py

infile = HDF5File("numdens_NAGSS.h5","r")

groups = Groups([1.00000E+01,5.00000E+00
                 ,4.50000E+00,4.00000E+00
                 ,3.50000E+00,3.00000E+00
                 ,2.76000E+00,2.74000E+00
                 ,2.50000E+00,2.12000E+00
                 ,2.10000E+00,2.00000E+00
                 ,1.82000E+00,1.80000E+00
                 ,1.68000E+00,1.66000E+00
                 ,1.38300E+00,1.37000E+00
                 ,1.35000E+00,1.34000E+00
                 ,1.32000E+00,1.30000E+00
                 ,1.28000E+00,1.18000E+00
                 ,1.16000E+00,1.00000E+00
                 ,8.70000E-01,8.60000E-01
                 ,8.50000E-01,8.45000E-01
                 ,8.40000E-01,8.30000E-01
                 ,8.20000E-01,8.15000E-01
                 ,8.05000E-01,8.00000E-01
                 ,7.50000E-01,7.00000E-01
                 ,6.00000E-01,5.20000E-01
                 ,5.00000E-01,4.50000E-01
                 ,4.00000E-01,3.00000E-01
                 ,2.00000E-01,1.50000E-01
                 ,1.00000E-01,7.50000E-02
                 ,7.00000E-02,6.00000E-02
                 ,4.50000E-02,3.00000E-02
                 ,2.00000E-02,1.00000E-02
                 ,1.00000E-03])

print groups.num_groups
print groups.bounds
```

```
outfile = GammaSourceField(infile,groups)

outfile.write_nagss()

field = ActivityField(infile)
siloout = SiloFile("activity.silo")
siloout.add_field(field,"activity")

eof7c

$MSX_POST input_msx_post_NAGSS.py
fi

fi
#
################################################################################
# step 8: run ADVANTG to generate gamma weight windows
if [ "$step8exec" = true ]
then
echo Beginning Step 8

if [ ! -d advantg_gamma ]
then
  mkdir advantg_gamma
fi
cd advantg_gamma

# Link inputs and cross-section library
ln -s ../mcnp_inp_G_adv .
ln -s /lustre/hydra/cades-nsed/proj-shared/iter_data/FENDL31_46n21g* .

# Copy over the previously generated runtpe to save time
mkdir model
cp ../model/runtpe model/

# Generate the ADVANTG input
```

```
cat << eof8 > input_photon_CADIS

method                      cadis

anisn_library  FENDL31_46n21g
mcnp_input      mcnp_inp_G_adv
mcnp_sb_type     none
mcnp_tallies   4

mcnp_min_source_samples 1e6
mcnp_max_source_samples 1e8
mcnp_target_source_density 1e5

mcnp_min_rays_per_face 100

mesh_x                -100.0 100.0
mesh_x_ints           40

mesh_y                 -100.0 100.0
mesh_y_ints           40

mesh_z                 -110.0 590.0
mesh_z_ints            140

denovo_quadrature      qr
denovo_quad_num_azi_vec  1 2 3 4 5 6 7 8
denovo_quad_num_polar  8

denovo_pn_order     3
denovo_tolerance    1E-4

denovo_transport_correction   cesaro

denovo_x_blocks   16
denovo_y_blocks   16

eof8
```

```
# Run ADVANTG to generate the gamma weight windows
$ADVANTG input_photon_CADIS

cd ..

fi
#
********************************************************************************************************
# step 9: run NAGSS to generate MCNP source
if [ "$step9exec" = true ]
then
echo Beginning Step 9

export OMP_PROC_BIND=TRUE

# Link needed files
ln -s ./advantg_gamma/output/wwinp wwinp_mscadis_gamma
ln -s ./advantg_gamma/output/inp_edits.txt .
ln -s model/runtpe blarg

# NAGSS input
# number of energy group files to search for
# number of batches to sample
# number of samples per batch per thread
# number of threads to execute
# number of random MCNP output files
# path to gamma ww
# path to gamma inp_edits (with response value)
# number of sdef point sources if run in sdef mode

cat << eof9 > nagss.inp
55
10
100000
16
256
```

```
./wwinp_mscadis_gamma
./inp_edits.txt
1000
eof9

$NAGSS -sample > nagss_log.out

fi
#
#*******************************************************************************************
# step 10: run MCNP to generate MCNP gamma results
#
if [ "$step10exec" = true ]
then
echo Beginning Step 10

if [ ! -d mcnp_gamma ]
then
  mkdir mcnp_gamma
fi
cd mcnp_gamma

cp  ../mcnp_inp_G .
cp ../config_G config
ln -s ../nagss_random* .
ln -s ../advantg_gamma/output/wwinp .
ln -s ../advantg_gamma/output/inp_edits.txt

cat inp_edits.txt >> mcnp_inp_G

NBERT=16
for ((ibert=0;ibert<NBERT;ibert++)); do

  ((qbert=ibert*2+1))
  cp mcnp_inp_G mcnp_inp_G_$ibert
  echo RAND GEN=2 SEED=$qbert STRIDE=30239789 > card_$ibert
  cat card_$ibert >> mcnp_inp_G_$ibert
```

