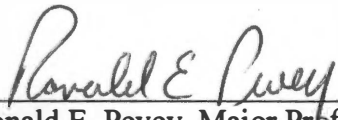
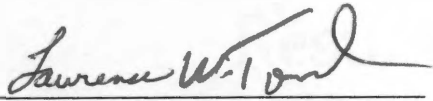


To the Graduate Council:

I am submitting herewith a thesis written by Susan B. Turner entitled "Installation, Testing, and Demonstration of Discrete Ordinates Particle Transport Software (PARTISN 2.64/DANTSYS3.1) For Use on the Y-12 National Security Complex SGI Supercomputer (Manhattan)." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Nuclear Engineering.


Ronald E. Pevey, Major Professor

We have read this thesis and
recommend its acceptance:


Lawrence Wilson


Lawrence Z Miller

Acceptance for the Council:


Vice Provost and Dean of
Graduate Studies

**INSTALLATION, TESTING, AND DEMONSTRATION OF
DISCRETE ORDINATES PARTICLE TRANSPORT
SOFTWARE (PARTISN 2.64/DANTSYS 3.1)
FOR USE ON THE Y-12 NATIONAL SECURITY
COMPLEX SGI SUPERCOMPUTER
(MANHATTAN)**

A Thesis Presented
for the Master of Science Degree
The University of Tennessee, Knoxville

**Susan B. Turner
May 2002**

Thesis
2002
187

DEDICATION

This work is dedicated to two people. First, to my late father, Robert J. Barnard, who attended the University of Tennessee as a chemical engineering major, but never finished his formal education due to work and family responsibilities. My father loved his family, loved his country, and loved the work he performed during WWII at the Oak Ridge Y-12 Plant, and later as a Cold War Veteran at the Oak Ridge K-25 Gaseous Diffusion Plant. As number 4 of 5 children, I inherited his interest in engineering and in the nuclear industry at Oak Ridge. Thanks, Dad, for all the good things you gave.

Second, to my late father-in-law, Guy Turner, who served his country during World War II in Japan, and later as a Cold War Veteran working at the Oak Ridge K-25 Gaseous Diffusion Plant. He gave me my first practical lesson in nuclear criticality safety when he told of a broken production line pipe in the cascade that was pouring out highly enriched uranium hexafluoride onto the concrete floor into a large pile. My father-in-law was not formally educated, but he understood enough as a chemical operator to take a piece of scrap cardboard and immediately flatten the pile into slab geometry before an accident occurred. Thanks, Guy, for the lesson.

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At my undergraduate graduation, Senator Fred Thompson gave the illustration of a turtle found on a fence post, surveying the world from his high perch. Senator Thompson reminded us graduates that though we had reached a high goal, like the turtle on the fence post, we would never have reached it without help from someone else. So to recognize that the work presented here could not have been accomplished without the contributions of many people, I would like to thank them individually:

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Most of all, for helping me to realize my dream, and for supplying the motivation and the logistical support, I want to thank my husband, **Wendell**, and my two children, **Brian** and **Rebecca**.

***Unless the Lord builds the house, its builders labor in vain;
unless the Lord watches over the city, the watchmen stand guard in vain.***

Psalms 127:1

ABSTRACT

The ultimate goal of this work is to provide the capability to evaluate Criticality Accident Alarm Systems (CAAS) placement designs for storage of highly enriched uranium in vault-type storage buildings at the Y-12 National Security Complex. The scope includes the procurement, installation, verification and validation of the Los Alamos National Laboratory multi-processor discrete ordinates transport code PARTISN 2.64/DANTSYS 3.1 on the Y-12 National Security Complex Engineering Division's SGI supercomputer (Manhattan). The scope also includes the development of a source term, the procurement of an appropriate cross section library based on the material isotopes of the model and the desired particles to be tracked, and the procurement of an appropriate response function set. The validation is accomplished by modeling standardized two-dimensional and three-dimensional benchmark shielding reference calculations from ANSI/ANS-6.6.1. The work includes the development of a three-dimensional model of a vault-type storage building design in order to confirm previously performed Monte Carlo (MCNP) code calculations. The model design is developed in accordance with various national standards and federal codes. Future work includes the validation of Kansas State University Skyshine Experiments in two- and three-dimensions, and CAAS placement design evaluation of additional two- and three-dimensional models of vault-type storage buildings for highly enriched uranium.

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1.0 BACKGROUND AND MOTIVATION OF THE WORK

Current events have heightened the need for safe and secure storage of highly enriched uranium at the Y-12 National Security Complex. Appendix E includes a local newspaper article emphasizing this need in light of the events of September 11, 2001. However, designing a fissile storage facility which provides adequate safety features to protect the workforce from an inadvertent nuclear criticality event involves sophisticated engineering problem solving. Y-12 has procured a multi-processor supercomputer, the Manhattan SGI supercomputer, which is currently severely underutilized for such problem solving. Appendix E also contains a recent Y-12 employee newspaper article which provides some detail in regard to the capabilities and use of the Manhattan.

To design a safe storage facility for fissile material, computer software which will mimic the materials and geometry of the facility along with the particle transport properties of the fissile material is essential. Several neutron and photon transport computer codes have been developed by the national laboratories over the years. Application to solving the problem of fissile storage and nuclear criticality accident alarms limits which computer codes are used. The availability of a multi-processor system to solve these problems further enhances the choice of computer codes. Currently, only one transport code is capable of use with shielding of particle applications on a multi-processor platform: PARTISN 2.64 as developed by Los Alamos National Laboratory.

The storage facility design is developed in accordance with various national standards and federal codes such as ANSI/ANS 8.3 (1986) (1), and DOE Order 420.1 (2) as they apply to nuclear criticality safety in the form of nuclear criticality accident alarm systems (CAAS). ANSI/ANSI 6.6.1 (1987) (3) contains standards for calculation and measurement of direct and scattered gamma radiation for determination of CAAS alarm placement. Studies of one preliminary vault design employed the Los Alamos Monte Carlo code MCNP, version 4b.2. Because of the absence of a published shielding experiment that closely models the materials and storage configuration of this

preliminary design, an analysis using a discrete ordinates code is performed to confirm the results of stochastic studies.

2.0 SCOPE AND ORGANIZATION OF THE WORK

The ultimate goal of this work is to provide the capability to evaluate Criticality Accident Alarm Systems (CAAS) placement designs for storage of highly enriched uranium in vault-type storage buildings at the Y-12 National Security Complex. With Y-12 development, design, and production of CAAS systems, configuration control of designs can be maintained in-house.

To enable use of the Manhattan for complicated radiation transport analyses, the following steps were taken in this work:

- (1) A three-dimensional discrete ordinates multi-processor transport code was procured, installed, and verified. The transport code chosen for this work is the PARTISN beta version 2.64 multi-processor transport code developed at Los Alamos National Laboratory. It is based on the single processor form of the discrete ordinates transport code DANTSYS 3.1 (4). (Other single processor discrete ordinate transport codes such as DOORS 3.1 (5) developed by Oak Ridge National Laboratory are available, but currently are not adapted for use with multi-processors. Future work includes verification and validation of other multi-processor transport codes as they become available.)

The PARTISN installation was verified by the running of problem sets provided by the code developer. The output of the problem sets produced by the Manhattan were compared for accuracy to the output provided by the code developer.

- (2) The associated data that is required for use of the transport code—such as cross section libraries, source terms, and response functions—were developed or procured. This task included the development of a source term corresponding to the minimum accident of concern discussed in ANS/ANSI 8.3 (1), in the energy group structure of the cross section library. It also included the choosing of an

appropriate cross section library based on the material isotopes of the model and the desired particles to be tracked, in this case, prompt photons which would first actuate CAAS alarms.

- (3) A set of sample shielding calculations was calculated for validation using available two-dimensional and three-dimensional benchmarks. This validation was accomplished by using PARTISN to model standardized benchmark shielding reference calculations and comparing the results with published experimental measurements.
- (4) A model was developed of a vault-type storage building design (which matches the area of applicability established by the validation) using the source term, cross section, and validated PARTISN code.

This model employs a simplified model of a single vault which can be repeated as many times as necessary to provide the desired final overall size of a storage building. Corridors outside and between multiple vaults in the building are also included in the model, as well as areas that could possibly be used for receiving, dispatching, and handling operations. It is anticipated that this design will be useful to future CAAS system designers at Y-12.

Finally, the model was calculated and compared to previously produced MCNP results of the same configuration.

This report is divided into ten sections. Sections 1.0 and 2.0 contain the Introduction and Scope, respectively. A brief overview of discrete ordinates theory of particle transport is given in Section 3.0. Section 4.0 contains results of installation and verification of the PARTISN 2.64/DANTSYS 3.1 code package. Section 5.0 contains information regarding cross section libraries, response function development, and source term development for shielding calculations with the transport code. Section 6.0 reports

results of code validation using ANSI/ANS-6.6.1 reference calculations. Section 7.0 contains the three-dimensional evaluation of a vault-type storage building using the PARTISN 2.64/DANTSYS 3.1 code package. Conclusions are presented in Section 8.0, and future work is discussed in Section 9.0.

3.0 THEORY OF THE PARTISN 2.64/DANTSYS 3.1 DISCRETE ORDINATES TRANSPORT CODE

The DANTSYS 3.1 code package is a modular computer program package designed to solve the time-independent, multigroup discrete ordinates form of the Boltzmann transport equation in several different geometries.

PARTISN 2.64 is a beta test multi-processor version of the DANTSYS 3.1 discrete ordinates transport code package currently under development, but is available only by request to Los Alamos National Laboratory. PARTISN 2.64 is not yet distributed commercially. It is based on the code structure of DANTSYS 3.1, but has some input features that are different from the DANTSYS 3.1 input. The discussion of discrete ordinates theory that follows addresses DANTSYS 3.1, but is also applicable to PARTISN 2.64.

3.1 Basic Properties of DANTSYS 3.1 Code

DANTSYS 3.1 is distributed as the RSICC code package CCC-547 (4). It was developed and contributed by Los Alamos National Laboratory. The coding language is mostly (99%) FORTRAN 77 and 0.1% C. It can be run on the Cray, SUN Sparcstation, IBM RS/6000, Hewlett Packard 9000, and Silicon Graphics (SGI). DANTSYS requires a Fortran 77 compiler, a C-language preprocessor, a C compiler, and GMAKE (GnuMake from Free Software Foundation.)

DANTSYS 3.1 replaces the original TWODANT-SYS code package and consists of five major codes: ONEDANT, TWODANT, TWOHEX, TWODANT-GQ, and THREEDANT. ONEDANT solves the one-dimensional multigroup transport equation in slab, cylindrical, spherical geometries. TWODANT solves the two-dimensional multigroup transport equation in (x-y), (r-z), and (r- θ) geometries. TWOHEX solves the two-dimensional multigroup transport equation on equilateral triangular meshes in the (x-y) plane. THREEDANT solves the three-dimensional multigroup transport equation

in (x, y, z) and (r, z, θ) geometries. TWODANT/GQ solves the two-dimensional transport equation in $(x-y)$ and $(r-z)$ geometries on general quadrilaterals.

DANTSYS accepts the basic multigroup cross section libraries for isotopes in either of the standard interface files (ISOTXS or GRUPXS) or in a card-image library whose form is referred to as Los Alamos, ANISN, or FIDO. The PSR-317/TRANSX2.15 code (which is part of the DANTSYS package) translates MATXS libraries into these formats. ONEDANT, TWODANT and TWOHEX were included in TWODANT-SYS originally. THREEDANT and TWODANT/GQ were added to the package in August 1995 with the first public release of DANTSYS. In March 1997 subroutines *perr* and *tolcm* were modified to correct a problem of overfilling a string (SITOP).

ONEDANT, TWODANT, TWODANT/GQ and THREEDANT use the discrete ordinates approximation for treating the angular variation of the particle distributions. The diamond difference scheme is generally used for space discretization, although TWODANT and THREEDANT include an adaptive weighted diamond difference option. Both inner and outer iterations are accelerated using the diffusion synthetic acceleration method.

The modular construction of the package separates the input processing, the transport equation solving, and the post processing (edit) functions into distinct codes modules: the input module, one or more solver modules, and the edit module, respectively. The input and edit modules are very general in nature and are common to all the solver modules.

The ONEDANT solver module contains a one-dimensional (slab, cylinder, and sphere), time-independent transport equation solver using the standard diamond-differencing method for space/angle discretization. Also included in the package are solver modules named TWODANT, TWODANT/GQ, THREEDANT, and TWOHEX.

The TWODANT solver module solves the time-independent two-dimensional transport equation using the diamond-differencing method for space/angle discretization. The adaptive weighted diamond differencing (AWDD) method for spatial and angular discretization has been incorporated into TWODANT as an option.

The TWOHEX solver module solves the time-independent two-dimensional transport equation on an equilateral triangle spatial mesh. The THREEDANT solver module solves the time independent three-dimensional transport equation for (x-y-z) and (r-z- θ) geometries using both diamond differencing with set-to-zero fixup and the AWDD method.

Some of the major features included in the DANTSYS code package are:

- a free-field format ASCII text input capability;
- standardized, data- and file-management techniques as defined and developed by the Committee on Computer Coordination (CCCC); both sequential file and random-access file handling techniques are used;
- the use of a diffusion synthetic acceleration scheme to accelerate the iterative process in the solver modules ONEDANT, TWODANT, and THREEDANT;
- direct (forward) or adjoint calculational capability;
- standard plane, two-angle plane, cylindrical or spherical geometry options for 1-D;
- (x-y), (r-z), (r- θ) equilateral triangular mesh x-y, and x-y and r-z geometries in 2-D;
- (x-y-z) and (r-z- θ) geometries in 3-D;
- arbitrary anisotropic scattering order;
- vacuum, reflective, periodic, white, albedo (only operative in ONEDANT), or surface source boundary condition options;
- inhomogeneous (fixed) source or k-eff calculation options as well as time-absorption (α), nuclide concentration, or dimensional search options;
- “diamond-differencing” for solution of the transport equation;

- AWDD available in the TWODANT and THREEDANT modules;
- A coupled S_N /Monte Carlo option for the TWODANT module.

3.2 Geometry

The geometry nomenclature used by DANTSYS includes the terms *fine mesh*, *coarse mesh*, and *zones*. These are defined for the three orthogonal geometry solvers: ONEDANT, TWODANT and THREEDANT.

The fine mesh is the spatial solution-mesh for the problem. There are IT, JT and KT number of fine meshes in the (x-y-z) or (r-z- θ) fine mesh intervals, respectively. No material discontinuities may occur within a fine mesh interval. There are IM, JM, and KM number of coarse meshes which are each a separate material zone. The specification of the fine mesh is accomplished by specifying how many equally sized fine mesh intervals there are in each coarse mesh.

The coarse mesh makes up the spatial boundaries of the fine mesh and is formed by partitioning the spatial domain of the problem into a number of coarse meshes. There are IM, JM, and KM number of coarse meshes in each of the (x-y-z) or (r-z- θ) coordinate directions spanning the problem. Each coarse mesh interval contains one or more fine mesh intervals. All fine meshes within a coarse mesh interval have equal widths. No material differences or discontinuities may occur within a coarse mesh.

A “zone” is a spatial grouping of coarse meshes and is characterized by a single set of multigroup cross section libraries, so that all fine meshes within a zone have the same cross section. The user assigns a zone number to each coarse mesh. The zone number tells the code which macroscopic cross section library set is to be used within that zone. A zone equal to zero is used to specify that a coarse mesh is a void.

3.3 Solving the Boltzmann Transport Equation

This section provides the specifics of the discrete ordinates method for the ONEDANT, TWODANT, and THREEDANT solver modules in the development of the multigroup discrete ordinates form of the time-independent Boltzmann transport equation. An iterative procedure is used to solve the transport equation.

3.3.1 The First Order Form of the Boltzmann Transport Equation

The time-independent, inhomogeneous Boltzmann transport equation may be written as:

$$\begin{aligned} \bar{\nabla} \cdot \hat{\Omega} \Psi(\bar{r}, E, \hat{\Omega}) + \sigma(\bar{r}, E) \Psi(\bar{r}, E, \hat{\Omega}) = & \iint \sigma_s(\bar{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}') \Psi(\bar{r}, E, \hat{\Omega}') dE' d\Omega' \\ & + \frac{1}{k_{eff}} \iint \chi(\bar{r}, E' \rightarrow E) \nu \sigma_f(\bar{r}, E') \Psi(\bar{r}, E', \hat{\Omega}') dE' d\Omega' + Q(\bar{r}, E, \Omega) \end{aligned}$$

where

$\Psi(\bar{r}, E, \hat{\Omega})$ = Particle fluence (particle number density times the particle speed defined such that $\Psi(\bar{r}, E, \hat{\Omega}) d\bar{r} dE d\hat{\Omega}$ is the flow of particles in dE about E in the space $d\bar{r}$ about $\bar{r}$ with direction $d\hat{\Omega}$.