```
done

# create OpenMPI stage and launch script

  rm launch.bash

  echo '#! /bin/bash' >> launch.bash
  echo '#' >> launch.bash
  echo 'echo Executing on rank $OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'rm -r temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'mkdir temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'ln -s '$EXECDIR'/mcnp_gamma/wwinp temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'ln -s '$EXECDIR'/mcnp_gamma/config temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'cp '$EXECDIR'/mcnp_gamma/mcnp_inp_G_$OMPI_COMM_WORLD_RANK temp_exec_$OMPI_COMM_WORLD_RANK'
>> launch.bash
  echo 'NTASKS=16' >> launch.bash
  echo 'rank=$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'for ((ibert=0;ibert<NTASKS;ibert++)); do' >> launch.bash
  echo '  ((qbert=NTASKS*rank+ibert))' >> launch.bash
  echo '  echo copying source file $qbert to local file $ibert' >> launch.bash
  echo '  ln -s '$EXECDIR'/mcnp_gamma/nagss_random_source_$qbert
temp_exec_$OMPI_COMM_WORLD_RANK/nagss_random_source_$ibert' >> launch.bash
  echo 'done' >> launch.bash
  echo 'cd temp_exec_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo  'export OMP_PROC_BIND=true' >> launch.bash
  echo 'chmod u+rwx *' >> launch.bash
  echo $MCNP5BASEG' inp=mcnp_inp_G_$OMPI_COMM_WORLD_RANK outp=out_gamma_$OMPI_COMM_WORLD_RANK
runtpe=trash wwinp=wwinp tasks 15' >> launch.bash
  echo 'mv meshtal.h5 '$EXECDIR'/mcnp_gamma/meshtal_g_$OMPI_COMM_WORLD_RANK.h5' >> launch.bash
  echo 'mv mctal '$EXECDIR'/mcnp_gamma/mctal_g_$OMPI_COMM_WORLD_RANK' >> launch.bash
  echo 'sleep 100' >> launch.bash

  chmod u+rx launch.bash

# mpiexec the launch script
mpiexec -np 16 --npersocket 1 launch.bash
```

```
ls -1 meshtal_g* > mergelist.txt
cat mergelist.txt | merge-meshtal-hdf5 -o merged_meshtal.h5 -

# merge the mctals as well
merge_mctal mctal*

fi

exit

#
```

APPENDIX B. COMPUTER CODE INPUTS

APPENDIX B. MCNP AND ORNL-TN INPUTS

mcnp_inp_G

```
Native MCNP6 Geometry for ITER SDDR
c Source cell
1 0 -1
c void space between source and sheild
2 0 -2
c steel and water (pink)
3 2 -6.536 3 -4
c void space inside steel and water
4 0 -3
c steel plate at the end
5 1 -7.93 -5
c steel cylinder
6 1 -7.93 6 -7
c void space around steel plate
7 0 5 -8
c void space around steel and water
8 0 4 -9
c largest void space in cylinder
9 0 -10
c void space before tallies
10 0 -11
c tallies
11 0 -12
12 0 12 -13
13 0 13 -14
14 0 14 -15
c void space around tallies
15 0 15 -16
c graveyard
999 0 999

1 rcc   0 0 -110   0 0 10   100
2 rcc   0 0 -100   0 0 100  100
3 rcc   0 0    0   0 0 210  7.5
4 rcc   0 0    0   0 0 210   48
5 rcc   0 0  535   0 0  15   48
6 rcc   0 0    0   0 0 550   50
7 rcc   0 0    0   0 0 550  100
8 rcc   0 0  535   0 0  15   50
9 rcc   0 0    0   0 0 210   50
10 rcc  0 0  210   0 0 325   50
11 rcc  0 0  550   0 0 30   100
12 rcc  0 0  580   0 0 10   15
13 rcc  0 0  580   0 0 10   30
14 rcc  0 0  580   0 0 10   45
15 rcc  0 0  580   0 0 10   60
16 rcc  0 0  580   0 0 10   100
```

```
999 rcc 0 0 -110   0 0 700  100

c Imps
imp:n 1 14r 0
imp:p 1 14r 0
c
c
c Materials
c
c steel
m1
       5000.04p  5.14E-05
       6000.04p  1.04E-03
       7000.04p  2.78E-03
       8000.04p  6.95E-05
      13000.04p  1.03E-03
      14000.04p  9.89E-03
      15000.04p  4.48E-04
      16000.04p  1.30E-04
      19000.04p  7.10E-06
      22000.04p  1.74E-03
      23000.04p  4.36E-05
      24000.04p  1.87E-01
      25000.04p  1.82E-02
      26000.04p  6.44E-01
      27000.04p  4.71E-04
      28000.04p  1.16E-01
      29000.04p  2.62E-03
      40000.04p  1.22E-05
      41000.04p  5.98E-05
      42000.04p  1.45E-02
      50000.04p  9.36E-06
      73000.04p  3.07E-05
      74000.04p  3.02E-06
      82000.04p  2.14E-06
      83000.04p  2.13E-06
c
c
c
c steel and water
m2
       1000.04p  1.46E-01
       5000.04p  4.02E-05
       6000.04p  8.14E-04
       7000.04p  2.17E-03
       8000.04p  7.29E-02
      13000.04p  8.04E-04
      14000.04p  7.73E-03
      15000.04p  3.50E-04
      16000.04p  1.02E-04
      19000.04p  5.55E-06
      22000.04p  1.36E-03
```

```
      23000.04p  3.41E-05
      24000.04p  1.46E-01
      25000.04p  1.42E-02
      26000.04p  5.03E-01
      27000.04p  3.68E-04
      28000.04p  9.06E-02
      29000.04p  2.05E-03
      40000.04p  9.52E-06
      41000.04p  4.67E-05
      42000.04p  1.13E-02
      50000.04p  7.31E-06
      73000.04p  2.40E-05
      74000.04p  2.36E-06
      82000.04p  1.68E-06
      83000.04p  1.66E-06
c
c Control
c
c sdef pos=0 0 -110 axs=0 0 1 ext=d1 rad=d2 par=1 erg=14
c si1  0  3i 10
c sp1 0 1 3r
c sb1 0 1 3r
c si2    0 3i 7.5 4i 48 50 5i 99.999
c sp2 -21 1
c sb2 0 1 15r
mode p
phys:p
print
c
c cell tally with dose modifier
f4:p 11 12 13 14
c
c
c ansi/ans-6.1.1-1977 flux-to-dose, photons (mrem/hr)/(p/cm**2/s)
de0  < INPUT DATA HERE >
df0  < INPUT DATA HERE >
c
f14:p 11 12 13 14
e14    0.1 0.4 0.6 0.8 1.0 1.22 1.44 1.66 2.0 2.5 3.0 4.0 5.0
       8.0 10.0 100.0
c
c
nps 2E7
prdmp 2E8 2E8 1 1 2E8
```

mcnp_inp_G_adv