$Q(\bar{r}, E, \hat{\Omega})$ = Rate at which particles are produced in the space from extraneous sources that are independent of the flux.

$\sigma(\bar{r}, E)$ = Macroscopic total cross section.

$\sigma_s(\bar{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}')$ = Macroscopic scattering cross section, from energy E' to energy E through scattering angle $\hat{\Omega} \cdot \hat{\Omega}'$.

$\sigma_f(\bar{r}, E')$ = Macroscopic fission cross section.

ν = Number of particles emitted isotropically ($1/4\pi$) per fission.

k_{eff} = K-effective eigenvalue of the system. If $Q(\vec{r}, E, \hat{\Omega})$ is not zero in this equation, then k_{eff} is set to 1.0.

3.3.2 The Multigroup Energy Approximation

In the energy variable, E , the energy domain is partitioned into G intervals of width $\Delta E_g = E_{g-1} - E_g$. The index g increases as energy decreases (since the normal transport of particles in energy is from high to low energy as they collide with nuclei in the medium). By integrating the Boltzmann equation with respect to energy over energy group g , we obtain the following group-wise Boltzmann transport equation:

$$\vec{\nabla} \cdot \hat{\Omega} \Psi_g(\vec{r}, \hat{\Omega}) + \sigma_{tg}(\vec{r}) \Psi_g(\vec{r}, \hat{\Omega}) = \frac{\chi_g(\vec{r}) \Phi(\vec{r})}{k_{eff}} + Q_g(\vec{r}, \hat{\Omega}) + \sum_{g'=1}^G \int_{4\pi} \sigma_{sg' \rightarrow g}(\vec{r}, \mu_0) \Psi_g(\vec{r}, \hat{\Omega}') d\hat{\Omega}'$$

where

$$\Psi_g(\vec{r}, \hat{\Omega}) = \text{Particle fluence for group, } g = \int_{E_g}^{E_{g-1}} \Psi(\vec{r}, E, \hat{\Omega}) dE.$$

$$\phi(\vec{r}, E) = \int \Psi(\vec{r}, E, \hat{\Omega}) d\hat{\Omega}.$$

$$\phi_g(\vec{r}) = \int_{E_g}^{E_{g-1}} \phi(\vec{r}, E) dE.$$

$$\sigma_{tg}(\vec{r}) = \text{Total cross section for group, } g = \frac{\int_{E_g}^{E_{g-1}} \sigma_t(\vec{r}, E) \phi(\vec{r}, E) dE}{\phi_g(\vec{r})}.$$

$$\chi_g(\vec{r}) = \text{Group fission spectrum} = \int_{E_g}^{E_{g-1}} \chi(\vec{r}, E) dE.$$

$$\Phi(\vec{r}) = \text{Fission production rate} = \sum_{g'=1}^G \nu \sigma_{fg'}(\vec{r}) \phi_{g'}(\vec{r}).$$

$$\nu \sigma_{fg}(\vec{r}) = \text{Nu-fission cross section for group } g$$

$$= \frac{\int_{E_g}^{E_{g-1}} \nu \sigma_f(\vec{r}, E) \phi(\vec{r}, E) dE}{\phi_g(\vec{r})}.$$

$$Q_g(\vec{r}, \hat{\Omega}) = \text{External source term for group } g = \int_{E_g}^{E_{g-1}} Q(\vec{r}, E, \hat{\Omega}) dE.$$

$$\sigma_{sg' \rightarrow g}(\vec{r}, \mu_0) = \text{Scattering cross section from group } g' \text{ to group } g$$

$$= \frac{\int_{E_g}^{E_{g-1}} \int_{E_g'}^{E_{g'-1}} \sigma_s(\vec{r}, E' \rightarrow E, \hat{\Omega} \cdot \hat{\Omega}') \phi(\vec{r}, E') dE' dE}{\phi_{g'}(\vec{r})}.$$

$$\mu_0 = \hat{\Omega} \cdot \hat{\Omega}'.$$

In practice, the multigroup cross section libraries are supplied to the DANTSYS code from a separate cross section library file that includes the energy groups, the weighting functions, and the results of resonance processing. Because the choice of a cross section library file to solve the transport equation is important in producing an accurate result, great care should be used in selecting the appropriate cross section library.

3.3.3 Discrete Ordinates Approximation Method

The next variable to discretize after energy, E , is the angular variable, $\hat{\Omega}$. In this method, the angle is discretized over the unit sphere (4π), through the use of an angular quadrature which seeks to satisfy the following conditions:

- (1) physical symmetries are preserved

- (2) spherical harmonics moments are well approximated in order to provide an accurate representation of the source terms, and
- (3) derivatives with respect to the angle coordinates that come from the streaming operator are simply approximated.

Not all of the above conditions can be simultaneously satisfied; therefore, simplifications are made. Basically each discrete ordinate is depicted as an angular direction vector, $\hat{\Omega}_m$, with an associated area on the unit sphere, w_m , where $m = 1$ to M , the number of discrete ordinates. This number of discrete ordinates is derived from the S_N order specified in Block-I of the input and can vary in different fine and coarse meshes. The

fundamental condition which must be met is that $\sum_{m=1}^M w_m = 1$.

To obtain the discrete ordinates approximation, the group-wise Boltzmann transport equation is first integrated over energy as shown previously and then evaluated at the particular directions in the quadrature:

$$\left[\hat{\Omega} \cdot \bar{\nabla} \Psi_g(\vec{r}, \hat{\Omega}) \right]_m + \sigma_{tg}(\vec{r}) \Psi_{gm}(\vec{r}) = \frac{\chi_g(\vec{r}) \Phi(\vec{r})}{k_{eff}} + Q_{gm}(\vec{r}) + SS_{gm}(\vec{r})$$

where

$$\Psi_{gm}(\vec{r}) = \Psi_g(\vec{r}, \hat{\Omega}_m).$$

$$\phi_g(\vec{r}) = \sum_{m=1}^M w_m \Psi_{gm}(\vec{r}).$$

$$Q_{g,m}(\vec{r}) = \sum_{l=0}^L \sum_{q=-l}^l (2l+1) Y_l^q(\hat{\Omega}_m) Q_{gl}^q(\vec{r}).$$

$$Q_{gl}^q(\vec{r}) = \int Y_l^{*q}(\hat{\Omega}) Q_g(\vec{r}, \hat{\Omega}) d\Omega.$$

$$Y_l^q(\hat{\Omega}) = \text{Spherical harmonic functions.}$$

$$SS_{gm}(\vec{r}) = \text{Scattering source in group } g, \text{ direction } m.$$

3.3.4 Iteration Procedure and Diffusion Synthetic Acceleration

An iterative procedure is used to solve the transport equation numerically. Two levels of iteration are used, inner and outer. In order to reduce the computation time in the DANTSYS modules, these iterations are accelerated toward convergence using the diffusion synthetic acceleration (DSA) method developed at Los Alamos (4).

Assuming isotropic scattering, the first inner iteration equation for energy group g and inner iteration l is given by

$$\hat{\Omega} \cdot \bar{\nabla} \Psi_g^l(\bar{r}, \hat{\Omega}) + \sigma_g(\bar{r}) \Psi_g^l(\bar{r}, \hat{\Omega}) = \sigma_{s,g' \rightarrow g}(\bar{r}) \phi_g^{l-1}(\bar{r}) + Q_g(\bar{r})$$

where

$\Psi_g^l(\bar{r}, \hat{\Omega})$ = Angular flux for group g at the l th inner iteration

using a scalar flux $\phi_g^{l-1}(\bar{r})$ assumed known from the previous inner iteration.

$Q_g(\bar{r})$ = Group source which remains unchanged for the group throughout the performance of inner iterations.

The group source contains scattering and fission contributions to the group together with any inhomogeneous source. The source is computed using the multigroup scalar fluxes and moments from the previous outer iteration. In the diffusion synthetic method, a corrected diffusion equation is used to determine the scalar flux needed for the next iteration.

One sweep through the space-angle mesh allows the inner iteration to use the scalar flux to solve for the angular flux. The sweeps are repeated until flux convergence to the transport equation is achieved (or a user-specified maximum number of inners per outer is achieved). The outer iterations update the multigroup source and are necessary if there

are fissions or upscattering processes (scattering from a lower energy group to a higher energy group) in the problem being evaluated.

3.3.5 Spherical Harmonics Expansion of the Scattering Source

The scattering cross section is represented by a finite Legendre polynomial expansion of an order L (denoted in DANTSYS modules as ISCT). The equation has the form

$$\sigma_{sg' \rightarrow g}(\vec{r}, \hat{\Omega} \cdot \hat{\Omega}') = \frac{1}{4\pi} \sum_{\ell=0}^L (2\ell+1) \cdot \sigma_{sg' \rightarrow g}^{\ell}(\vec{r}) P_{\ell}(\hat{\Omega}' \cdot \hat{\Omega}).$$

The group scattering source $SS_{gm}(\vec{r})$ can then be written as

$$SS_{gm}(\vec{r}) = \sum_{g'} \sum_{\ell=0}^L \sum_{q=-\ell}^{\ell} (2\ell+1) \sigma_{sg' \rightarrow g}^{\ell}(\vec{r}) Y_{\ell}^q(\hat{\Omega}_m) \phi_{\ell g'}^q(\vec{r})$$

where

L = Legendre expansion order ($L=1$ to 4 for the MENDF cross section libraries used in this work).

$Y_{\ell}^q(\hat{\Omega}_m)$ = Spherical harmonics appropriate to the geometry.

$\phi_{\ell g'}^q(\vec{r})$ = Angular flux moments which correspond to the appropriate spherical harmonics

$$= \sum_m (2\ell+1) w_m Y_{\ell}^{*q}(\hat{\Omega}_m) \Psi_{gm}(\vec{r}).$$

3.3.6 Quadrature

For one-dimensional geometries, the number of discrete ordinates or angles depends on the symmetry and the S_N order desired. Table 3-1 gives the number of angles used in each case.

Table 3-1. Number of Quadrature Points, M, as a Function of S_N Order, N.

N	Standard Plane Geometry	Cylindrical Geometry	Spherical Geometry
2	2	2	2
4	4	6	4
6	6	12	6
8	8	20	8
12	12	42	12
16	16	72	16
N	N	$N \cdot (N + 2)/4$	N

For standard plane geometry, azimuthal symmetry is assumed in ϕ so that $\hat{\Omega}(\mu, \phi)$ becomes $\hat{\Omega}(\mu)$ and $d\hat{\Omega}$ becomes $2\pi d\mu$. The angular flux moments are then approximated by:

$$\phi_\ell(x) \equiv \sum_{m=1}^{MM} w_m P_\ell(\mu_m) \Psi_m(x).$$

The discrete ordinates approximation to the transport equation then becomes

$$\mu_m \frac{d\Psi_m(x)}{dx} + \sigma(x) \Psi_m(x) = S_m(x).$$

For cylindrical geometry the multigroup transport equation is

$$\mu \frac{\partial (\bar{r} \Psi(r, \hat{\Omega}))}{\partial r} + \frac{\partial (\eta \Psi(r, \hat{\Omega}))}{\partial \phi} + r \sigma_r(r) \Psi(r, \hat{\Omega}) = r S(r, \hat{\Omega}).$$

The discrete ordinates approximation is then

$$\begin{aligned} \mu_m \frac{d(r \Psi_m(r))}{dr} + \{\alpha_{m+1/2} / w_m\} \cdot \Psi_{m+1/2}(r) - \{\alpha_{m-1/2} / w_m\} \cdot \Psi_{m-1/2}(r) + r \sigma \Psi_m(r) \\ = r S_m(\bar{r}). \end{aligned}$$

where $\alpha_{m+1/2}$ and $\alpha_{m-1/2}$ are angular coupling coefficients and satisfy the recursion relation

$$\alpha_{m+1/2} - \alpha_{m-1/2} = -w_m \mu_m.$$

For spherical geometry, the multigroup transport equation is

$$\mu \frac{d(r^2 \Psi(r))}{dr} + r \frac{d[(1-\mu^2)\Psi(r)]}{d\mu} + r^2 \sigma(r) \Psi(r) = r^2 S(r, \mu)$$

where azimuthal symmetry in ϕ is assumed. The discrete ordinates approximation is then

$$\begin{aligned} \mu_m \frac{d(r^2 \Psi_m(r))}{dr} + \{ \beta_{m+1/2} / w_m \} \cdot \Psi_{m+1/2}(r) - \{ \beta_{m-1/2} / w_m \} \cdot \Psi_{m-1/2}(r) \} r \\ + r^2 \sigma \Psi_m(r) = r^2 S_m(r) \end{aligned}$$

where $\beta_{m+1/2}$ and $\beta_{m-1/2}$ are angular coupling coefficients and satisfy the recursion relation:

$$\beta_{m+1/2} - \beta_{m-1/2} = -2w_m \mu_m.$$

For one-dimensional curved geometries such as cylinders and spheres, there are three angular flux variables to be determined at each position, r : the two angular cell edge fluxes $\Psi_{m+1/2}(r)$ and $\Psi_{m-1/2}(r)$, and the average angular flux, $\Psi_m(r)$. The $\Psi_{m-1/2}(r)$ term is generally assumed to be known (except for $m=1$) from the previous computation of angular cell mesh and continuity is also assumed at the boundaries. The diamond difference assumption in angle is made relating $\Psi_{m+1/2}(r)$ to $\Psi_m(r)$ by:

$$\Psi_m(r) = \frac{\Psi_{m-1/2}(r) + \Psi_{m+1/2}(r)}{2}.$$

Since $m=1$ is not known, ONEDANT uses an inward direction start condition in curved geometries to calculate the first $\Psi_{m+1/2}(\bar{r})$ term and assumes isotropic scattering for the

angular flux. Therefore, $\partial \Psi / \partial \mu \big|_{\bar{r}=0} = 0$ implies that $\Psi_m(0) = \text{constant}$ for all m . The constant is found by solving the starting direction equation as $d\Psi/d\bar{r} + \sigma \Psi = S$.

3.3.7 Discretization of the Spatial Variable in One Dimension

The spatial domain of the problem is partitioned into a number of fine-mesh intervals of (r, z, θ) or (x, y, z) axes, as in $\Delta x_i \equiv x_{i+1/2} - x_{i-1/2}$, etc.

Spatial discretization of one-dimensional problems is performed by integrating equations for one-dimensional geometries (spheres) over a mesh cell. For a one-dimensional geometry, the resulting equation is discretized, is called the discretized balance equation, and is solved by the ONEDANT code. This balance equation for slabs, cylinders and spheres is written in the following form:

$$\mu_m (A_{i+1/2} \Psi_{m,i+1/2} - A_{i-1/2} \Psi_{m,i-1/2}) + (A_{i+1/2} - A_{i-1/2}) (\alpha_{m+1/2} \Psi_{im+1/2} - \alpha_{m-1/2} \Psi_{im-1/2}) / w_m + \sigma_i V_i \Psi_{im} = S_{mi} V_i$$

where

- $m = 1 \dots MM = \text{Index of direction.}$
- $i = 1 \dots IT = \text{Index of spatial cells.}$
- $\Psi_{mi} = \text{Spatial cell centered angular flux.}$
- $\Psi_{m,i+1/2} = \text{Cell edge angular flux at the right cell edge.}$
- $A_{i+1/2} = \text{Area of the cell at the right edge.}$
- $V_i = \text{Volume of cell } i.$

The diamond difference approximation is then used to specify the relationship between the cell centered flux and the cell edge flux:

$$\Psi_{mi} = \frac{\Psi_{m,i+1/2} + \Psi_{m,i-1/2}}{2} = \frac{\Psi_{m+1/2,i} + \Psi_{m-1/2,i}}{2}$$

where $m = 1 \dots M$; $i = 1 \dots IT$.

These last equations eliminate the unknown edge flux in terms of the known edge flux and the cell centered flux by starting from a known boundary condition (edge flux at that boundary) and following the particle flow. The information can then be plugged into the previous balance equation to determine the cell centered flux and then the unknown edge flux. Many times, the cells are too large (in number of mean free paths) and the value for the unknown edge flux can extrapolate to a negative value, a physically impossible event. The ONEDANT code then sets this negative flux value at the edge to zero (negative flux fixup) and determines the average flux needed to satisfy particle balance.

3.3.8 Discretization of the Spatial Variable in Two and Three Dimensions

The angular and spatial discretization that is performed in ONEDANT is also performed in TWODANT and THREEDANT with the extensions to the second and third dimensions, respectively. Geometries in TWODANT include planar (x,y), cylindrical (r, θ), and polar (R, Θ). In TWODANT the angular variable is treated the same way as in ONEDANT, but the geometries are extended to include hemispheres.