```
Native MCNP5 Geometry for ITER SDDR
c Source cell
1 0 -1
c void space between source and sheild
2 0 -2
c steel and water (pink)
3 2 -6.536 3 -4
c void space inside steel and water
4 0 -3
c steel plate at the end
5 1 -7.93 -5
c steel cylinder
6 1 -7.93 6 -7
c void space around steel plate
7 0 5 -8
c void space around steel and water
8 0 4 -9
c largest void space in cylinder
9 0 -10
c void space before tallies
10 0 -11
c tallies
11 0 -12
12 0 12 -13
13 0 13 -14
14 0 14 -15
c void space around tallies
15 0 15 -16
c graveyard
999 0 999

1 rcc   0 0 -110   0 0 10   100
2 rcc   0 0 -100   0 0 100  100
3 rcc   0 0    0   0 0 210  7.5
4 rcc   0 0    0   0 0 210   48
5 rcc   0 0  535   0 0  15   48
6 rcc   0 0    0   0 0 550   50
7 rcc   0 0    0   0 0 550  100
8 rcc   0 0  535   0 0  15   50
9 rcc   0 0    0   0 0 210   50
10 rcc  0 0  210   0 0 325   50
11 rcc  0 0  550   0 0 30   100
12 rcc  0 0  580   0 0 10   15
13 rcc  0 0  580   0 0 10   30
14 rcc  0 0  580   0 0 10   45
15 rcc  0 0  580   0 0 10   60
16 rcc  0 0  580   0 0 10   100
999 rcc 0 0 -110   0 0 700  100
```

```
c Imps
imp:n 1 14r 0
imp:p 1 14r 0
c
c
c Materials
c
c steel
m1
c       5000     5.14E-05    B
       5010.21c    1.02E-05
       5011.21c    4.12E-05
c       6000.21c    1.04E-03 C
       6012.21c   1.04E-03
c       7000    2.78E-03     N
       7014.21c    2.77E-03
       7015.21c    1.01E-05
c       8000    6.95E-05     O
       8016.21c    6.95E-05
c      13000    1.03E-03     Al
      13027.21c    1.03E-03
c      14000.21c    9.89E-03 Si
      14028.21c 9.12E-03
      14029.21c 4.63E-04
      14030.21c 3.06E-04
c      15000    4.48E-04     P
      15031.21c    4.48E-04
c      16000.21c    1.30E-04  S
     16032.31c  1.23E-04
     16033.31c  9.75E-07
     16034.31c  5.53E-06
     16036.31c  1.30E-08
c      19000.21c    7.10E-06  K
      19039.31c  6.62E-06
      19040.31c  8.31E-10
      19041.31c  4.78E-07
c      22000.21c 1.74E-03    Ti
      22046.21c    1.44E-04
      22047.21c    1.29E-04
      22048.21c    1.28E-03
      22049.21c    9.41E-05
      22050.21c    9.01E-05
c      23000.21c 4.36E-05     V
      23050.31c  1.09E-07
      23051.31c  4.35E-05
c      24000.21c    1.87E-01 Cr
      24050.21c    8.13E-03
      24052.21c    1.57E-01
      24053.21c    1.78E-02
      24054.21c    4.42E-03
c      25000    1.82E-02     Mn
      25055.21c    1.82E-02
```

```
c      26000.21c    6.44E-01 Fe
       26054.21c 3.76E-02
       26056.21c 5.91E-01
       26057.21c 1.36E-02
       26058.21c 1.82E-03
c      27000    4.71E-04     Co
       27059.21c    4.71E-04
c      28000.21c    1.16E-01 Ni
       28058.21c    7.90E-02
       28060.21c    3.04E-02
       28061.21c    1.32E-03
       28062.21c    4.22E-03
       28064.21c    1.07E-03
c      29000.21c    2.62E-03 Cu
       29063.21c    1.81E-03
       29065.21c    8.08E-04
c      40000.21c    1.22E-05  Zr
      40090.31c  6.28E-06
      40091.31c  1.37E-06
      40092.31c  2.09E-06
      40094.31c  2.12E-06
      40096.31c  3.42E-07
c      41000    5.98E-05     Nb
       41093.21c    5.98E-05
c      42000.21c    1.45E-02 Mo
       42092.21c    2.11E-03
       42094.21c    1.33E-03
       42095.21c    2.30E-03
       42096.21c    2.42E-03
       42097.21c    1.39E-03
       42098.21c    3.54E-03
       42100.21c    1.42E-03
c      50000.21c    9.36E-06 Sn
       50112.31c  9.08E-08
       50114.31c  6.18E-08
       50115.31c  3.18E-08
       50116.31c  1.36E-06
       50117.31c  7.19E-07
       50118.31c  2.27E-06
       50119.31c  8.04E-07
       50120.31c  3.05E-06
       50122.31c  4.33E-07
       50124.31c  5.42E-07
c      73000.21c    3.07E-05 Ta
       73181.21c    3.07E-05
c      74000.21c    3.02E-06 W
       74180.31c 3.62E-09
       74182.21c 8.00E-07
       74183.21c 4.32E-07
       74184.21c 9.25E-07
       74186.21c 8.59E-07
c      82000.21c    2.14E-06 Pb
```