The spatially discretized two-dimensional transport equation is

$$\begin{aligned} \mu_m (A_{i+1/2,j} \Psi_{m,i+1/2,j} - A_{i-1/2,j} \Psi_{m,i-1/2,j}) + \eta_m B_{i,j} (\Psi_{m,i,j+1/2} - \Psi_{m,i,j-1/2}) \\ + (A_{i+1/2,j} - A_{i-1/2,j}) (\alpha_{m+1/2} \Psi_{m+1/2,i,j} - \alpha_{m-1/2} \Psi_{m-1/2,i,j}) / w_m \\ + \sigma_{ij} V_{ij} \Psi_{mij} = S_{mij} V_{ij} \end{aligned}$$

where

$$\Psi_{m,i+1/2,j} = \text{Flux on the right edge of the mesh cell.}$$

- $\Psi_{m,i,j+1/2}$ = Flux on the top edge of the mesh cell.
 $\Psi_{m+1/2,i,j}$ = Angular direction edge flux.
 Ψ_{mij} = Cell center angular flux.
 $A_{i+1/2,j}$ = Mesh cell area in the i coordinate direction.
 B_{ij} = Mesh cell area in the j coordinate direction.
 V_{ij} = Mesh cell volume.

As with ONEDANT, the diamond difference approximation is then used in TWODANT to specify the relationship between the cell-centered flux and the cell edge fluxes (in both spatial directions and the angular direction):

$$\Psi_{mij} = \frac{\Psi_{m,i+1/2,j} + \Psi_{m,i-1/2,j}}{2} = \frac{\Psi_{m,i,j+1/2} + \Psi_{m,i,j-1/2}}{2} = \frac{\Psi_{m+1/2,i,j} + \Psi_{m-1/2,i,j}}{2}$$

where $m = 1 \dots MM$; $i = 1 \dots IT$; and $j = 1 \dots JT$.

These last equations eliminate the unknown edge flux in terms of the known edge flux and the cell centered flux by starting from a known boundary condition (edge flux at that boundary) and following the particle flow. The information can then be plugged into the previous balance equation for a two dimensional problem to determine the cell-centered flux and then the unknown edge flux. As is true for ONEDANT, the cells in TWODANT may be too large (in number of mean free paths) and the value for the unknown edge flux can extrapolate to a negative value, a physically impossible event. The TWODANT code then sets this negative flux value at the edge to zero (negative flux fix-up) in order to resolve the balance equation.

For TWODANT, a second technique that can be used for spatial discretization is adaptive weighted diamond differencing (AWDD). This method is based on a predictor corrector

method to determine the weights that will give a positive edge flux rather than setting the negative flux to zero. The details of AWDD are beyond the scope of this work.

For THREEDANT, the methods are the same except for the extension to three dimensions, (x, y, z) and (r, z, θ) . The S_N quadrature is the same except that 8 octants are used instead of the 4 quadrants in two dimensions in TWODANT. The spherical harmonics in THREEDANT are also the same as the slab entries from ONEDANT. The spatial discretization has the same two options of negative flux fix-up and AWDD.

4.0 INSTALLATION AND VERIFICATION OF PARTISN 2.64/DANTSYS 3.1 ON THE MANHATTAN (WITH MACHINE SPECIFICATIONS)

4.1 Installation

There are separate installation procedures for DANTSYS 3.1 and for PARTISN 2.64. Both are outlined in their respective README files which are supplied with the code package. The installation consists of running a code named GMAKE to create the executable file, *dant.x* for DANTSYS 3.1 and *partisn* for PARTISN 2.64. The executable files are used to supply the code modules with the proper paths to the input and output files.

Using the supplied instructions in the README files, the DANTSYS 3.1 and PARTISN 2.64 codes were first installed by electronic transfer from the code developer to the Manhattan computer custodian. Because machine errors were found later by running the first set of PARTISN 2.64 verification problems, a second installation by compact disc was performed by the Manhattan computer custodian.

4.2 Verification

Verification of the code consists of running a set of sample problems provided in the code package to demonstrate that the installation has been done correctly. Typically these sample problems are designed to exercise all important code options, not to represent actual physical situations. The input files for these sample problems are supplied in the code package. Output and results of the sample problems run after installation of the code on the Manhattan are compared to results published and supplied by the code developers at Los Alamos. Verification of proper installation is confirmed when the results match those provided.

For verification of installation of DANTSYS 3.1, a set of five sample problems were run. Results comparison with the published results supplied by Los Alamos code developers demonstrated that the installation results were identical to the published results.

For verification of installation of PARTISN 2.64, the multi-processor form of DANTSYS 3.1, a set of sixty sample problems were run from the electronic transfer of the code from LANL to Y-12. Twenty-eight of the 60 sample problems failed to run or to compare well with the published results supplied by Los Alamos code developers, demonstrating that there was a problem with the installation of the code.

The process of verification revealed several machine processing problems. The problem input files which were sent electronically to Y-12 from LANL appeared to be corrupted in many cases, which was suspected to be the cause of some of the 60 problems not to run initially. A request was made to LANL to send the sample problems on a compact disc through the mail to prevent the corruption of the input files. Also, the verification process revealed that the version of the MPI program running the multi-processor function on the Manhattan was out of date and needed to be replaced. The version of the compiler was also checked and was verified to be the same version as that used at LANL for their multi-processing computer system. Maintenance was also performed on the Manhattan by SGI technicians and the operation of the machine was improved.

The second attempt to run 74 verification problems, this time from compact disc installation, was successful. The results are shown in Table 4-1. Of the 74 problems, seven input decks were not provided, seven of them failed for reasons that were shown to not indicate an installation error, and the remaining 60 problems passed the test.

Table 4-1. Comparison of Results of PARTISN Sample Problems.

Verification Problem Number	Verification Problem Output Identifier	Status of Problem Run on Manhattan/Match Status	Comments
1	2dld.sgi.new	Ran/matched	ievt=0; both run w/4 processors
2	3dfc10.sgi.new	Ran/matched	ievt=0; both run w/4 processors
3	3dfc5_1.sgi.new	Ran/matched	ievt=0; both run w/1 processor
4	3dfc5_2.sgi.new	Ran/matched	ievt=0; both run w/2 processors
5	3dfeh2o.sgi.new	Ran/matched	ievt=0; both run w/16 processors
6	3dfeh2o_a.sgi.new	Ran/matched	ievt=0; both run w/1 processor
7	ball.sgi.new	Failed	ievt=0; failed in Block 1. Corruption Error in input file: "nzone<3" instead of nzone=3. Does not appear to be installation error.
8	ball_1d.sgi.new	NA	Input not included in CD files.
9	ball_restart.sgi.new	NA	Input not included in CD files.
10	ball_t.sgi.new	NA	Input not included in CD files.
11	bdrydd.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
12	bdryfl.sgi.new	Failed	ievt=0; error in Block 5, array name "asfrnt" undefined; both run w/ 4 processors. Does not appear to be installation error, possibly current installed PARTISN version 2.64 does not utilize "asfrnt" array name.
13	bdrynl.sgi.new	Ran/ matched	ievt=0; both run w/16 processors.

Table 4-1. Continued.

Verification Problem Number	Verification Problem Output Identifier	Status of Problem Run on Manhattan/Match Status	Comments
14	bdryrz.sgi.new	Ran/matched	ievt=0; both run w/8 processors.
15	blksrc.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
16	blockld.sgi.new	Ran/matched	ievt=0; both run w/15 processors.
17	blrztime.sgi.new	Ran/matched	ievt=0; both run w/1 processor.
18	bndfile.sgi.new	Ran/matched	ievt=0; both run w/4 processors, leakages different, but within machine precision.
19	bs1_3d.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
20	bs1_3d.timeq.sgi.new	Ran/matched	time dependent file, matched within machine precision.
21	bs1_3d_rstrt.timeq.sgi.new	Ran/matched	time dependent file, matched within machine precision.
22	bs1_3d_rstrt.sgi.new	Ran/matched	ievt=0; time dependent file, matched within machine precision.
23	bs2_3d.sgi.new	Ran/matched	ievt=1; both run w/4 processors.
24	bs2_3d.timeq.sgi.new	Ran/matched	time dependent file, matched within machine precision.
25	bs2_3d_rstrt.sgi.new	Ran/matched	ievt=1;
26	bs2_3d_rstrt.timeq.sgi.new	Ran/matched	ievt=1; time dependent file, matched within machine precision.
27	bs2_3d_mgll.sgi.new	Failed	ievt=1; Error in Block 5, "unknown diffusion solver option, error tinpt21." Does not appear to be installation error. Possible current installed PARTISN version 2.64 does not utilize this option.

Table 4-1. Continued.

Verification Problem Number	Verification Problem Output Identifier	Status of Problem Run on Manhattan/Match Status	Comments
28	bs2_3d_mg11_rstrt.sgi.new	Failed	ievt=1; read/seek local file does not exist. This file possibly dependent on previous output. Does not appear to be installation error.
29	chimix.sgi.new	NA	Input not included in CD files.
30	cube000.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
31	cube111.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
32	cyl1dk.sgi.new	Ran/matched	ievt=1; both run w/1 processor.
33	fehn1.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
34	grpdsn.sgi.new	Ran/matched	ievt=1; both run w/16 processors.
35	grpdsn_mg11.sgi.new	Failed	ievt=1; Error in Block 5 "unknown diffusion solver option, fatal input error - tinpt21" In Block 5, diffsol=mg11, PARTISN 2.64 does not accept this array command.
36	grpdsn_mg31.sgi.new	Ran/matched	ievt=1; both run w/16 processors. (diffsol=mg in Block 5 in this file and is accepted)
37	k_blk.dbl.coar.sgi.new	Ran/matched	ievt=1; both run w/4 processors.
38	k_blk.sgi.new	Ran/matched	ievt=1; both run w/4 processors.
39	k_blk.uniform.coar.sgi.new	Ran/matched	ievt=1; both run w/4 processors.
40	lwr1.sgi.new	Ran/matched	ievt=1; both run w/16 processors.
41	plssn1.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
42	plssn2.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
43	plssn3.sgi.new	Ran/matched	ievt=0; both run w/8 processors

Table 4-1. Continued.

Verification Problem Number	Verification Problem Output Identifier	Status of Problem Run on Manhattan/Match Status	Comments
44	rtswp2da.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
45	rtswp2db.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
46	rz.sgi.new	Ran/matched	ievt=0; both run w/1 processor.
47	rza.sgi.new	Ran/matched	ievt=2; both run w/1 processor; leakages different, but within machine precision.
48	rzswp2d.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
49	rzt.sgi.new	Ran/ some answers different	ievt=0; both run w/1 processor , bottom and front leakages did not match, but possibly not important.
50	rzt3da.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
51	rzt3db.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
52	rzt3dc.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
53	rztbox.sgi.new	Ran/matched	ievt=0; both run w/2 processors.
54	rztime.sgi.new	Ran/matched	ievt=0; both run w/1 processor.
55	rztime_rstrt.sgi.new	Ran/matched	ievt=0; time dependent file.
56	rztime.timeq.sgi.new	Ran/matched	time dependent file
57	rztime_rstrt.timeq.sgi.new	Ran/matched	time dependent file.

Table 4-1. Continued.

Verification Problem Number	Verification Problem Identifier	Status of Problem Run on Manhattan/Match Status	Comments
58	slab1d.sgi.new	Ran/matched	ievt=1; both run w/1 processor, some values in balance table different, but within machine precision.
59	snu235.sgi.new	NA	Input not included in CD files.
60	sphere1d.sgi.new	Ran/matched	ievt=0; both run w/1 processor.
61	sphere1d.timeq.sgi.new	Ran/matched	time dependent file.
62	sphndi1.sgi.new	NA	Input not included in CD files.
63	sphndi2.sgi.new	Failed	ievt=1; "ndi library error, ndi check option error inpt20=-20808, set iso ndi error in inpt20=-20808." Ndi library not provided. Not installation error.
64	src_blk_coar.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
65	src_coar.sgi.new	Ran/matched	ievt=0; both run w/16 processors, some leakages different, but within machine precision.
66	src_coar.incol3d.sgi.new	Ran/matched	NA to verification (appears to be utility file).
67	t3d.1b.incol3d.sgi.new	Ran/matched	NA to verification (appears to be utility file).
68	t3d.1b.sgi.new	Ran/matched	ievt=1;
69	well.sgi.new	Failed	ievt=0; both run w/16 processors. Error: "reed/seek local file does not exist, bsxlib missing." Not an installation error.
70	xy.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
71	xyz.sgi.new	Ran/some answers different	ievt=0; both run w/4 processors, leakage terms in balance table do not match, but may not be important.

Table 4-1. Continued.

Verification Problem Number	Verification Problem Identifier	Status of Problem Run on Manhattan/Match Status	Comments
72	xyz_bl.sgi.new	Ran/matched	ievt=0; both run w/4 processors.
73	xyzperz.sgi.new	Ran/matched	ievt=0; both run w/16 processors.
74	zonchi.sgi.new	NA	Input not included in CD files.

4.3 Machine Specifications

The Manhattan is an SGI Origin 2000 with 96 *R10000* 100-250 MHz processors with 14 GB of RAM, 6000 GB disk storage (Raid 5 and JBOD), and 20.6 TB uncompressed tape storage (6 DLT 7000 drives, a robotic tape library and a 252 tape capacity). It is more powerful than the previous Y-12 Engineering HP, with 112 times more RAM and 300 times more disk storage.

Current application software available on the Manhattan includes Fortran 90, C and C++ compilers and various parallelizing, performance, and networking utilities such as Auto Parallelizing Option software, Performance Co-Pilot and Legato Networker. It is equipped with the LS Dyna Dynamic Stress and Thermal Analysis package as well as the Metaphase product data management package and an Oracle database. The Manhattan has been or will be equipped with the following:

- (1) MCNP code packages (Monte Carlo transport codes for nuclear criticality and shielding applications),
- (2) ABAQUS (commercial stress analysis),
- (3) Patran Pthermal (mesh generator and thermal analysis),
- (4) ANSYS (commercial stress/thermal analysis),
- (5) Pro/Engineer CAD package,
- (6) Pronto 3D Transient solid dynamics package,
- (7) JAS3D (3D implicit solids code for large deformations),
- (8) Goma (multi-physics, free and moving boundaries), and
- (9) Coyote (non-linear heat conduction solver).

For PARTISN 2.64/ DANTSYS 3.1 executions, there are 80 processors available, with 12 GB of RAM and 260 GB user disk storage. A simple set of test cases were run with a

PARTISN 2.64 THREEDANT input file using various numbers of processors to find the optimum performance of the code with respect to speed of the execution of the solver and edit modules. With no other users sharing the multi-processors, the ANS6612.inp THREEDANT version of the input file was run with 16, 32, and 64 processors. The calculations took about 31 minutes, 13 minutes, and 8 minutes, respectively. However, it was observed in one instance that when other users were sharing the multi-processors, a 64 processor run took longer than a 32 processor run using the same input file. This is probably due to the fact that the 32 processor run was allocated 43 M of memory per processor, but the 64 processor run was allocated only 17M of memory per processor. More inefficiency is also introduced using the 64 processor run because information must be shared between the processors in executing the solver and edit modules. This “conversation” of many smaller memory processors takes more time than the communication of fewer larger memory processors. This phenomenon varies significantly with the number of users sharing the Manhattan and how large the jobs are. The Manhattan may also be subject to a “weakest link” phenomena where the overall timing is controlled by the slowest processor, but there is no firm evidence of this.

As a result of the test cases, benchmark and vault model cases were run most of the time with 32 processors to reduce or eliminate inefficiency in the processing and sharing of information between the processors. It also provided a fairly constant measuring stick of how long a calculation would take given the same coarse and fine mesh sizes. As the models became more finely tuned and larger through the increase of the number of fine meshes, however, the cases were run with 64 processors in order to save time overall. Though the number of users and size of the jobs run on the Manhattan is not controlled, current demand is not high enough on a regular basis to impact running the benchmark and vault model cases in a timely manner. This was aided by the PARTISN 2.64 jobs being given a higher priority than other jobs. No notification has been made by the owner of the Manhattan to indicate usage is expected to increase drastically in the near future.

5.0 DEVELOPMENT OF CROSS SECTION LIBRARIES, RESPONSE FUNCTIONS, AND SOURCE TERM FOR PARTISN 2.64/DANTSYS 3.1

The three topics of this section, cross section libraries, response function development, and source term development are all problem-dependent data used by transport codes for shielding applications. The cross section libraries chosen for this work must be consistent with the types of reactions that will take place in a fast (as opposed to thermal) metal (as opposed to solution) nuclear criticality accident. For this type of accident, prompt photons are generated with prompt nuclear fission of ^{235}U . Secondary or production photons are generated by neutron transport through other materials such as concrete and air. CAAS detectors used in buildings for fissile material activities at Y-12 are gamma-activated detectors, either sodium-iodide crystal or plastic scintillation types (6). Nuclear data specifications (Cross Section Library) are input in the DANTSYS/PARTISN transport code Block-III Cross Sections LIB data item of the INPUT module.

The source term chosen for a certain shielding study should be consistent with the type of nuclear reactions and materials expected in the model. For storage of fissile material without inherent hazards of loss of moderation control, a fast metal nuclear criticality accident is the most likely type of accident. Prompt photons are generated with prompt nuclear fission of ^{235}U . Secondary or production photons are generated by neutron transport through other materials such as concrete and air. Therefore, the source term should ideally include both neutrons and photons. The source term group energy information is input in the DANTSYS/PARTISN transport code Block-V SOURCE array of the SOLVER module.

5.1 Cross Section Libraries

Nuclear data specification information is organized for the nuclear industry in computer files known as cross section libraries. A *cross section* is a measurement of the probability of a certain particle interaction (e.g., neutron-nucleus) to occur within a certain material

isotope. A cross section library with more isotopes is naturally a larger file. Cross section libraries are typically organized by particle type, such as neutron only, gamma only, or neutron-gamma coupled libraries.

A neutron-nucleus reaction can be of several types as well. A fission reaction is the absorption of a neutron by a nucleus and the resultant splitting of the nucleus into two smaller nuclei with accompanying release of energy and 2-5 additional neutrons. A capture reaction is the absorption of a neutron by a nucleus and the formation of a new nucleus. A scattering reaction is the elastic or inelastic bouncing of a neutron off of a nucleus (or briefly absorbed and forming a compound nucleus in an excited state before the emission of a neutron) (7).

These cross sections are determined experimentally. To illustrate, one may assume a beam of neutrons traveling at the same speed and direction incident on a material target would be expected to have a certain reaction rate with that material proportional to the number of neutrons/unit area · unit time (I) and the number of target nuclei/unit area (N_A). A unit of proportionality (σ) which results from this assumption is called the *microscopic cross section*:

$$R = \sigma I N_A$$

$$R = \sigma \text{ (# neutrons/cm}^2 \cdot \text{s)} \text{ (# target atoms/cm}^3 \text{)}$$

where R is the reaction rate in (interactions/sec), σ is in cm^2 , and can contain a subscript to indicate specific interactions, i.e., σ_a for absorption, σ_s for scattering, and σ_t for the total of absorption and scattering.

A nucleus is generally considered to have a radius of 10^{-12} cm, with a geometric cross sectional area of 10^{-24} cm^2 . Microscopic cross sections have an equivalent size unit called a *barn*. However, other factors may affect this probability of interaction so that a strict geometric interpretation is not valid. One of the factors seen in the fission cross

section for ^{235}U is found in the resonance region of the spectrum, where the quantum mechanics of the neutron-nucleus interaction cause the probability to vary widely. If one assumes that the neutron beam incident on a material target of differential thickness, one can calculate the total reaction rate per unit area as:

$$\partial R = \sigma_t I(x) \partial N_A = \sigma_t I(x) N \partial x$$

where the number of target nuclei per cm^2 in ∂x is given by $\partial N_A = N \partial x$ and N is number density of nuclei in the target. Noting that the depletion of the beam occurs for every interaction, we have:

$$\partial I(x) = -\partial R = N \sigma_t I(x) \partial x.$$

Solving for $I(x)$:

$$I(x) = I_0 e^{-N\sigma_t x}.$$

The product of N and σ_t becomes what is known as the *macroscopic cross section*:

$$\begin{aligned} \Sigma_t &\equiv N\sigma_t = (\# \text{ particles/unit volume}) (\text{unit area}) \\ &= (\# \text{ particles}/\text{cm}^3) (\text{cm}^2) = \text{cm}^{-1} \end{aligned}$$

which is the probability of a particle interacting with a large mass of material whereas a *microscopic cross section* is the probability of a particle interacting with a single nucleus of material. However it is more accurate to label Σ_t as the probability that a particle will interact with a nucleus in a material per unit path length traveled. Furthermore, there is the dependence of the macroscopic cross section on the particle's energy.

Several multigroup cross section libraries were considered for use with PARTISN 2.64/DANTSYS 3.1 on the Manhattan. The first preference was to use local Oak Ridge developed multigroup cross section libraries that have been successfully applied to KENO.Va criticality calculations and DOORS shielding analyses. Two such libraries developed at Oak Ridge are the 27-group neutron/18-group gamma coupled library and the BUGLE-96 47-group neutron /20-group gamma coupled library (8). (A continuous-energy cross section library, such as is used with MCNP, is not usable by PARTISN 2.64/DANTSYS 3.1.)

However, during research of the various cross section libraries available, we found that the Los Alamos MENDF cross section library set was recommended by another UTNE research project that involved installation, verification, and validation of DANTSYS 3.1 on the Y-12 NCSD HP workstation (9). The project's future work recommendation was to acquire Los Alamos MENDF cross section library sets to be installed at Y-12 work stations in order to avoid errors and confusion encountered with the Legendre polynomial $2^{\circ} + 1$ term. Los Alamos codes and Oak Ridge transport codes use different definitions of the anisotropic scattering cross sections. For this reason, an Oak Ridge developed cross section library may not be compatible with a Los Alamos developed transport code.

The primary interest in validating PARTISN 2.64/DANTSYS 3.1 on the Manhattan is for prompt photons and the secondary interest is in neutron and secondary photon production in a criticality accident. Fast source neutrons interact with surrounding materials, can generate photons through inelastic scattering and (n,γ) absorption reactions. Ignoring secondary photon production is a conservative treatment in a CAAS analysis since the true radiation levels are underestimated.

For use in analyses that consider only prompt photon data, personnel from Los Alamos provided the MENDFG cross section library which is extracted from the coupled neutron-photon cross section library MENDF5G. The MENDF5 and MENDF6 cross section libraries were also acquired for installation and use on the Manhattan with the

help of personnel from Los Alamos National Laboratory and from the Radiation Safety Information Computational Center (RSICC) located at Oak Ridge National Laboratory. BUGLE-96 was also acquired for future work.

MENDF5 is a 30-group neutron cross section library with 99 nuclides, and MENDF5G is a 30-group neutron and 12-group gamma cross section library with the same 99 nuclides. These libraries are designed for use in modeling fast (non-thermal) systems and are based on ENDF/B-V nuclear evaluated data. There is no upscatter, all isotopes are at room temperature, and P0 through P4 scattering angle matrices are provided. MENDF5G contains photon-production and photon transport cross section libraries. MENDFG is a subset of the MENDF5G library containing only the 12-group photon library.

MENDF6 is a 30-group neutron cross section library which includes data for 167 nuclides. It is based on ENDF/B-VI nuclear evaluated data with several improvements over MENDF5: more physical description of secondary particle energy-angle distributions, extension in energy and detail of the resolved resonance data, isotopic rather than elemental evaluations, and more consistent evaluations for standard reactions. As with MENDF5, these cross section libraries are not designed for use in modeling problems dominated by thermal neutrons. Also, as with MENDF5, there is no upscatter, all cross section libraries are at room temperature, and P0 through P4 scattering angle matrices are provided.

Some materials were re-evaluated in MENDF6: D, ^6Li , ^9Be , ^{16}O , Fe, Pb, ^{235}U , ^{238}U , and ^{239}Pu . However, for certain problems, ENDF/B-V still outperforms ENDF/B-VI, and it is important to remember that specific results are material and application dependent. At the time the MENDF6 cross section library was acquired in early Fall, 2001 (along with documentation dated February, 1996), there was no photon-production and photon transport cross section libraries prepared based on ENDF/B-VI data. Table 5-1 lists the isotopes included in MENDFG.

Table 5-1. Isotopes Included in MENDFG Library.

ZAID	Isotope	ZAID	Isotope	ZAID	Isotope	ZAID	Isotope
1001.50	¹ H	19000.50	K-nat	47000.55	Ag-nat	79197.56	¹⁹⁷ Au
1002.50	² H	20000.50	Ca-nat	47107.50	¹⁰⁷ Ag	82000.50	Pb-nat
1003.50	³ H	22000.50	Ti-nat	47109.50	¹⁰⁹ Ag	83209.50	²⁰⁹ Bi
2003.50	³ He	23000.50	V-nat	48000.50	Cd-nat	90232.50	²³² Th
2004.50	⁴ He	24000.50	Cr-nat	50120.35	Fission Products	91233.50	²³³ Th
3006.50	⁶ Li	25055.50	⁵⁵ Mn	50998.99	Fission Products-- P	92233.50	²³³ U
3007.55	⁷ Li	26000.55	Fe-nat	50999.99	Fission Products-- A	92234.50	²³⁴ U
4007.35	⁷ Be	27059.50	⁵⁹ Co	54000.35	Xe-nat	92235.50	²³⁵ U
4009.50	⁹ Be	28000.50	Ni-nat	56138.50	¹³⁸ Ba	92236.50	²³⁶ U
5010.50	¹⁰ B	29000.50	Cu-nat	63000.35	Eu-nat	92237.50	²³⁷ U
5011.56	¹¹ B	31000.50	Ga-nat	63151.55	¹⁵¹ Eu	92238.50	²³⁸ U
6000.50	C-nat	33075.35	⁷⁵ As	63153.55	¹⁵³ Eu	92239.35	²³⁹ U
6012.50	¹² C	36078.50	⁷⁸ Kr	64000.35	Gd-nat	93237.55	²³⁹ Np
7014.50	¹⁴ N	36080.50	⁸⁰ Kr	67165.55	¹⁶⁵ Ho	94237.35	²³⁷ Pu
7015.55	¹⁵ N	36082.50	⁸² Kr	69169.55	¹⁶⁹ Th	94238.50	²³⁸ Pu
8016.50	¹⁶ O	36083.50	⁸³ Kr	73181.50	¹⁸¹ Ta	94239.55	²³⁹ Pu
9019.50	¹⁹ F	36084.50	⁸⁴ Kr	74000.55	W-nat	94240.50	²⁴⁰ Pu
11023.50	²³ Na	36086.50	⁸⁶ Kr	74182.55	¹⁸⁵ W	94241.50	²⁴¹ Pu
12000.50	Mg-nat	39089.50	⁸⁹ Y	74183.55	¹⁸³ W	94242.50	²⁴² Pu
13027.50	²⁷ Al	40000.50	Zr-nat	74184.55	¹⁸⁴ W	95241.50	²⁴¹ Am
14000.50	Si-nat	41093.50	⁹³ Nb	74186.55	¹⁸⁶ W	95242.50	^{242m} Am
15031.50	³¹ P	42000.50	Mo-nat	75185.50	¹⁸⁵ Re	95243.50	²⁴³ Am
16032.50	³² S	45103.50	¹⁰³ Rh	75187.50	¹⁸⁷ Re	96242.50	²⁴² Cm
17000.50	Cl-nat	45117.90	Average fission product from ²³⁵ U	77000.55	Ir-nat	96244.50	²⁴⁴ Cm
18000.35	Ar-nat	46119.90	Average fission product from ²³⁹ Pu	78000.35	Pt-nat		

***Note:** ZAID is the material identification number for Los Alamos National Laboratory developed cross sections. The number value before the period is symbolic of the atomic number of the material and its atomic weight, i.e., "1001" is hydrogen, atomic number 1 and atomic weight of 1.007. Deuterium is identified as "1002" with atomic number 1 but atomic weight 2.014. The number value after the period is the cross section identifier, i.e., ".50" identifies the cross section is derived from ENDFB-V nuclear data, ".55 is derived from ENDFB-V, Release 2, nuclear data.

Because of the availability of needed isotopes and the decision to restrict our analysis to photon sources, the choice was made to use the MENDFG cross section library with the 12-group photon library to validate PARTISN 2.64/DANTSYS 3.1 CAAS detector placement in a vault-type storage building. The number of groups indicated in the TWODANT input files command for *ngroup* is equal to 12. The number of isotopes indicated in the TWODANT input files command for *niso* is equal to 99.

5.2 Response Function Development

A response function is an energy-dependent function that is multiplied by particle fluxes to estimate biological effects or detector response. They are generally calculated using radiation transport codes and the appropriate mathematical models of target bodies (e.g., detectors, human body models (phantoms)). Response functions are provided in table form in various standards, code modules, and reports.

The response functions used for determining the response of a CAAS detector are based on the physical characteristics of the detector. For example, for determining a rate of exposure in air, a response function based on units of milliRoentgen/hour (mR/hr) is used, and for determining absorbed dose rate or kerma, a response function based on units of millirad/hour (mr/hr) or Gray/hr is used. The number of energy values used to characterize a response function is not a limiting factor since the piecewise linear response function shape can be integrated over the proper energy group ranges to be consistent with a specified cross section library. The resulting group-wise response function information is input in the DANTSYS/PARTISN transport code Block-VI RSPE data item of the EDIT module.

Two documents were reviewed for their possible applicable content to response function. The first is ANSI/ANS 6.1.1 *American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors* (1991 and 1977) (10). The second one is ICRU-57, *Conversion Coefficients for use in Radiological Protection Against External Radiation*, (1998) (11).

5.2.1 ANSI/ANS 6.1.1

This standard is intended for use by shield designers to calculate whole-body dose equivalents to radiation workers and the general public, but not to establish occupational or public limits. Using ANSI/ANS 6.1.1 in cases where the dose equivalents exceed occupational exposure guidelines is not recommended by the standard itself.

The standard includes data recommended for computing biological dose equivalents due to neutron and gamma-ray radiation fields. The data include flux-to-dose-rate conversion factors for neutron energies from 2.5×10^{-8} to 20 MeV, and for gamma-ray energies from 0.01 to 15 MeV.

Values from ANSI/ANS-6.1.1-1977, *Neutron and Gamma Ray Flux-to-Dose-Rate Factors*, were considered for determining the response functions for the 12 gamma groups used in the cross section library MENDFG for this work, but were not used because the response function is in units of (rem/hr)/(photons/cm² · s). The MCNP model being confirmed by this work used the response functions given in ICRU-57 with units of pGy · cm².

5.2.2 ICRU-57

This report summarizes the work of the Joint Task Group on Dose-Related Quantities for Radiological Protection against External Radiation established in 1991. In 1990, basic recommendations in ICRU-26 were replaced by those in ICRU-60 and included new quantities for use in radiological protection. ICRU-57 is a review of basic data used in the protection against external exposure to sources of ionizing radiation as they relate to the new quantities discussed in ICRU-60. Some of the pertinent definitions included in ICRU-57 are given below:

Absorbed Dose (D): is the quotient of mean energy imparted by ionizing radiation and matter of mass, m , $D = d\bar{\epsilon} / dm$. The unit is $1 \text{ J/kg} = 100 \text{ rad} = 1 \text{ gray (Gy)}$.

Effective Dose (E): is the summation of the equivalent doses in tissue multiplied by the appropriate weighting factor, $E = \sum_T w_T \cdot H_T$.

Equivalent Dose ($H_{T,R}$): is the absorbed dose in tissue multiplied by the appropriate radiation weighting factor, $H_{T,R} = w_R \cdot D_{T,R}$. When the radiation field is composed of radiation with different values of w_R , the absorbed dose is subdivided into blocks, each multiplied by its own radiation weighting factor and the total is given by:

$$H_T = \sum_R w_R \cdot D_{T,R}. \text{ The unit is sievert (Sv).}$$

Dose Equivalent (H): the product of the quality factor and the absorbed dose at a point in tissue, $H = QD$. The unit is sievert (Sv).

Directional Dose Equivalent ($H'(d, \Omega)$): is the dose equivalent at a point in a radiation field that would be produced by the ICRU sphere at a depth, d , on a radius in direction, Ω . The unit is sievert (Sv).

Fluence (Φ): is the quotient of dN by da , where dN is the number of particles incident on a sphere of cross-sectional area da , $\Phi = dN / da$. The unit is # of particles/cm².

Kerma (K): the quotient of dE_{tr} by dm , where dE_{tr} is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles in a volume element of mass dm , $K = dE_{tr} / dm$. The unit is $1 \text{ J/kg} = 100 \text{ rad} = 1 \text{ gray (Gy)}$.

A *protection quantity* is a dosimetric quantity specified in the human body by the ICRP, e.g., effective dose and equivalent dose. An *operational quantity* is a quantity with which by means of its measurement, compliance with the system of protection is demonstrated, e.g., directional dose equivalent. Section 4 of ICRU-57 gives the conversion coefficients that relate either air kerma free-in-air or particle fluence to protection and operational quantities.

The conversion coefficient links the protection and operational quantities to physical quantities characterizing the radiation field. The physical quantities usually calculated or used are the tissue-absorbed dose (D_T), air kerma free-in-air (K_a), and particle fluence (Φ).

The 25 energy point values of ICRU-57 Conversion coefficients for air kerma per unit fluence (K_a / Φ) of monoenergetic photons were integrated over the 12 energy group ranges required for MENDFG:

$$\frac{\int_{E_{low}}^{E_{high}} f(E) dE}{\int_{E_{low}}^{E_{high}} dE} = \text{response function for each of the 12 energy groups}$$

where $f(E)$ = the response functions given in ICRU-57 and presented in Table 5-2.

Table 5-2. Resulting Response Function Group Values for MENDFG Based on ICRU-57 for Air Kerma per unit Fluence (K_a/Φ) of Monoenergetic Photons.