```
      82204.31c    3.00E-08
      82206.21c    5.16E-07
      82207.21c    4.73E-07
      82208.21c    1.12E-06
c      83000    2.13E-06     Bi
      83209.21c    2.13E-06
c
c
c
c steel and water
m2
c       1000    1.46E-01     H
       1001.21c    1.46E-01
       1002.21c    1.68E-05
c       5000    4.02E-05     B
       5010.21c    8.00E-06
       5011.21c    3.22E-05
c       6000.21c    8.14E-04 C
       6012.21c    8.14E-04
c       7000    2.17E-03     N
       7014.21c    2.16E-03
       7015.21c    7.90E-06
c       8000    7.29E-02     O
       8016.21c    7.29E-02
c      13000    8.04E-04     Al
      13027.21c    8.04E-04
c      14000.21c    7.73E-03 Si
      14028.21c 7.13E-03
      14029.21c 3.62E-04
      14030.21c 2.39E-04
c      15000    3.50E-04     P
      15031.21c    3.50E-04
c      16000.21c    1.02E-04  S
     16032.31c  9.69E-05
     16033.31c  7.65E-07
     16034.31c  4.34E-06
     16036.31c  1.02E-08
c     19000.21c    5.55E-06  K
     19039.31c  5.18E-06
     19040.31c  6.49E-10
     19041.31c  3.74E-07
c      22000.21c    1.36E-03 Ti
      22046.21c    1.12E-04
      22047.21c    1.01E-04
      22048.21c    1.00E-03
      22049.21c    7.36E-05
      22050.21c    7.04E-05
c      23000.21c    3.41E-05 V
      23050.31c  8.53E-08
      23051.31c  3.40E-05
c     24000.21c    1.46E-01  Cr
     24050.21c    6.34E-03
```

```
     24052.21c    1.22E-01
     24053.21c    1.39E-02
     24054.21c    3.45E-03
c      25000    1.42E-02     Mn
      25055.21c    1.42E-02
c      26000.21c    5.03E-01 Fe
      26054.21c 2.94E-02
      26056.21c 4.62E-01
      26057.21c 1.07E-02
      26058.21c 1.42E-03
c     27000.21c    3.68E-04 Co
     27059.21c    3.68E-04
c      28000.21c    9.06E-02 Ni
      28058.21c    6.17E-02
      28060.21c    2.38E-02
      28061.21c    1.03E-03
      28062.21c    3.29E-03
      28064.21c    8.39E-04
c      29000.21c    2.05E-03 Cu
      29063.21c    1.42E-03
      29065.21c    6.32E-04
c     40000.21c    9.52E-06 Zr
     40090.31c  4.90E-06
     40091.31c  1.07E-06
     40092.31c  1.63E-06
     40094.31c  1.65E-06
     40096.31c  2.67E-07
c      41000    4.67E-05     Nb
      41093.21c    4.67E-05
c      42000.21c    1.13E-02 Mo
      42092.21c    1.64E-03
      42094.21c    1.03E-03
      42095.21c    1.79E-03
      42096.21c    1.88E-03
      42097.21c    1.08E-03
      42098.21c    2.76E-03
      42100.21c    1.11E-03
c      50000.21c    7.31E-06 Sn
      50112.31c  7.09E-08
      50114.31c  4.82E-08
      50115.31c  2.49E-08
      50116.31c  1.06E-06
      50117.31c  5.61E-07
      50118.31c  1.77E-06
      50119.31c  6.28E-07
      50120.31c  2.38E-06
      50122.31c  3.38E-07
      50124.31c  4.23E-07
c      73000.21c    2.40E-05 Ta
      73181.21c    2.40E-05
c      74000.21c    2.36E-06 W
      74180.31c 2.83E-09
```

```
      74182.21c 6.25E-07
      74183.21c 3.38E-07
      74184.21c 7.23E-07
      74186.21c 6.71E-07
c      82000.21c    1.68E-06 Pb
      82204.31c    2.35E-08
      82206.21c    4.05E-07
      82207.21c    3.71E-07
      82208.21c    8.80E-07
c      83000    1.66E-06     Bi
      83209.21c    1.66E-06
c
c Control
c
sdef pos=0 0 -110 axs=0 0 1 ext=d1 rad=d2 erg=14
si1  0  3i 10
sp1 0 1 3r
sb1 0 1 3r
si2    0 3i 7.5 4i 48 50 5i 99.999
sp2 -21 1
sb2 0 1 15r
mode p
phys:p
print
c cell tally with dose modifier
f4:p 11 12 13 14
c
c ansi/ans-6.1.1-1977 flux-to-dose, photons (mrem/hr)/(p/cm**2/s)
de0  < INPUT DATA HERE >
df0  < INPUT DATA HERE >
c
nps 1E9
prdmp 1E8 1E8 1 1 1E8
```

mcnp_inp_N

```
Native MCNP5 Geometry for ITER SDDR
c Source cell
1 0 -1
c void space between source and sheild
2 0 -2
c steel and water (pink)
3 2 -6.536 3 -4
c void space inside steel and water
4 0 -3
c steel plate at the end
5 1 -7.93 -5
c steel cylinder
6 1 -7.93 6 -7
c void space around steel plate
7 0 5 -8
c void space around steel and water
8 0 4 -9
c largest void space in cylinder
9 0 -10
c void space before tallies
10 0 -11
c tallies
11 0 -12
12 0 12 -13
13 0 13 -14
14 0 14 -15
c void space around tallies
15 0 15 -16
c graveyard
999 0 999

1 rcc   0 0 -110   0 0 10   100
2 rcc   0 0 -100   0 0 100  100
3 rcc   0 0    0   0 0 210  7.5
4 rcc   0 0    0   0 0 210   48
5 rcc   0 0  535   0 0  15   48
6 rcc   0 0    0   0 0 550   50
7 rcc   0 0    0   0 0 550  100
8 rcc   0 0  535   0 0  15   50
9 rcc   0 0    0   0 0 210   50
10 rcc  0 0  210   0 0 325   50
11 rcc  0 0  550   0 0 30   100
12 rcc  0 0  580   0 0 10   15
13 rcc  0 0  580   0 0 10   30
14 rcc  0 0  580   0 0 10   45
15 rcc  0 0  580   0 0 10   60
16 rcc  0 0  580   0 0 10   100
999 rcc 0 0 -110   0 0 700  100
```

```
c Imps
imp:n 1 14r 0
imp:p 1 14r 0
c
c
c Materials
c
c steel
m1
c       5000     5.14E-05    B
       5010.21c    1.02E-05
       5011.21c    4.12E-05
c       6000.21c    1.04E-03 C
       6012.21c   1.04E-03
c       7000    2.78E-03     N
       7014.21c    2.77E-03
       7015.21c    1.01E-05
c       8000    6.95E-05     O
       8016.21c    6.95E-05
c      13000    1.03E-03     Al
      13027.21c    1.03E-03
c      14000.21c    9.89E-03 Si
      14028.21c 9.12E-03
      14029.21c 4.63E-04
      14030.21c 3.06E-04
c      15000    4.48E-04     P
      15031.21c    4.48E-04
c      16000.21c    1.30E-04  S
     16032.31c  1.23E-04
     16033.31c  9.75E-07
     16034.31c  5.53E-06
     16036.31c  1.30E-08
c      19000.21c    7.10E-06  K
      19039.31c  6.62E-06
      19040.31c  8.31E-10
      19041.31c  4.78E-07
c      22000.21c 1.74E-03    Ti
      22046.21c    1.44E-04
      22047.21c    1.29E-04
      22048.21c    1.28E-03
      22049.21c    9.41E-05
      22050.21c    9.01E-05
c      23000.21c 4.36E-05     V
      23050.31c  1.09E-07
      23051.31c  4.35E-05
c      24000.21c    1.87E-01 Cr
      24050.21c    8.13E-03
      24052.21c    1.57E-01
      24053.21c    1.78E-02
      24054.21c    4.42E-03
c      25000    1.82E-02     Mn
      25055.21c    1.82E-02
```

```
c      26000.21c    6.44E-01 Fe
       26054.21c 3.76E-02
       26056.21c 5.91E-01
       26057.21c 1.36E-02
       26058.21c 1.82E-03
c      27000    4.71E-04     Co
       27059.21c    4.71E-04
c      28000.21c    1.16E-01 Ni
       28058.21c    7.90E-02
       28060.21c    3.04E-02
       28061.21c    1.32E-03
       28062.21c    4.22E-03
       28064.21c    1.07E-03
c      29000.21c    2.62E-03 Cu
       29063.21c    1.81E-03
       29065.21c    8.08E-04
c      40000.21c    1.22E-05  Zr
      40090.31c  6.28E-06
      40091.31c  1.37E-06
      40092.31c  2.09E-06
      40094.31c  2.12E-06
      40096.31c  3.42E-07
c      41000    5.98E-05     Nb
       41093.21c    5.98E-05
c      42000.21c    1.45E-02 Mo
       42092.21c    2.11E-03
       42094.21c    1.33E-03
       42095.21c    2.30E-03
       42096.21c    2.42E-03
       42097.21c    1.39E-03
       42098.21c    3.54E-03
       42100.21c    1.42E-03
c      50000.21c    9.36E-06 Sn
       50112.31c  9.08E-08
       50114.31c  6.18E-08
       50115.31c  3.18E-08
       50116.31c  1.36E-06
       50117.31c  7.19E-07
       50118.31c  2.27E-06
       50119.31c  8.04E-07
       50120.31c  3.05E-06
       50122.31c  4.33E-07
       50124.31c  5.42E-07
c      73000.21c    3.07E-05 Ta
       73181.21c    3.07E-05
c      74000.21c    3.02E-06 W
       74180.31c 3.62E-09
       74182.21c 8.00E-07
       74183.21c 4.32E-07
       74184.21c 9.25E-07
       74186.21c 8.59E-07
c      82000.21c    2.14E-06 Pb
```

```
      82204.31c    3.00E-08
      82206.21c    5.16E-07
      82207.21c    4.73E-07
      82208.21c    1.12E-06
c      83000    2.13E-06     Bi
      83209.21c    2.13E-06
c
c
c
c steel and water
m2
c       1000    1.46E-01     H
       1001.21c    1.46E-01
       1002.21c    1.68E-05
c       5000    4.02E-05     B
       5010.21c    8.00E-06
       5011.21c    3.22E-05
c       6000.21c    8.14E-04 C
       6012.21c    8.14E-04
c       7000    2.17E-03     N
       7014.21c    2.16E-03
       7015.21c    7.90E-06
c       8000    7.29E-02     O
       8016.21c    7.29E-02
c      13000    8.04E-04     Al
      13027.21c    8.04E-04
c      14000.21c    7.73E-03 Si
      14028.21c 7.13E-03
      14029.21c 3.62E-04
      14030.21c 2.39E-04
c      15000    3.50E-04     P
      15031.21c    3.50E-04
c      16000.21c    1.02E-04  S
     16032.31c  9.69E-05
     16033.31c  7.65E-07
     16034.31c  4.34E-06
     16036.31c  1.02E-08
c     19000.21c    5.55E-06  K
     19039.31c  5.18E-06
     19040.31c  6.49E-10
     19041.31c  3.74E-07
c      22000.21c    1.36E-03 Ti
      22046.21c    1.12E-04
      22047.21c    1.01E-04
      22048.21c    1.00E-03
      22049.21c    7.36E-05
      22050.21c    7.04E-05
c      23000.21c    3.41E-05 V
      23050.31c  8.53E-08
      23051.31c  3.40E-05
c     24000.21c    1.46E-01  Cr
     24050.21c    6.34E-03
```