Conversion coefficients for Air Kerma/Unit Fluence from ICRU-57 (25 energy points)		Conversion coefficients for Air Kerma/Unit Fluence (13 energy points)	
Photon Energy (MeV)	K_a/Φ (pGy·cm ²)	Photon Energy (MeV)	K_a/Φ (pGy·cm ²)
0.010	7.43	0.010	0.8410
0.015	3.12	0.1	1.3736
0.020	1.68	0.5	3.46
0.030	0.721	1.0	6.075
0.040	0.429	2.0	9.8925
0.050	0.323	4.0	13.1
0.060	0.289	5.0	15.1
0.080	0.307	6.0	17.1
0.100	0.371	7.0	19.1
0.150	0.599	8.0	21.075
0.200	0.856	9.0	23.025
0.300	1.38	10.0	24.0
0.400	1.89	20.0	37.6715
0.500	2.38		
0.600	2.84		
0.800	3.69		
1.000	4.47		
1.500	6.14		
2.000	7.55		
3.000	9.96		
4.000	12.1		
5.000	14.1		
6.000	16.1		
8.000	20.1		
10.000	24.0		

According to ICRU-57, reference radiation fields are specified in terms of field quantities, which, for both photons and neutrons, are normally fluence. Most dose calculations are performed assuming that charged particle equilibrium exists at the point of interest (detector). Often a kerma approximation of absorbed dose is applied because absorbed dose is difficult to measure and calculate (when uncharged particles ionize material they produce charged particles which deposit their energy elsewhere and are harder to track). The kerma approximation assumes that, at the point of interest, the charged particles are in equilibrium, so kerma is a good approximation to absorbed dose. In the case of photon radiation, the kerma approximation assumes that secondary electrons produced by photon interaction with target nuclei are in equilibrium with those produced by bremsstrahlung.

Introduction to Health Physics (1983) discusses kerma from a more practical view (12). It focuses on the initial kinetic energy of the primary ionizing particles resulting from indirectly ionizing radiation such as photons and fast neutrons. For photons, these primary ionizing particles produced are photoelectrons, Compton electrons and pair production positron-negatron pairs. The quantity of these primary ionizing particles per unit mass of target produced by the incident radiation is defined as the kerma. Kerma values decrease continuously across the thickness of the target because of the continuous decrease in the flux of the primary ionizing particles. The text further contrasts kerma with absorbed dose by explaining that absorbed dose increases across the thickness of the target as the density of the primary ionizing particles and the secondary particles they produce increases. Once a maximum is reached, the absorbed dose decreases across the remaining thickness of the target. This maximum is reported to occur at a depth about equal to the maximum range of the primary ionizing particles. This relationship between kerma and absorbed dose is shown in Figure 6.7 of *Introduction to Health Physics* (12).

Several authors listed in ICRU-57 have determined that the kerma approximation for absorbed dose is valid for photon energies up to about 3 MeV. At higher photon energies, charged particle and radiation equilibrium becomes less assured. There are other authors who question the assumptions of the kerma approximation and take the view that at photon energies above 3 MeV, secondary charged particles resulting from interaction in air between the source and the detector must be determined and compensated for in detector calibration procedures. However, it is stated in ICRU-57 that the calculated conversion coefficients assume that secondary charge-particle equilibrium exists at the point of interest of the radiation field where the measurement is made and is valid up to 3 MeV photon energy. This is possible because it is valid to assume that the slowing down of electrons is a smooth process as a function of energy, provided that the range of the electrons is small with respect to the volume of the model (11). Therefore, it is valid to evaluate the absorbed dose by means of a kerma approximation (multiplying the incident fluence by the kerma conversion coefficients).

To determine whether the source term used in this work will generate photons at energies predominantly below 3 MeV and thereby be valid for use of the kerma approximation, a literature search was conducted to determine number and energy of the photons generated from thermal neutron fission of ^{235}U . The first reference, *Reactor Handbook, Shielding* (1962) (13), includes information from two sets of experiments, the older set reporting an average prompt photon energy range from 0.9 to 2.5 MeV and a total photon energy release of about 5 MeV. The newer set of experiments (conducted at ORNL) reported an average prompt photon energy of 0.87 MeV and a total emitted photon energy of 7.5 MeV per fission. Both of these sources indicate that the average fission photon energy is well below 3 MeV.

The second reference, *Radiation Shielding and Dosimetry* (1979), reports the following curve fit for its prompt-fission gamma spectrum (14):

	6.6 photons/fission-MeV	0.1 < E < 0.6 MeV
$\Gamma_E =$	$20.0 (e^{-1.78E})$	0.6 < E < 1.5 MeV
	$7.2 (e^{-1.09E})$	1.5 < E < 10.5 MeV

The prompt-fission gamma ray spectrum for thermal neutron fission of ^{235}U and is shown in Figure 2.26 of *Radiation Shielding and Dosimetry*. The reported values of the prompt-fission gamma ray spectrum for thermal neutron fission of ^{235}U and is shown in Table 2.10 of *Radiation Shielding and Dosimetry*. Integration of this function indicates that only about 3.3% of fission photons have energy greater than 3 MeV:

$$\begin{aligned} \int_0^3 \Gamma_E(E) dE &= 6.6 * 0.5 + 20/1.78 (e^{-1.78 * (0.6)} - e^{-1.78 * (1.5)}) \\ &\quad + 7.2/1.09 (e^{-1.09 * (1.5)} - e^{-1.09 * (3)}) \\ &= 7.421. \end{aligned}$$

$$\begin{aligned} \int_3^{10} \Gamma_E(E) dE &= 7.2/1.09 (e^{-1.09 * (3)}) \\ &= 0.251. \end{aligned}$$

$$\begin{aligned} \text{Percent above 3 MeV} &= 0.251 / (0.251 + 7.421) \\ &= 3.27. \end{aligned}$$

The last reference, *The Absolute Spectrum of Photons Emitted in Coincidence with Thermal-Neutron Fission of Uranium-235* (1970) (15), contains the results of experiments to determine the absolute energy spectrum of prompt photons emitted as a result of prompt fission of ^{235}U by thermal neutrons. These experiments were conducted at the Oak Ridge National Laboratory. The average number of photons per fission was reported at 8.13 ± 0.35 MeV and the energy release per fission was reported at $7.25 \pm$

0.26 MeV. These two results yielded an average energy per photon from thermal neutron fission of ^{235}U of 0.89 ± 0.05 MeV. All values corresponded to a photon energy range from 0.01 to 10.5 MeV. Furthermore, the report states that the energy yield per fission from photons below 0.01 MeV and above 10.5 MeV should be negligible. This information is presented in the report's Table VI-3, *Photon Yields per Fission*. The data from this table reaffirms that about 97% of photons from thermal fission of ^{235}U occur at photon energies less than 3 MeV.

The report further defines "prompt" for their spectrometer systems by coincidence resolving times to be in the range of 50-70 nanoseconds. This report is focused more on the types of detectors (spectrometers) used, more detailed background corrections, and the error propagation of the measuring method in order to more correctly predict total photon energy release per fission since previous attempts fell short of observed measurements.

After determining that there is sufficient evidence that the bulk of photon energies due to neutron fission falls below 3 MeV (justifying the use of the kerma approximation for absorbed dose), the final task is to ensure that there is no significant photon spectral "shift" for fission events based on fast metal systems in contrast to thermal moderated systems. Though no documentation was found as a result of a literature search and discussions with several experienced experimentalists and nuclear engineers, most were of the opinion that the increase in gamma energy as a result of fast neutron fission is not significant.

In support of this engineering judgment, it is well known that very little work has been done to determine the characteristics of prompt fission of nuclides other than ^{235}U . However, some studies have revealed that the prompt photon energy spectra from neutron fission of other nuclides such as ^{233}U , ^{239}Pu , and ^{252}Cf is very similar to that of ^{235}U (13). As a result, it is accepted practice to use the ^{235}U prompt photon spectrum for shielding applications involving these other isotopes. Similarly, the investigation and

documentation of the energy spectrum of prompt fission photons from fast metal accidents is probably very small; therefore, it is reasonable to assume the energy spectrum is very similar to that of thermal moderated accidents.

Therefore, it has been shown that there is sufficient evidence that the bulk of photon energies due to neutron fission falls below 3 MeV and that the use of the kerma approximation for absorbed dose is justified. In addition to the estimate that only 3% of the fission photons will have energy above 3 MeV, it is also expected that most of these energetic photons will slow down (by pair production and Compton scattering) before reaching the detector position, further justifying the use of the kerma approximation.

5.3 Source Term Development

The source term for particle transport code calculations is the input used to represent the source particles (e.g., neutrons, photons) emitted from a problem-dependent nuclear reaction (e.g., nuclear fission). The units for a source term are equal to the number of particles emitted per unit volume ($\#/cm^3$) in each energy group. When the source particles travel through a target thickness or problem geometry, the result is a particle fluence as a function of position and energy group through that geometry, in units of number of particles per unit area ($\#/cm^2$). If the source is emitting particles at a constant rate, then the result is a fluence rate or particle flux in units of number of particles per unit area per unit time ($\#/cm^2 \cdot s$).

For the validation problems reported in Section 6 of this report, the source particle type, number, and spectrum were specified for us. Therefore, our source term development effort was focused on determining the source for the criticality accident being considered in the vault analysis reported in Section 7.

An actual nuclear fission event occurs over an extended volume and is therefore difficult to model explicitly in the analysis. To simplify the model, a nuclear fission source is

often represented as a point source that emits the same type, number, and spectrum of particles as escapes from the actual accident event. This technique is valid as long as the detectors placed in the problem model are assumed to be at a sufficient distance from the source (typically 5-10 diameters) that the true accident source appears “point-like”.

The source term chosen for a certain shielding study should be consistent with the type of nuclear reactions and materials expected in the problem. For storage of fissile material without inherent hazards of loss of moderation control, a fast (as opposed to thermal) metal (as opposed to solution) nuclear criticality accident is the most likely type of accident. Prompt photons are generated with prompt nuclear fission of ^{235}U . Secondary or production photons are generated by neutron transport through other materials such as concrete and air. Therefore, the source term chosen should include both neutrons and photons. The source term group energy information is input in the DANTSYS/PARTISN transport code Block-V SOURCE array of the SOLVER module.

The source term was chosen based on the GODIVA experiment conducted at Los Alamos National Laboratory. GODIVA is a 52.42 kg enriched uranium (93.2 wt % ^{235}U) sphere with a radius of 8.741 cm. It was chosen because it closely resembles the type of nuclear criticality accident that is most likely in a highly enriched uranium storage vault with multiple failures in the form of loss of interaction and mass control, that is, assembly of multiple uranium parts. Loss of moderation control is a possibility in storage areas that are equipped with heat- or smoke-actuated water sprinkler systems, but other failures such as loss of interaction or mass control would also have to occur before a moderated nuclear criticality accident were considered very likely.

Several sources of information on GODIVA were reviewed before a final source term input file was chosen. These sources were:

#1: The input file for GODIVA which is provided for the HEU-MET-FAST-001 nuclear criticality benchmark experiment in the Office of Experimental Criticality Data

(OECD) published manuals of benchmarks (16). The input file included a uranium density of 18.74 g/cm^3 and an input radius of 8.7407 cm. The uranium mass of the assembly is 52.42 kg with a ^{235}U enrichment of 93.71 wt %. Per the benchmark, these specifications have been used for many years by various evaluators across the industry in validating nuclear data and codes (11). The only shortcoming of the data seems to be the omission of content for ^{236}U , which should be a small but significant constituent of the fuel.

#2: A version of GODIVA used by students in the NE 421 Introduction to Nuclear Engineering course at the University of Tennessee and was supplied in class notes. This input file is based on standard composition theoretical uranium density of 19.05 g/cm^3 , which is multiplied by 0.985 for a resulting uranium density of 18.76 g/cm^3 . The input file uses an input radius of 8.72 cm (probably found by a critical radius search). The uranium mass of the assembly is 52.1158 kg with a ^{235}U enrichment of 93.2 wt %, with contents of given for the uranium isotopes ^{234}U and ^{236}U .

#3: A version from the LANL DANTSYS 3.1 class training manual which uses GODIVA as an example problem for its students and is almost identical to the HEU-MET-FAST-001 input. This input file included a uranium density of 18.74 g/cm^3 and an input radius of 8.741 cm. The uranium mass of the assembly is 52.4337 kg with a ^{235}U enrichment of 93.71 wt %. The principle shortcoming of this input deck was the unphysical omission of any consideration of the expected ^{234}U and ^{236}U content.

#4: A mixture of sources #2 and #3 above to attempt to use the strengths of each: the critical dimensions and fuel density from #3 and the more physically reasonable isotopics from #2.

For each of these sources, the dimension, fuel density, and isotopics are given in Table 5-3, along with the k-effective estimates from various combinations of computer codes and

cross section libraries. All of the result k-effective eigenvalues are within 1.3% of critical.

Even though the ORNL version of GODIVA is closer to unity than the other two versions, the ORNL version was not chosen because its model parameters could not be confirmed. Therefore, the OECD benchmark version of GODIVA was chosen to extract the outside boundary leakage values and collapse them for creation of the source term input for a vault-type storage building model on the Manhattan.

Table 5.4 presents the outside boundary leakage values extracted from the OECD Benchmark of GODIVA. The 18 photon energy groups were collapsed into the 12 energy groups of the MENDFG photon cross section library, assuming that the source particles in each group are uniformly distributed across the group. Appendix B contains the input files from all four of the source term GODIVA models. The output from the OECD benchmark GODIVA model is also included.

Table 5-3. Comparative Results of Four GODIVA Models.

Category	LANL (srcterm1)	Student (srcterm2)	LANL/Student (srcterm3)	OECD (srcterm4)
²³⁵U Density	18.74 g/cm ³	18.76 g/cm ³	18.74 g/cm ³	18.74 g/cm ³
Radius	8.741	8.72	8.741	8.74141 cm
²³⁴U Isotopic	NA	1.0 wt %	1.0 wt %	1.02 wt %
²³⁵U Isotopic	93.7 wt %	93.2 wt %	93.7 wt %	93.7 wt %
²³⁶U Isotopic	NA	0.2 wt %	0.2 wt %	NA
²³⁸U Isotopic	6.3 wt %	5.6 wt %	5.6 wt %	5.27 wt %
CSAS1X K_{eff} Using 27n-18g Coupled Library Y-12 CMODB HP	1.00068	1.00138	1.0023	1.00485
ONEDANT K_{eff} Reported in OECD Using ENDF/B-IV 27 Group Library	1.0079	1.0079	1.0079	1.0079
ONEDANT K_{eff} Using MENDF5 Library Y-12 Manhattan (P3)	NA	NA	0.99035	1.0048
ONEDANT K_{eff} Using MENDF5 Library Y-12 Manhattan (P4)	NA	NA	NA	NA
ONEDANT K_{eff} Using MENDF6 Library Y-12 Manhattan (P3)	NA	0.9874	0.9885	NA
ONEDANT K_{eff} Using MENDF6 Library Y-12 Manhattan (P4)	NA	0.98702	NA	NA

Table 5-4. Outside Boundary Leakage Extracted from CSAS1X Output for Development of Source Term.

Photon Energy Group for Source Term	Source Value for Group for Source Term (photons/cm ² -s)	Upper Energy of group (MeV)	Photon Energy Group from Outside Boundary Leakage (RBL in output file)	Source Value for Group (from RBL in output file) (photons/cm ² -s)	Upper Energy of group (MeV)
1	4.409385E-8*	20	1	9.13699E-8	10
2	4.409385E-8	9	2	3.52715E-4	8
3	2.35945E-4	8	3	1.06940E-3	6.5
4	4.750756E-4	7	4	1.90944E-3	5
5	7.142066E-4	6	5	5.55783E-3	4
6	1.91204E-3	5	6	6.32565E-3	3
7	5.56546E-3	4	7	1.12292E-2	2.5
8	1.758498E-2	3	8	1.17675E-2	2
9	5.11491E-2	2	9	1.67855E-2	1.66
10	4.03269E-2	1	10	2.24965E-2	1.33
11	1.2259059E-2	0.5	11	1.58598E-2	1
12	2.921392E-5	0.1	12	1.68207E-2	0.8
		0.01	13	1.51351E-2	0.6
			14	3.62150E-3	0.4
			15	9.35242E-4	0.3
			16	1.12778E-4	0.2
			17	2.73780E-5	0.1
			18	1.78643E-6	0.05
					0.01

*Read as 4.409385x10⁻⁸

6.0 BENCHMARK CALCULATIONS FOR PARTISN/DANTSYS 3.1 CODE VALIDATION ON THE MANHATTAN

6.1 Shielding Reference Calculations

There are currently no OECD shielding benchmarks using either a Monte Carlo stochastic code package or a discrete ordinates code package. Therefore, to try to identify suitable benchmark problems for validation purposes, several standards and other references were reviewed: ANSI/ANS 6.6.1, other transport codes' sample problems, and the Kansas State University skyshine experiments conducted in 1977 (17), but never formally included in the OECD shielding benchmarks.

Research of possible shielding problems from national standards that would be suitable benchmarks included review of the ANSI/ANS 6.6.1 benchmark problems. These reference problems match several important characteristics of the CAAS vault analysis with DANTSYS 3.1/PARTISN 2.64: materials including air, ground, and a physical structure made of concrete, a point source term, and a particle detector. The geometry is also similar: photon point source either in free air or placed in the center of a thick-walled rectangular structure with no roof and detectors at various distances from the building.

Another set of photon experiments which were highly recommended because they had been modeled successfully using MCNP is the set of Kansas State University skyshine experiments performed in 1977 and reported in Nuclear Science and Engineering in 1992 (17). These experiments also are consistent with the vault problems materials: air, ground, and concrete. The geometry is also similar: concrete silo with various strength photon point sources, originally presented with no roof, 21 cm roof, and 42 cm roof, and detectors at various distances from the silo. (Unfortunately, in discussion with Dick Olsher, one of the original experimenters, the KSU skyshine experiments were never performed with the two roof thicknesses.)

A search of other literature regarding shielding benchmarks included the manual for the particle transport code COG, a code designed to solve the Boltzmann equation for deep penetration (shielding) problems developed by Thomas Wilcox and Edward Lent (18). COG includes a total of eight analytical and experimental comparison problems evaluating neutron transport, photon transport, and secondary photon production in shielding applications and one nuclear criticality problem. It also includes a wide variety of materials and geometries. Only a few were applicable to this work, but not as good a fit to the desired properties as the ones chosen from ANSI/ANS 6.6.1 and the Kansas State University Skyshine experiments; therefore, the COG benchmarks were not used.

The literature search also identified the Shielding Benchmark Problems published by Oak Ridge National Laboratory and the Radiation Shielding Information Center in July, 1974 (19). This set of benchmarks include a total of seven problems with a variety of materials, point sources, and plane sources. Materials included water, borated polyethylene, iron, thick sodium, air, and ground, only the last two of which were applicable to this work. As with the COG benchmarks, the RSIC 1974 benchmarks that used some applicable materials were not as good a fit as the ANSI/ANS 6.6.1 benchmarks or the KSU skyshine benchmarks. Therefore, the RSIC 1974 benchmarks were not used.

6.2. ANSI/ANS 6.6.1 Reference Calculations

Calculated data are presented in ANSI/ANS 6.6.1 (5) which can be compared with calculated data performed by individual investigators or analysts. The calculational methods used to obtain the results presented in ANSI/ANS 6.6.1 include Monte Carlo, discrete ordinates, point kernel, and numerical integration of parametric air-scattering data. All four reference calculations from the ANSI/ANS 6.6.1 are described below, but only Reference Calculation I.1 and I.2 are used as benchmarks in this work because they are consistent with the materials and geometry needed for the evaluation of the vault-type

storage building model. Solutions of the reference problems were provided by various members of the ANSI/ANS-6.6.1 Working Group.

Reference Calculations I.1. Problem I.1 is for a point isotropic source of ^{16}N gamma rays (6.2 MeV) with a source strength of 1 photon/sec. The point source is positioned at a height of 60 ft (18.3 m) above the air-ground interfaces. Detectors are at horizontal positions ranging from 200 ft (61 m) to 5000 ft (1,500 m) from the point source at a height of 3 ft (0.91 m) above grade. See Figure 6-1 for a graphical representation.

Reference Calculations I.2. Problem I.2 is for an ^{16}N point source of 1 photon/sec positioned within a building having 4 ft (1.22 m) thick concrete walls on all four sides with the source located in the center of the building at a height of 60 ft (18.3 m). The height of the concrete walls is 62 ft. (18.9 m), and the inside dimensions of the 4-wall building (no roof) are 100 ft (30.5 m) by 150 ft (45.7 m). Detectors are positioned as described above for Problem I.1. See Figure 6-2 for a graphical representation.

Reference Calculations II.1 Problem No. II.1 is for a cylindrical tank, 12 ft (3.7 m) in diameter and 35 ft (10.7 m) high, containing water with a uniformly-distributed source of 0.8 MeV photons. The volumetric source strength is assumed to be 30 MeV/cc-sec with the tank wall neglected. Dose rates are determined at a height of 3 ft (0.91 m) above grade at horizontal distances up to 1000 ft (305 m) from the axis of the tank. (See Figure 6.2 of the Standard for a graphical representation.) This problem is presented here for information only. It was not modeled in PARTISN 2.64/DANTSYS 3.1 for this work.

Reference Calculation II.2 Problem No. II.2 has the same geometry and source distribution as that described for Reference Calculation No. II.1 except that the tank is surrounded by a 35 ft (10.7 m) high annular concrete shield with a 2 ft (0.61 m) thickness. (See Figure 6.2 of the Standard for a graphical representation.) This problem is presented here for information only. It was not modeled in PARTISN 2.64/DANTSYS 3.1 for this work.

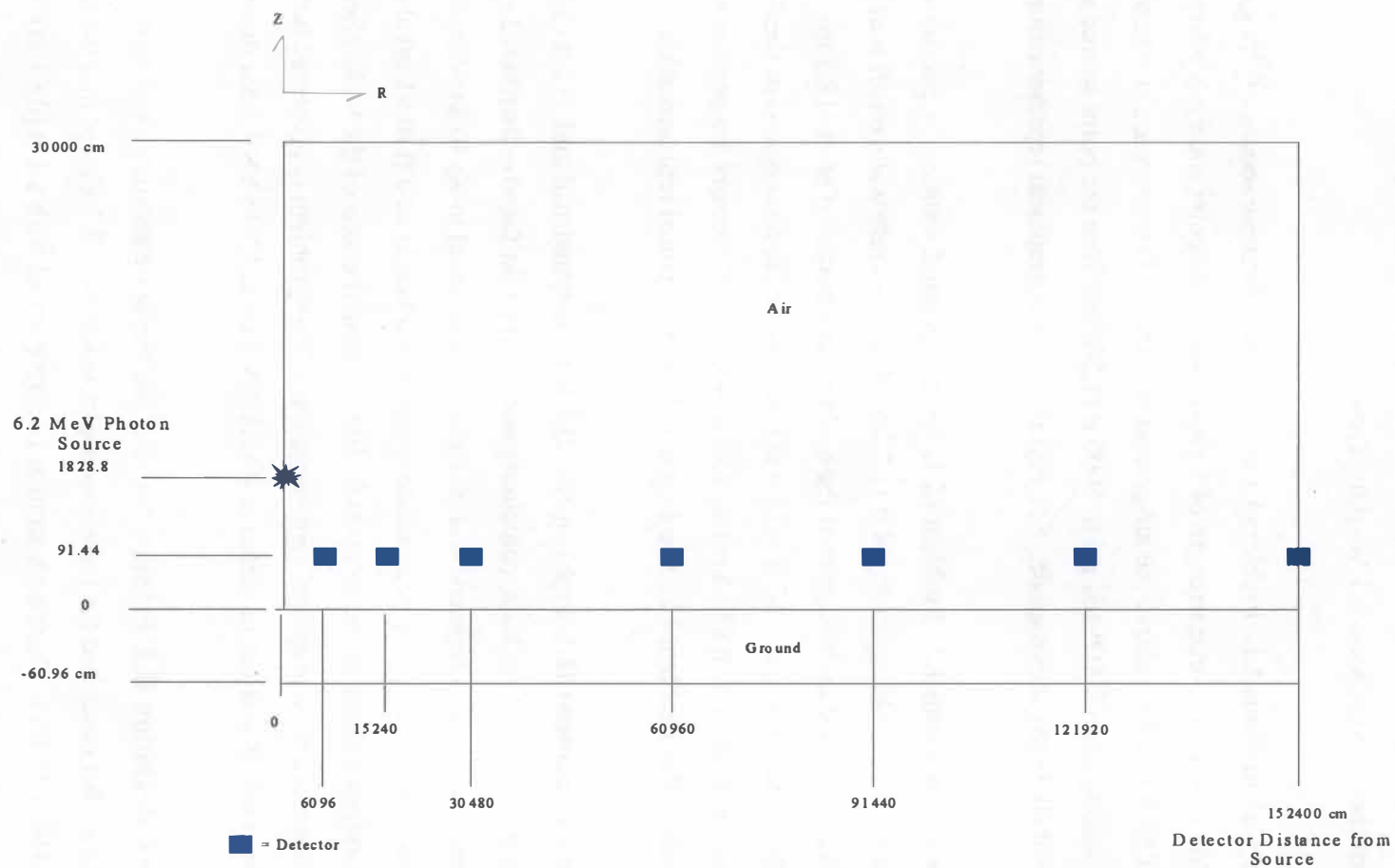


Figure 6-1. Two-Dimensional Cylindrical Configuration for Reference Calculations I.1 of ANSI/ANS 6.6.1.

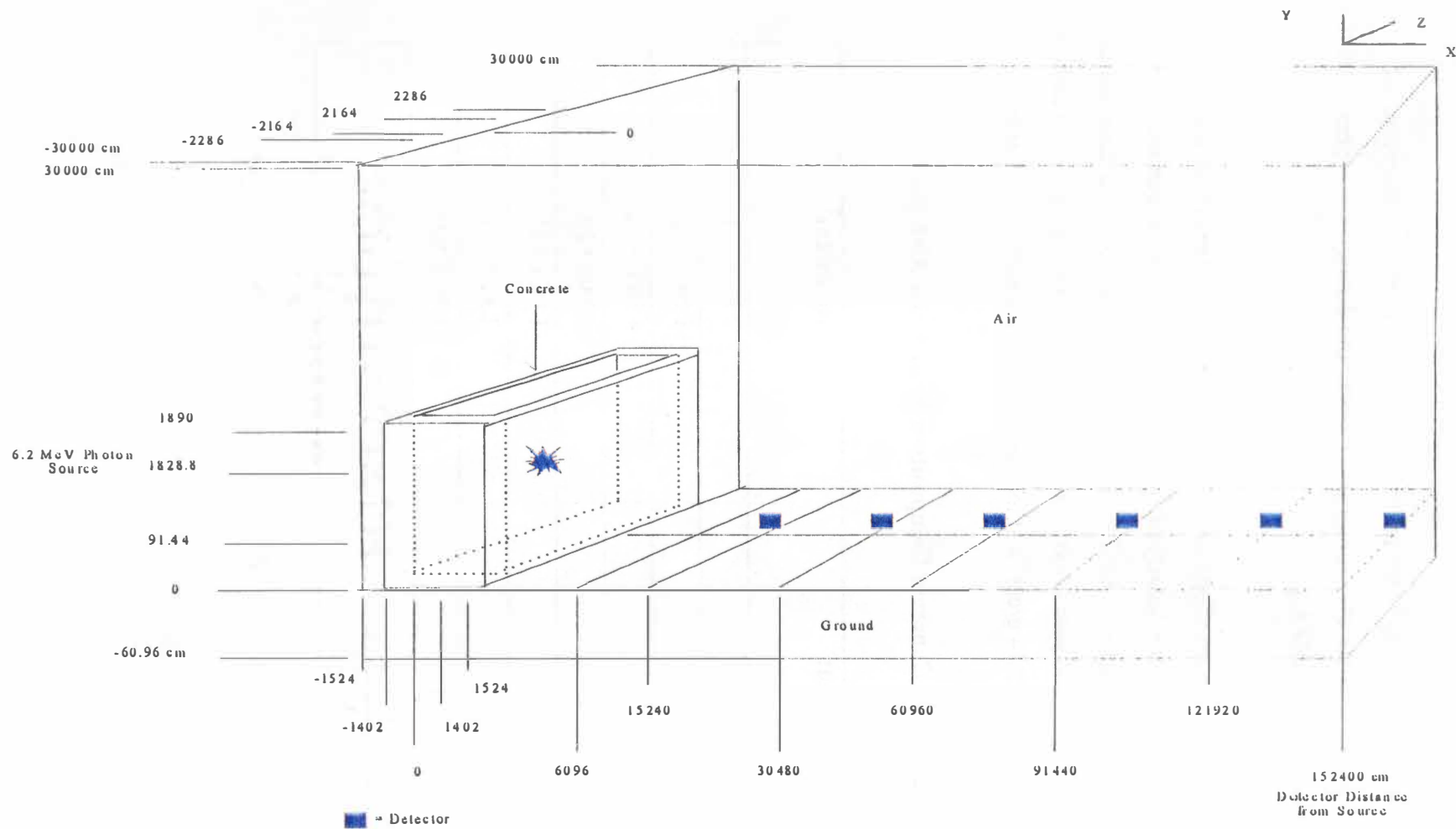


Figure 6-2. Three-Dimensional Configurations for Reference Calculations 1.2 of ANSI/ANS 6.6.1.

The density of water is 1.0 g/cm^3 with a number density of $6.69 \times 10^{22} \text{ atoms/cm}^3$ of hydrogen and $3.34 \times 10^{22} \text{ atoms/cm}^3$ of oxygen. The ground density is 1.7 g/cm^3 with the composition presented in Table 6-2.

For both of the reference calculations used for this work, the air density is taken to be $1.22 \times 10^{-3} \text{ g/cm}^3$ with a number density of $1.07 \times 10^{19} \text{ atoms/cm}^3$ of oxygen and $4.02 \times 10^{19} \text{ atoms/cm}^3$ of nitrogen. All dose rates are reported as absorbed dose rate in units of rads (in air)/yr. One year is assumed to be 8766 hr (24hr/day x 365.25 days/yr). The density of concrete is 2.34 g/cm^3 and its composition is presented in Table 6-1.

Table 6-1. Concrete Composition from ANSI/ANS 6.6.1.

Element	Atoms/cm ³
H	7.86 E+21
Si	1.58 E+22
O	4.38 E +22
K	6.90E+20
Na	1.05 E+21
Ca	2.92 E+21
Mg	1.40 E+20
Fe-10	3.10 E+20
Al	2.39E+21

Table 6-2. Ground Composition from ANSI/ANS 6.6.1.

Element	Atoms/cm³
H	9.77E+21
O	3.48E+22
Al	4.88E+21
Si	1.16E+22

6.2.1 Reference Problem I.1

The scattered and total absorbed dose rates in air for Reference Problem No. I.1 are functions of distance from the source. These results are presented in Table 6-3. The dose rates shown in Table 6-3 are for a detector elevation of 3 ft (0.91 m) above grade. The results shown were computed with the QADMOD, DOT-II, SKY-SHINE, SKREEN, COHORT-II, OGRE, and GGG computer programs.

The response functions used for this work are kerma/unit fluence which also has the units of absorbed dose but in Grays instead of rads.

Table 6-3 reports the comparison between the ANSI/ANS 6.6.1 shielding benchmark problem I.1 absorbed dose results and the computer calculated absorbed dose results. The uncollided flux using a point kernel method is also reported. Because of ray effects, in order for good agreement to occur, a first collision source treatment is applied to the two-dimensional r-z model. Because of the lack of a point analytical treatment availability for r-z geometry in PARTISN 2.64 which is run using multi-processors, a ray-tracing first collision source treatment is applied instead (20). This treatment uses ray tracing and stochastic techniques to generate an uncollided flux file. The uncollided flux file is used to create a first collision source which is then fed to the code discrete ordinate

solver as a distributed fixed source. The resulting flux distribution from the first collision source calculation is added to the uncollided flux distribution to get the total flux rate in each calculational cell. The detector response is calculated from this total flux distribution.

The ray-tracing first collision source treatment in PARTISN 2.64 has two options for running. The first is to generate the uncollided flux file with only one processor, and then to continue directly into the solver and edit modules using only one processor. This is done by assigning FCSRC=RAYTR, FCNRAY=10000 (default number of ray tracings per batch) and FCNTR=25 (default number of batches). The second option is to add FCRSTRT=2 in Block 5 with the first three commands. This option generates the uncollided flux file with one processor, then stops the run. The uncollided flux file is called up in a second run of the same input file, but uses multi-processors to complete the first collision source and distributed fixed source feed into the solver module.

For the second option, FCRSTRT=1 and FCNTR=0 to begin the solver and edit modules, but with FCSRC, FCNRAY edited out. Only option 1 is used for problem I.1.

The problem I.1 reference model is a 708 by 602 two-dimensional fine mesh size. After a single trial where the fine mesh distribution was adjusted and the number of inner iterations was set at 100, the calculation did not converge, but took over 100 hours to run using a single processor. A second trial was started with the number of inner iterations set at 200. This trial took over 150 hours to run using a single processor. Again, the calculation did not converge, but the values of the detector responses did not change. Because of a lack of time to finish a third trial to increase the number of inner iterations, the ANSI/ANS 6.6.1 Problem I.1 benchmark calculation reported in Table 6.3 is the unconverged second trial with 200 inner iterations. Even though the problem fluxes are not completely converged at all space points and energy groups, the detector responses have converged, matching the reference calculation result ranges within 15%.