```
     24052.21c    1.22E-01
     24053.21c    1.39E-02
     24054.21c    3.45E-03
c      25000    1.42E-02     Mn
      25055.21c    1.42E-02
c      26000.21c    5.03E-01 Fe
      26054.21c 2.94E-02
      26056.21c 4.62E-01
      26057.21c 1.07E-02
      26058.21c 1.42E-03
c     27000.21c    3.68E-04 Co
     27059.21c    3.68E-04
c      28000.21c    9.06E-02 Ni
      28058.21c    6.17E-02
      28060.21c    2.38E-02
      28061.21c    1.03E-03
      28062.21c    3.29E-03
      28064.21c    8.39E-04
c      29000.21c    2.05E-03 Cu
      29063.21c    1.42E-03
      29065.21c    6.32E-04
c     40000.21c    9.52E-06 Zr
     40090.31c  4.90E-06
     40091.31c  1.07E-06
     40092.31c  1.63E-06
     40094.31c  1.65E-06
     40096.31c  2.67E-07
c      41000    4.67E-05     Nb
      41093.21c    4.67E-05
c      42000.21c    1.13E-02 Mo
      42092.21c    1.64E-03
      42094.21c    1.03E-03
      42095.21c    1.79E-03
      42096.21c    1.88E-03
      42097.21c    1.08E-03
      42098.21c    2.76E-03
      42100.21c    1.11E-03
c      50000.21c    7.31E-06 Sn
      50112.31c  7.09E-08
      50114.31c  4.82E-08
      50115.31c  2.49E-08
      50116.31c  1.06E-06
      50117.31c  5.61E-07
      50118.31c  1.77E-06
      50119.31c  6.28E-07
      50120.31c  2.38E-06
      50122.31c  3.38E-07
      50124.31c  4.23E-07
c      73000.21c    2.40E-05 Ta
      73181.21c    2.40E-05
c      74000.21c    2.36E-06 W
      74180.31c 2.83E-09
```

```
      74182.21c 6.25E-07
      74183.21c 3.38E-07
      74184.21c 7.23E-07
      74186.21c 6.71E-07
c      82000.21c    1.68E-06 Pb
      82204.31c    2.35E-08
      82206.21c    4.05E-07
      82207.21c    3.71E-07
      82208.21c    8.80E-07
c      83000    1.66E-06     Bi
      83209.21c    1.66E-06
c
c Control
c
sdef pos=0 0 -110 axs=0 0 1 ext=d1 rad=d2 par=1 erg=14
si1  0  3i 10
sp1 0 1 3r
si2    0 3i 7.5 4i 48 50 5i 99.999
sp2 -21 1
mode n
c phys:p
print
c
c Global meshtals
c
fmesh204:n origin =-100 -100 0 geom=xyz
      imesh = 100.0
      iints = 40
      jmesh = 100.0
      jints = 40
      kmesh = 550.0
      kints = 110
      emesh =  1.00001E-07
               4.13994E-07
               5.31579E-07
               6.82560E-07
               8.76425E-07
               1.12300E-06
               1.44000E-06
               1.85539E-06
               2.38237E-06
               3.05902E-06
               3.92786E-06
               5.04348E-06
               6.47595E-06
               8.31529E-06
               1.06770E-05
               1.37096E-05
               1.76035E-05
               2.26033E-05
               2.90232E-05
               3.72665E-05
```

4.78512E-05
6.14421E-05
7.88932E-05
1.01301E-04
1.30073E-04
1.67017E-04
2.14454E-04
2.75364E-04
3.53575E-04
4.53999E-04
5.82947E-04
7.48518E-04
9.61117E-04
1.23410E-03
1.58461E-03
2.03468E-03
2.24867E-03
2.48517E-03
2.61259E-03
2.74654E-03
3.03539E-03
3.35463E-03
3.70744E-03
4.30742E-03
5.53084E-03
7.10174E-03
9.11882E-03
1.05946E-02
1.17088E-02
1.50344E-02
1.93045E-02
2.18749E-02
2.35786E-02
2.41755E-02
2.47875E-02
2.60584E-02
2.70001E-02
2.85011E-02
3.18278E-02
3.43067E-02
4.08677E-02
4.63092E-02
5.24752E-02
5.65622E-02
6.73795E-02
7.20245E-02
7.94987E-02
8.25034E-02
8.65170E-02
9.80365E-02
1.11090E-01
1.16786E-01

1.22773E-01
1.29068E-01
1.35686E-01
1.42642E-01
1.49956E-01
1.57644E-01
1.65727E-01
1.74224E-01
1.83156E-01
1.92547E-01
2.02419E-01
2.12797E-01
2.23708E-01
2.35177E-01
2.47235E-01
2.73237E-01
2.87246E-01
2.94518E-01
2.97211E-01
2.98491E-01
3.01974E-01
3.33733E-01
3.68832E-01
3.87742E-01
4.07622E-01
4.50492E-01
4.97871E-01
5.23397E-01
5.50232E-01
5.78443E-01
6.08101E-01
6.39279E-01
6.72055E-01
7.06512E-01
7.42736E-01
7.80817E-01
8.20850E-01
8.62936E-01
9.07180E-01
9.61672E-01
1.00259E+00
1.10803E+00
1.16484E+00
1.22456E+00
1.28735E+00
1.35335E+00
1.42274E+00
1.49569E+00
1.57237E+00
1.65299E+00
1.73774E+00
1.82684E+00

1.92050E+00
2.01897E+00
2.12248E+00
2.23130E+00
2.30693E+00
2.34570E+00
2.36533E+00
2.38513E+00
2.46597E+00
2.59240E+00
2.72532E+00
2.86505E+00
3.01194E+00
3.16637E+00
3.32871E+00
3.67879E+00
4.06570E+00
4.49329E+00
4.72367E+00
4.96585E+00
5.22046E+00
5.48812E+00
5.76950E+00
6.06531E+00
6.37628E+00
6.59241E+00
6.70320E+00
7.04688E+00
7.40818E+00
7.78801E+00
8.18731E+00
8.60708E+00
9.04837E+00
9.51229E+00
1.00000E+01
1.05127E+01
1.10517E+01
1.16183E+01
1.22140E+01
1.25232E+01
1.28403E+01
1.34986E+01
1.38403E+01
1.41907E+01
1.45499E+01
1.49182E+01
1.56831E+01
1.64872E+01
1.69046E+01
1.73325E+01
1.96403E+01

C

```
c
nps 1E7
prdmp 1E7 1E7 1 1 1E7
```

mcnp_inp_N_adv

```
Native MCNP5 Geometry for ITER SDDR
c Source cell
1 0 -1
c void space between source and sheild
2 0 -2
c steel and water (pink)
3 2 -6.536 3 -4
c void space inside steel and water
4 0 -3
c steel plate at the end
5 1 -7.93 -5
c steel cylinder
6 1 -7.93 6 -7
c void space around steel plate
7 0 5 -8
c void space around steel and water
8 0 4 -9
c largest void space in cylinder
9 0 -10
c void space before tallies
10 0 -11
c tallies
11 0 -12
12 0 12 -13
13 0 13 -14
14 0 14 -15
c void space around tallies
15 0 15 -16
c graveyard
999 0 999