**Table 6-3. Results Comparison Between ANSI/ANS 6.6.1 Reference Calculation I.1 as Modeled Using
THREEDANT—PARTISN 2.64/DANTSYS 3.1.**

Benchmark Problem I.1 Radius	Calculated Radius	Reference Calculation Problem I.1 Compilation of 7 Code Results Absorbed Dose	Hand Calculated Uncollided Flux (Point Kernel)		PARTISN Calculated Absorbed Dose W/out First Collision Source Treatment (12ANS6611.o)		PARTISN Calculated Absorbed Dose W/ First Collision Source Treatment (15ANS6611.o)	
			(rads/yr)	(% difference)	(rads/yr)	(% difference)	(rads/yr)	(% difference)
(ft)	(cm)	(rads/yr)						
200	6096	9.0E-11 to 1.0E-10	8.82E-11	2	8.25E-12	91	9.21E-11	within range
500	15240	1.5E-11	1.15E-11	23	2.47E-12	84	1.54E-11	2.7
1000	30480	2.5E-12	1.82E-12	27	5.95E-13	76	2.44E-12	-2.4
2000	60960	2.5E-13 to 3.5E-13	1.81E-13	28	9.96E-14	60	2.93E-13	within range
3000	91440	5.0E-14 to 7.5E-14	3.19E-14	36	2.28E-14	54	5.97E-14	within range
4000	121920	1.5E-14 to 2.0E-14	7.10E-15	53	6.49E-15	57	1.27E-14	within range
5000	152400	4.0E-15 to 6.0E-14	1.80E-15	55	1.71E-15	57	3.44E-15	-14

6.2.2 Reference Problem I.2

The scattered and total absorbed dose rates in air for Reference Problem I.2 are functions of distance from the source. These results are presented in Table 6-4. The dose rates in Table 6-4 are for a detector elevation of 3 ft (0.91 m) above grade. The results shown were computed with GGG, SKYSHINE, OGRE, SKREEN and QADF, and COHORT-II.

The ANSI/ANS 6.6.1 shielding benchmark problem I.2 is a 388 by 182 by 20 three-dimensional fine mesh size. As with the two-dimensional benchmark problem, because of ray effects, a first collision source treatment is applied to the three-dimensional x-y-z model. A point analytical treatment is available for x-y-z geometry in PARTISN 2.64 which uses multi-processors, but is not applied because its development is not complete. Instead, both options for the ray-tracing first collision source are used. Input file 8ANS6612 used the FCSRC=RAYTR option with one processor, but did not stop the run to restart with multi-processors. This run took over 280 hours to complete. Input file 9ANS6612 used the FCSRC=RAYTR option with one processor, but also used FCRSTRT=2 to stop the run and be restarted with multi-processors. This initial run, which generated the uncollided flux file with one processor, took about 68 hours. It was restarted to generate the first collision source and send the distributed fixed source to the solver module as input file 10ANS6612 with FCRSTRT=1 and FCNTR=0 using 32 processors. This run took about 35 hours to complete. Both sets of results are close, as reported in Table 6-4, although theoretically both sets of results should be identical.

All but one detector of the computer calculated results using the first collision source treatment show good agreement with the benchmark results. This is most likely due to continued ray effects, which would be nullified with a higher quadrature order. Even so, the calculated results with the first collision source treatment are somewhat of an improvement over the calculated results without the first collision source treatment. (The

improvement is not as dramatic as in Problem I.1, which is probably due to the concrete wall, which provides some scattering to mitigate the ray effects.)

**Table 6-4. Results Comparison Between ANSI/ANS 6.6.1 Reference Calculation I.2 as Modeled Using
THREEDANT–PARTISN 2.64/DANTSYS 3.1.**

Benchmark Problem I.2 Radius	Calculated Radius	Reference Calculation Problem I.2 Compilation of 5Code Results Absorbed Dose	PARTISN Calculated Absorbed Dose W/out First Collision Source Treatment (7ANS6612.o)		PARTISN Calculated Absorbed Dose W/ First Collision Source Treatment (1 processor) (8ANS6612.o)		PARTISN Calculated Absorbed Dose W/ First Collision Source Treatment (32 processors) (10ANS6612.o)	
(ft)	(cm)	(rads/yr)	(rads/yr)	(% difference)	(rads/yr)	(% difference)	(rads/yr)	(% difference)
200	6096	8.5E-13 to 2.0E-12	7.63E-12	282	5.56E-12	178	5.25E-12	163
500	15240	5.0E-13 to 8.0E-13	1.04E-12	30	9.93E-13	24	9.96E-13	25
1000	30480	1.8E-13 to 3E-13	3.78E-13	26	3.82E-13	27	3.84E-13	28
2000	60960	2.2E-14 to 6.0E-14	6.77E-14	13	6.99E-14	17	6.94E-14	16
3000	91440	8.0E-15 to 1.6E-14	2.11E-14	32	1.68E-14	5	1.67E-14	4.4
4000	121920	1.2E-15 to 5.0E-15	6.85E-15	37	5.07E-15	1.4	5.03E-15	0.6
5000	152400	7.0E-16 to 2.0E-15	2.15E-15	8	1.26E-15	Within range	1.27E-15	Within range

7.0 THREE-DIMENSIONAL EVALUATION OF A VAULT-TYPE STORAGE BUILDING ON THE MANHATTAN SUPERCOMPUTER USING PARTISN 2.64/DANTSYS 3.1

7.1 Model

7.1.1 CAAS Detectors

The CAAS detectors used in the proposed building design are photon rate meters which have the alarm set point set at 30 millirads per hour. Therefore, the only interactions of interest between the fission source (nuclear criticality accident) and the detector are prompt gammas coming directly from fission and those interactions which generate photons such as (n, gamma) reactions with surrounding materials.

7.1.2 Fission Source and CAAS Detector Placement

The fission source is modeled in the center of a 15-foot corridor in between two adjacent vaults 25 cm from the floor (21). The first detector is modeled 508 cm from the floor in the corridor running perpendicular to the corridor between the two adjacent vaults but placed at the far end of the corridor. The second detector is also modeled 508 cm from the floor in the corridor running perpendicular to the corridor between the two adjacent vaults, but immediately in front of the corridor between the two adjacent vaults. See Figures 7-1 and 7-2 for details.

7.2 Analytical Method

7.2.1 Standards and Guidance

ANSI/ANS 8.3 does not require a CAAS for areas containing fissile material as long as:

- 1) the total amount of fissile material present does not exceed 700 grams of ^{235}U ;
- or

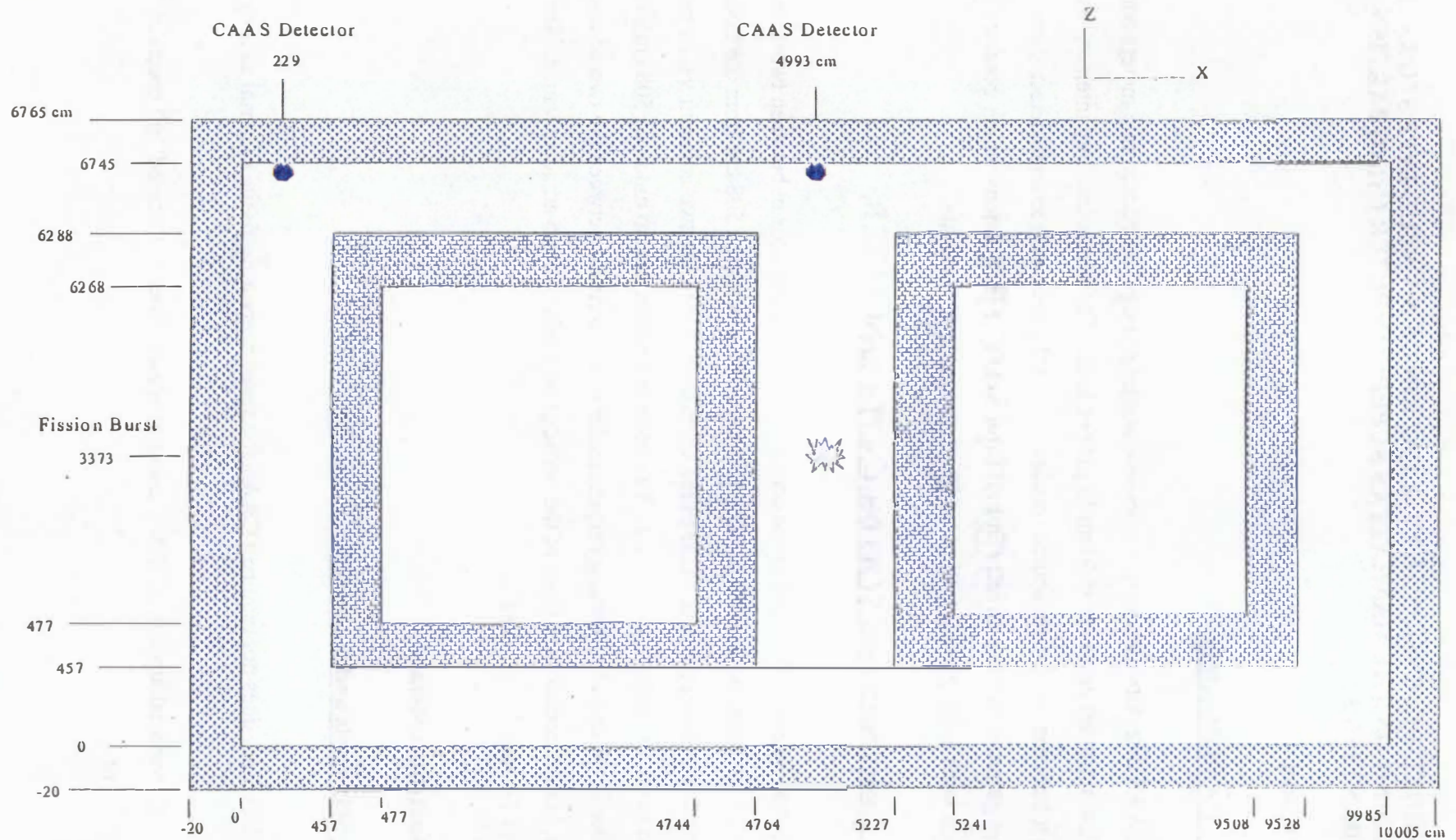


Figure 7-1. Two Dimensional View of X-Y-Z Geometry of Vault-Type Storage Building.

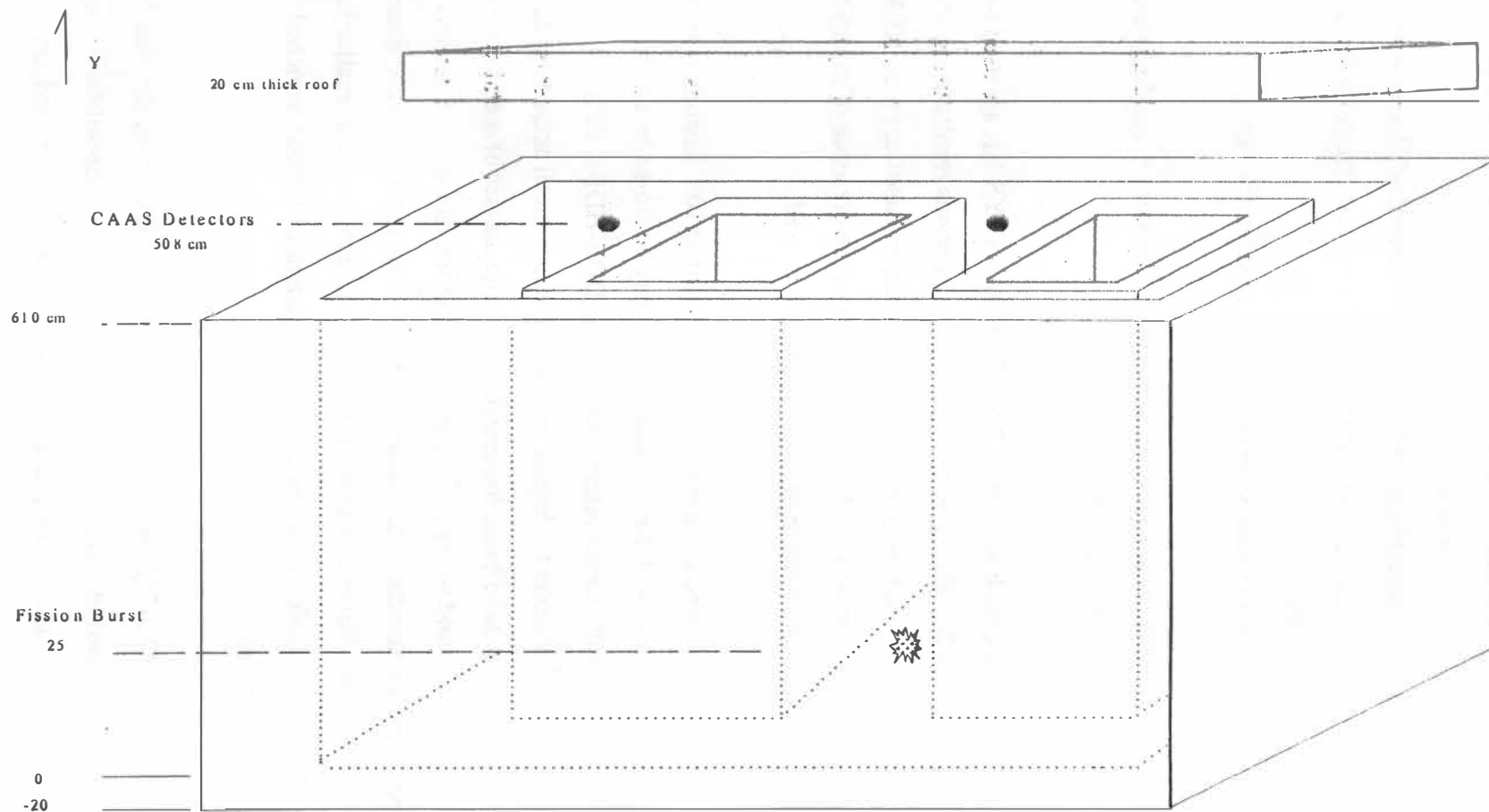


Figure 7-2. Three-Dimensional View of X-Y-Z Geometry of Vault-Type Storage Building.

- 2) the physical form of the fissile material present is such that a nuclear criticality accident is not possible; or
- 3) a Probabilistic Risk Assessment (PRA) has been performed, documented, and approved by DOE which shows that the risk of a nuclear criticality accident is less than 10^{-6} per year; or
- 4) the expected dose in the area will not exceed 12 rads in free air.

However, none of these conditions are assumed to be met in the storage building design modeled for this work; therefore, a CAAS is required.

Discrete ordinate calculations, such as in PARTISN 2.64/DANTSYS 3.1, are used to model the simple storage vault building in order to confirm previous results using Monte Carlo shielding calculations. Fluence to dose conversion factors based upon air KERMA fluence data for photons is taken from ICRU-57. Because of the presence of ray effects in the model, a ray-tracing first collision source treatment was used.

It is postulated in previous documents that a burst in excess of 1×10^{18} fissions is expected for a nuclear criticality accident with fissile material that may be stored in a highly enriched uranium storage vault. Other references, such as DOE-HDBK-3010-94 postulates a burst of 3×10^{19} fissions for highly enriched uranium metal accidents (22). However, the excursions that have been documented for large masses of metal systems in DOE-HDBK-3010-94 are bound by 1×10^{17} fissions. Therefore, as long as a detector system can detect a smaller accident that would yield a burst of 1×10^{17} fissions, it can detect a larger burst as well. For this reason, it is conservative to choose a smaller fission source of 1×10^{17} fissions to model a nuclear criticality accident in a highly enriched uranium storage configuration.

The concrete modeled in Y/DD-735 for large storage pallets is taken from the shielding benchmark problems discussed in ANSI/ANS 6.6.1 (1987). This composition is used because the design of the storage building and its contents is preliminary, and any

materials used for construction of large storage pallets will have similar characteristics to materials used in modeling concrete walls, firewalls, ceilings, and floors. These characteristics include similar scattering properties and similar densities. However, concrete used for large storage pallets will most likely contain a neutron absorber and be slightly less dense than the concrete modeled in Y/DD-735. Therefore, using the concrete composition is a conservative treatment of any large storage pallets that end up in the final storage design.

7.2.2 Materials

The air composition is 9.6533×10^{-6} atoms/b-cm oxygen and 4.1425×10^{-5} atoms/b-cm nitrogen. The concrete composition used for the PARTISN calculations is shown in Table 7-1.

7.3 Results

Table 7.2 shows the results of the calculations and compares them to the previous Monte Carlo shielding calculations. Note that the MCNP results include the effect of time (i.e., the results are in dose per unit time). Inclusion of this effect means that the time characteristic of the detector response from a prompt burst has been somehow taken into account. The PARTISN results, however, do not have time rates in them, but are presented as time-integrated dose. Actual determination of whether the detectors will respond requires that these time issues be addressed. It is also a possibility that an insufficient number of iterations in MCNP run or ray effects in the PARTISN run will affect the prompt photon dose.