1 rcc   0 0 -110   0 0 10   100
2 rcc   0 0 -100   0 0 100  100
3 rcc   0 0    0   0 0 210  7.5
4 rcc   0 0    0   0 0 210   48
5 rcc   0 0  535   0 0  15   48
6 rcc   0 0    0   0 0 550   50
7 rcc   0 0    0   0 0 550  100
8 rcc   0 0  535   0 0  15   50
9 rcc   0 0    0   0 0 210   50
10 rcc  0 0  210   0 0 325   50
11 rcc  0 0  550   0 0 30   100
12 rcc  0 0  580   0 0 10   15
13 rcc  0 0  580   0 0 10   30
14 rcc  0 0  580   0 0 10   45
15 rcc  0 0  580   0 0 10   60
16 rcc  0 0  580   0 0 10   100
999 rcc 0 0 -110   0 0 700  100
```

```
c Imps
imp:n 1 14r 0
imp:p 1 14r 0
c
c
c Materials
c
c steel
m1
c       5000     5.14E-05    B
       5010.21c    1.02E-05
       5011.21c    4.12E-05
c       6000.21c    1.04E-03 C
       6012.21c   1.04E-03
c       7000    2.78E-03     N
       7014.21c    2.77E-03
       7015.21c    1.01E-05
c       8000    6.95E-05     O
       8016.21c    6.95E-05
c      13000    1.03E-03     Al
      13027.21c    1.03E-03
c      14000.21c    9.89E-03 Si
      14028.21c 9.12E-03
      14029.21c 4.63E-04
      14030.21c 3.06E-04
c      15000    4.48E-04     P
      15031.21c    4.48E-04
c      16000.21c    1.30E-04  S
     16032.31c  1.23E-04
     16033.31c  9.75E-07
     16034.31c  5.53E-06
     16036.31c  1.30E-08
c      19000.21c    7.10E-06  K
      19039.31c  6.62E-06
      19040.31c  8.31E-10
      19041.31c  4.78E-07
c      22000.21c 1.74E-03    Ti
      22046.21c    1.44E-04
      22047.21c    1.29E-04
      22048.21c    1.28E-03
      22049.21c    9.41E-05
      22050.21c    9.01E-05
c      23000.21c 4.36E-05     V
      23050.31c  1.09E-07
      23051.31c  4.35E-05
c      24000.21c    1.87E-01 Cr
      24050.21c    8.13E-03
      24052.21c    1.57E-01
      24053.21c    1.78E-02
      24054.21c    4.42E-03
c      25000    1.82E-02     Mn
      25055.21c    1.82E-02
```

```
c      26000.21c    6.44E-01 Fe
      26054.21c 3.76E-02
      26056.21c 5.91E-01
      26057.21c 1.36E-02
      26058.21c 1.82E-03
c      27000    4.71E-04     Co
      27059.21c    4.71E-04
c      28000.21c    1.16E-01 Ni
      28058.21c    7.90E-02
      28060.21c    3.04E-02
      28061.21c    1.32E-03
      28062.21c    4.22E-03
      28064.21c    1.07E-03
c      29000.21c    2.62E-03 Cu
      29063.21c    1.81E-03
      29065.21c    8.08E-04
c      40000.21c    1.22E-05  Zr
     40090.31c  6.28E-06
     40091.31c  1.37E-06
     40092.31c  2.09E-06
     40094.31c  2.12E-06
     40096.31c  3.42E-07
c      41000    5.98E-05     Nb
      41093.21c    5.98E-05
c      42000.21c    1.45E-02 Mo
      42092.21c    2.11E-03
      42094.21c    1.33E-03
      42095.21c    2.30E-03
      42096.21c    2.42E-03
      42097.21c    1.39E-03
      42098.21c    3.54E-03
      42100.21c    1.42E-03
c      50000.21c    9.36E-06 Sn
      50112.31c  9.08E-08
      50114.31c  6.18E-08
      50115.31c  3.18E-08
      50116.31c  1.36E-06
      50117.31c  7.19E-07
      50118.31c  2.27E-06
      50119.31c  8.04E-07
      50120.31c  3.05E-06
      50122.31c  4.33E-07
      50124.31c  5.42E-07
c      73000.21c    3.07E-05 Ta
      73181.21c    3.07E-05
c      74000.21c    3.02E-06 W
      74180.31c 3.62E-09
      74182.21c 8.00E-07
      74183.21c 4.32E-07
      74184.21c 9.25E-07
      74186.21c 8.59E-07
c      82000.21c    2.14E-06 Pb
```

```
      82204.31c    3.00E-08
      82206.21c    5.16E-07
      82207.21c    4.73E-07
      82208.21c    1.12E-06
c      83000    2.13E-06     Bi
      83209.21c    2.13E-06
c
c
c
c steel and water
m2
c       1000    1.46E-01     H
       1001.21c    1.46E-01
       1002.21c    1.68E-05
c       5000    4.02E-05     B
       5010.21c    8.00E-06
       5011.21c    3.22E-05
c       6000.21c    8.14E-04 C
       6012.21c    8.14E-04
c       7000    2.17E-03     N
       7014.21c    2.16E-03
       7015.21c    7.90E-06
c       8000    7.29E-02     O
       8016.21c    7.29E-02
c      13000    8.04E-04     Al
      13027.21c    8.04E-04
c      14000.21c    7.73E-03 Si
      14028.21c 7.13E-03
      14029.21c 3.62E-04
      14030.21c 2.39E-04
c      15000    3.50E-04     P
      15031.21c    3.50E-04
c      16000.21c    1.02E-04  S
     16032.31c  9.69E-05
     16033.31c  7.65E-07
     16034.31c  4.34E-06
     16036.31c  1.02E-08
c     19000.21c    5.55E-06  K
     19039.31c  5.18E-06
     19040.31c  6.49E-10
     19041.31c  3.74E-07
c      22000.21c    1.36E-03 Ti
      22046.21c    1.12E-04
      22047.21c    1.01E-04
      22048.21c    1.00E-03
      22049.21c    7.36E-05
      22050.21c    7.04E-05
c      23000.21c    3.41E-05 V
      23050.31c  8.53E-08
      23051.31c  3.40E-05
c     24000.21c    1.46E-01  Cr
     24050.21c    6.34E-03
```

```
     24052.21c    1.22E-01
     24053.21c    1.39E-02
     24054.21c    3.45E-03
c      25000    1.42E-02     Mn
      25055.21c    1.42E-02
c      26000.21c    5.03E-01 Fe
      26054.21c 2.94E-02
      26056.21c 4.62E-01
      26057.21c 1.07E-02
      26058.21c 1.42E-03
c     27000.21c    3.68E-04 Co
     27059.21c    3.68E-04
c      28000.21c    9.06E-02 Ni
      28058.21c    6.17E-02
      28060.21c    2.38E-02
      28061.21c    1.03E-03
      28062.21c    3.29E-03
      28064.21c    8.39E-04
c      29000.21c    2.05E-03 Cu
      29063.21c    1.42E-03
      29065.21c    6.32E-04
c     40000.21c    9.52E-06 Zr
     40090.31c  4.90E-06
     40091.31c  1.07E-06
     40092.31c  1.63E-06
     40094.31c  1.65E-06
     40096.31c  2.67E-07
c      41000    4.67E-05     Nb
      41093.21c    4.67E-05
c      42000.21c    1.13E-02 Mo
      42092.21c    1.64E-03
      42094.21c    1.03E-03
      42095.21c    1.79E-03
      42096.21c    1.88E-03
      42097.21c    1.08E-03
      42098.21c    2.76E-03
      42100.21c    1.11E-03
c      50000.21c    7.31E-06 Sn
      50112.31c  7.09E-08
      50114.31c  4.82E-08
      50115.31c  2.49E-08
      50116.31c  1.06E-06
      50117.31c  5.61E-07
      50118.31c  1.77E-06
      50119.31c  6.28E-07
      50120.31c  2.38E-06
      50122.31c  3.38E-07
      50124.31c  4.23E-07
c      73000.21c    2.40E-05 Ta
      73181.21c    2.40E-05
c      74000.21c    2.36E-06 W
      74180.31c 2.83E-09
```

```
      74182.21c 6.25E-07
      74183.21c 3.38E-07
      74184.21c 7.23E-07
      74186.21c 6.71E-07
c      82000.21c    1.68E-06 Pb
      82204.31c    2.35E-08
      82206.21c    4.05E-07
      82207.21c    3.71E-07
      82208.21c    8.80E-07
c      83000    1.66E-06     Bi
      83209.21c    1.66E-06
c
c Control
c
sdef pos=0 0 -110  erg=14
c sdef pos=0 0 -110 axs=0 0 1 ext=d1 rad=d2 par=1 erg=14
c si1 H  0  3i 10
c sp1 0 1 3r
c si2    0 3i 7.5 4i 48 50 5i 99.999
c sp2 -21 1
mode n
c phys:p
print
c
c Global meshtals
c
fmesh204:n origin =-100 -100 0 geom=xyz
      imesh = 100.0
      iints = 40
      jmesh = 100.0
      jints = 40
      kmesh = 550.0
      kints = 110
      emesh =  1.00001E-07
               4.13994E-07
               5.31579E-07
               6.82560E-07
               8.76425E-07
               1.12300E-06
               1.44000E-06
               1.85539E-06
               2.38237E-06
               3.05902E-06
               3.92786E-06
               5.04348E-06
               6.47595E-06
               8.31529E-06
               1.06770E-05
               1.37096E-05
               1.76035E-05
               2.26033E-05
               2.90232E-05
```

3.72665E-05
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1.49182E+01
1.56831E+01
1.64872E+01
1.69046E+01
1.73325E+01
1.96403E+01

```
c
nps 1E9
prdmp 1E8 1E8 1 1 1E8
```

config

```
#
#  INITIALIZATION OPTIONS
#

# Use improved algorithms for geometry initialization?
igeom_fast_init                    yes

# Calculate cell volumes?
igeom_volume_calculations          yes


#
#  MESH TALLY OPTIONS
#

# Enable batch statistics?
fmesh_batch_statistics             yes

# Number of batches
fmesh_num_batches                  10

# Number of particles per batch
fmesh_num_per_batch                10000000

# Number of score buffers per transport thread
fmesh_num_buffers                  10

# Score buffer capacity (in number of scores)
fmesh_buffer_size                  200000

# Sleep interval (in millisecs) when waiting for resources/work
fmesh_sleep_interval               10

# Write mesh tally results to an HDF5 file instead of a text file?
fmesh_hdf5_output                  yes

# Disable mesh tally relative error calculations?
fmesh_disable_re                   yes
```

config_G

```
#
#  INITIALIZATION OPTIONS
#

# Use improved algorithms for geometry initialization?
igeom_fast_init                    yes

# Calculate cell volumes?
igeom_volume_calculations          yes


#
#  MESH TALLY OPTIONS
#

# Enable batch statistics?
fmesh_batch_statistics             yes

# Number of batches
fmesh_num_batches                  10

# Number of particles per batch
fmesh_num_per_batch                20000000

# Number of score buffers per transport thread
fmesh_num_buffers                  10

# Score buffer capacity (in number of scores)
fmesh_buffer_size                  200000

# Sleep interval (in millisecs) when waiting for resources/work
fmesh_sleep_interval               10

# Write mesh tally results to an HDF5 file instead of a text file?
fmesh_hdf5_output                  yes

# Disable mesh tally relative error calculations?
fmesh_disable_re                   yes
```