Appendix A contains the input and (abridged) output files for the PARTISN 2.64/DANTSYS 3.1 calculations.

Table 7-1. Concrete Composition for Simple Storage Model.

Element	Element Identifier	Number Density (atoms/b·cm³)
Hydrogen	1001.50	1.4660E-1
Oxygen	8016.50	5.1465E-2
Sodium-23	11023.50	8.5857E-4
Magnesium	12000.50	1.0828E-4
Aluminum-27	13027.50	1.6651E-3
Silicon	14000.50	1.0575E-2
Potassium	19000.50	3.3176E-4
Calcium	20000.50	1.3696E-3
Iron	26000.55	1.0435E-4

Table 7-2. Comparison of PARTISN Calculational Results to MCNP Calculational Results for Simple Storage Vault Model with a 10^{17} Fast Fission Accident.

Calculated Detector Radius from Inside wall-X	Calculated Detector Height from Floor-Y	MCNP Calculational Results Absorbed Dose (Prompt)	PARTISN Calculated Absorbed Dose W/out First Collision Source Treatment (2mod2.o)	PARTISN Calculated Absorbed Dose W/out First Collision Source Treatment (Based on 10^{17} fissions, 7.2 photons/fission) (2mod2.o)	PARTISN Calculated Absorbed Dose W/out First Collision Source Treatment (Based on 10^{17} fissions, 7.2 photons/fission) (2mod2.o)
(cm)	(cm)	(Roentgen/hr)	(pGy/fission photon)	(Roentgen)	(mrad)
229	251	NA	1.83E-11	1.16E-03	1.33E+00
229	508	0	2.89E-11	1.83E-03	2.10E+00
229	600	NA	1.73E-11	1.09E-03	1.26E+00
1906	251	NA	1.28E-10	8.09E-03	9.30E+00
1906	508	NA	2.88E-10	1.82E-02	2.09E+01
1906	600	NA	1.60E-10	1.01E-02	1.16E+01
3314	251	NA	3.34E-10	2.11E-02	2.43E+01
3314	508	NA	5.67E-10	3.58E-02	4.12E+01
3314	600	NA	3.24E-10	2.05E-02	2.35E+01
4993	251	NA	2.04E-9	1.29E-01	1.48E+02
4993	508	4.2	5.18E-9	3.27E-01	3.76E+02
4993	600	NA	4.19E-9	2.65E-01	3.04E+02

8.0 CONCLUSIONS

8.1 Demonstration of Method Using PARTISN 2.64 on the Manhattan

The successful installation of the multi-processor transport code on the Manhattan demonstrates that the code is a viable tool for use at Y-12 for shielding calculations. The demonstration of good agreement between reference benchmarks and calculated results on the Manhattan using a well-accepted standard such as ANSI/ANS 6.6.1 further proves that the transport code is dependable for producing accurate results for further shielding studies at Y-12.

8.2 CAAS Detector Placement

The goal in determining detector placement is to ensure that the calculated photon dose rates from the prompt and (n, gamma) contributions exceed the CAAS detector alarm set point of 30 mR/hr (millirad/hr) even in the presence of massive shielding. If the prompt photon contribution alone exceeds the CAAS detector alarm set point, then a conservative approach is valid, and it is possible that the total number of CAAS detectors in the building may be reduced.

If prompt photon contribution alone does not exceed the CAAS detector alarm set point, then the (n, gamma) contribution must be included and it may not be possible to reduce the number of CAAS detectors. In the results reported in Table 7-2, the prompt photon contribution alone exceed the CAAS detector alarm set point, and the (n, gamma) contribution is not necessary.

9.0 FUTURE WORK

Future work should include the continuation of the validation of the ANSI/ANS 6.6.1 I.1 and I.2 benchmark reference problems. The I.2 benchmark should be run with a point analytical first collision source treatment to verify the adequacy of the treatment to nullify ray effects in three-dimensional geometry once the code developers have revisited the application.

Future work should also include the validation of more experimental benchmarks on the Manhattan, including the completion of the validation of the KSU Skyshine Experimental Benchmarks as the use of PARTISN 2.64/DANTSYS 3.1 develops into a production code and is used by the Nuclear Criticality Safety staff in shielding studies. This is a very important facet of the modernization of the Y-12 National Security Complex. To have a broader set of experimental benchmarks will enable Y-12 to continue performing its own shielding studies and have ownership of design and change control as facilities and processes change with time. Appendix C includes initial information, tables and figures to be used for completion of the validation.

Future work should also include two-dimensional evaluations of vault-type storage building with simplified geometry using the PARTISN 2.64/DANTSYS 3.1 code package, and to evaluate the more complex three-dimensional pallet storage vault model for confirmation with previous MCNP calculational studies. In addition, for analysis of detector placement outside fissile storage vaults, neutron dose rates should be calculated for accidents occurring in corridors and operating areas outside of the storage vaults. This should be considered because there will not be significant shielding or opportunity for neutron capture as much as inside the storage vault. The limitation to this consideration would be to assign any neutron traveling in excess of three mean free paths into a surrounding wall to neutron capture and not able to contribute to the final neutron dose rate.

There are two basic considerations to the method of calculating detector placement in the proposed pallet-storage design. These are 1) where to place detectors inside the fissile storage vaults where the pallets are stored, and 2) where to place detectors outside fissile storage vaults where transfer and handling of fissile material and other operations such as repackaging occur. For both, the prompt gamma dose rate and the secondary gamma dose rate due to (n, gamma) reactions should be calculated. Also, inside the vault, the streaming of photons in the air gap between the top of the pallet storage in the vault and the ceiling should also be analyzed since this is considered to be a probable significant contributor to the downstream dose rate. Appendix D includes initial information, tables and figures to be used for completion of the confirmatory studies.

It is highly desirable to add other tools to the toolbox for future shielding analysts to use. The first addition is the installation, verification, and validation of the discrete ordinate transport code package DOORS which is developed at Oak Ridge National Laboratory. DOORS contains the two-dimensional code module DORT and the three-dimensional code module TORT. Because these are run only on a single processor, it is also desirable to add any future code developments to DOORS that enable DORT and TORT to be run on a multi-processor platform.

One of the most important goals for users of PARTISN 2.64/DANTSYS 3.1 on the Manhattan should be to add BUGLE-96 cross section libraries to the validation as well as MENDF5G coupled neutron-gamma cross section libraries. Using a coupled cross section library may enable shielding analysts to justify reducing the number of required CAAS detectors once the production photon fragment of the source term is included.

LIST OF REFERENCES

LIST OF REFERENCES

1. ANSI/ANS 8.3, *Criticality Accident Alarm Systems* (1997), American Nuclear Society, 555 North Kensington Avenue, LaGrange Park, Illinois, 60525, American National Standards Institute, Inc. 5/28/97.
2. DOE Order 420.1, *Facility Safety*, Office of Environment, Safety and Health, U. S. Department of Energy, Washington, D. C., November 22, 2000.
3. ANSI/ANS 6.6.1, *Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants* (1987), American Nuclear Society, 555 North Kensington Avenue, LaGrange Park, Illinois, 60525, American National Standards Institute, Inc. 6/24/87.
4. DANTSYS 3.1, *One-, Two- and Three-Dimensional Multigroup Discrete Ordinates Transport Code System*, CCC-547, contributed by Los Alamos National Laboratory as LA-12969-M, Los Alamos New Mexico, distributed by the Radiation Safety Information Computational Center (RSICC), Oak Ridge National Laboratory, Oak Ridge, Tennessee, March, 1997.
5. DOORS 3.1, *One-, Two-, and Three-Dimensional Discrete Ordinate Neutron/Photon Transport Code System*, CCC-650, contributed by Oak Ridge National Laboratory, Oak Ridge, Tennessee, distributed by the Radiation Safety Information Computational Center (RSICC), Oak Ridge National Laboratory, Oak Ridge, Tennessee, August, 1996.
6. *Gamma Alarm System NMC Model GA-6*, Part No. 0002062-9, Model No. GA-6-1-2-3-3-1-1S-05S, Nuclear Measurements Corporation (NMC) Nuclear Instrumentation, P.O. Box 18248, Indianapolis, Indiana, 42618, 10/23/86.
7. Duderstadt, J.J., Hamilton, L.J., *Nuclear Reactor Analysis*, Department of Nuclear Engineering, University of Michigan, Ann Arbor, 1976.
8. BUGLE-96, *Coupled 47 Neutron, 20 Gamma-Ray Group Cross Section Library Derived from ENDF/B-VI for Light Water Reactor Shielding and Pressure Vessel Dosimetry Applications*, DLC-185, distributed by the Radiation Safety Information Computational Center (RSICC), Oak Ridge National Laboratory, Oak Ridge, Tennessee, July, 1999.
9. Paschal, Lane, *Verification and Validation of DANTSYS on the Y-12 HP Workstation* (U), Oak Ridge Y-12 Plant, July, 1995.

LIST OF REFERENCES (continued)

10. ANSI/ANS 6.1.1, *Neutron and Gamma-Ray Fluence-to-Dose Factors* (1991), American Nuclear Society, 555 North Kensington Avenue, LaGrange Park, Illinois, 60525, American National Standards Institute, Inc., 8/26/91.
11. *Conversion Coefficients for use in Radiological Protection Against External Radiation*, ICRU-57, International Commission on Radiation Units and Measurements, Bethesda, Maryland, August 1, 1998.
12. Cember, Herman, *Introduction to Health Physics*, Pergamon Press, 1983.
13. *Reactor Handbook, Shielding*, Volume III, Part B, USAEC, Second Edition, Interscience Publishers, 1962.
14. Profio, A. E., *Radiation Shielding and Dosimetry*, Wiley-Interscience, 1979.
15. Peelle, R. W., Maienschein, F. C., *The Absolute Spectrum of Photons Emitted in Coincidence with Thermal-Neutron Fission of Uranium-235*, ORNL-4457, Oak Ridge National Laboratory, April, 1970
16. LaBauve, R. J., Los Alamos National Laboratory, HEU-MET-FAST-001, *GODIVA*, Organization for Economic Cooperation and Development (OECD) International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95) 03/II, Volume II, Revision 0, March 31, 1995.
17. Olsher, R.H., Hsu, Hsiao-Hun, Harvey, W.F., *Benchmarking the MCNP Monte Carlo Code with a Photon Skyshine Experiment*, Nuclear Science and Engineering, Volume 114, pg 219-227, 1993.
18. Wilcox, Jr., Thomas P. and Len, Edward M., *COG—A Particle Transport Code Designed to Solve the Boltzmann Equation for Deep-Penetration (Shielding) Problems*, M-221-4, Volume 4 Benchmark Problems, Lawrence Livermore National Laboratory, December 2, 1988.
19. *Shielding Benchmark Problems*, ORNL-RSIC-25, ANS-SD-9, Oak Ridge National Laboratory, Radiation Shielding Information Center, 7/74.
20. Baker, R. S., *A Stochastic First Collision Source for TWODANT*, LA-UR-94-176, Los Alamos National Laboratory, Los Alamos, New Mexico, 87545, submitted to Eighth International Conference on Radiation Shielding, April 24-27, 1994, Arlington, Texas.

LIST OF REFERENCES (continued)

21. Lewis, K.L., *Preliminary Plan for Placement of CAAS Detectors in the HEUMF Facility* (U), Y/DD-935, Revision 1, November 2000, Y-12 National Security Complex. (Unclassified Controlled Nuclear Information)
22. DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Volume 1—Analysis of Experimental Data, U. S. Department of Energy, Washington, D. C., 20585, December, 1994.

APPENDICES

APPENDIX A: PARTISN 2.64/DANTSYS 3.1 Input/Output Files

```

3      0      0
ANS 6.6.1-1987 Problem I.1 TWODANT 1 gamma/s N-16 (6.2 MeV), iso. pt source
1828.8 cm above ground; det 91.44 cm above grnd and horiz.@ 6096cm & 1.524e5cm
12ans6611.inp/12ans6611.o
/ geometry      - r-z
/ cross sections - MENDFG, xslibb.mendfg, 12 gamma energy groups only
/ mixing        - isotopes mixed to make materials named air
/              and ground
/ solver        - S16-P4, source in group 4, first collision source
/ edits        - card input supplied
/
/ block i
  igeom=7, ngroup=12, isn=16 niso=99 mt=2 nzone=2
  im=15 it=708 jm=8 jt=602
  maxscm=16000000 maxlcm=34000000 t
/
/ block ii (geometry)
  xmesh= 0.0 10.0 6091,6101, 15235, 15245, 30475, 30485,
        60955, 60965, 91435, 91445, 121915, 121925, 152395, 152405
  xints= 1, 100, 1, 100, 1, 100, 1, 100, 1, 100, 1, 100, 1, 100, 1
  ymesh= -60.96, 0.0, 86.44, 96.44, 1824.0, 1834.0 3000.0, 6000.0, 30000.0
  yints= 40, 10, 1, 100, 1, 50, 100, 300
  zones= 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 t
/
/ block iii (cross sections)
  lib=xslibb savbxs=1 /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=dirt "1001.50" 9.77-3 /H
            "8016.50" 3.48-2 /O
            "13027.50" 4.88-3 /Al
            "14000.50" 1.16-2; /Si
  air1 "8016.50" 1.07-5 /O
       "7014.50" 4.02-5; /N

```

```

      /conc  1001.50  7.86-3  /H
      /      8016.50  4.38-2  /O
      /      11023.50 1.05-3  /Na
      /      12000.50 1.40-4  /Mg
      /      13027.50 2.39-3  /Al
      /      14000.50 1.58-2  /Si
      /      19000.50 6.90-4  /K
      /      20000.50 2.92-3  /Ca
      /      26000.55 3.10-4;  /Fe
assign=ground dirt 1.0;      /zone 1
      air      airl 1.0  t      /zone 2
      /concrete conc 2.34
/
/ block v (solver)
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
  levt=0 iitm=100 oitm=50 isct=4 ibr=0 ibt=0 ibb=0
  norm=1.0 fluxp=1 xsctp=0 sourcp=1 balp=0
/ energy grp (4 of 12) for the 6.2 Mev photon/s src. use whenfcsrc=ana:
  source= 0,0,0,1,f0
/ fine mesh location on the x axis (r) of the point source:
  sourcx= 1, f0
/ fine mesh location on the z axis of the point source:
  sourcy= 152z, 1, f0
  /fcsrc=ptana
  /fcxpos=1
  /fcypos=148
  t
/
/
/ * * * * block vi (edits) * * * *
  pted=1 zned=1 igrped=3
/ use (j-1)NX + i j=jm=51;NX=708; i=im=102,203,304,405,506,607,708
  points=35502, 35603, 35704, 35805, 35906, 36007, 36108
/ Resp fcns in Air Kerma/unit Fluence in pGy/cm^2 for 12 energy groups:
  rsfe=23.025, 21.075, 19.1, 17.1 15.1, 13.1,
  11.03 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

```

      3      0      0
ANS 6.6.1-1987 Problem I.1 TWODANT 1 gamma/s N-16 (6.2 MeV), iso. pt source
1828.8 cm above ground; det 91.44 cm above grnd and horiz.@ 6096cm & 1.524e5cm
15ans6611.inp
/ geometry      - r-z
/ cross sections - MENDFG, xslibb.mendfg, 12 gamma energy groups only
/ mixing        - isotopes mixed to make materials named air
/               and ground
/ solver        - S16-P4, source in group 4, first collision source
/ edits         - card input supplied
/
/ block i
  igeom=7, ngroup=12, isn=16 niso=99 mt=2 nzone=2
  im=15 it=708 jm=8 jt=602
  maxscm=16000000 maxlcm=34000000 t
/
/ block ii (geometry)
  xmesh= 0.0 10.0 6091,6101, 15235, 15245, 30475, 30485,
        60955, 60965, 91435, 91445, 121915, 121925, 152395, 152405
  xints= 1, 100, 1, 100, 1, 100, 1, 100, 1, 100, 1, 100, 1
  ymesh= -60.96, 0.0, 86.44, 96.44, 1824.0, 1834.0 3000.0, 6000.0, 30000.0
  yints= 40, 10, 1, 100, 1, 50, 100, 300
  zones= 1 1 1 1 1 1 1 1 1 1 1 1 1;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 t
/
/ block iii (cross sections)
  lib=xslibb savbxs=1 /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=dirt "1001.50" 9.77-3 /H
            "8016.50" 3.48-2 /O
            "13027.50" 4.88-3 /Al
            "14000.50" 1.16-2; /Si
  air1 "8016.50" 1.07-5 /O
       "7014.50" 4.02-5; /N

```

```

      /conc  1001.50  7.86-3  /H
      /      8016.50  4.38-2  /O
      /      11023.50 1.05-3  /Na
      /      12000.50 1.40-4  /Mg
      /      13027.50 2.39-3  /Al
      /      14000.50 1.58-2  /Si
      /      19000.50 6.90-4  /K
      /      20000.50 2.92-3  /Ca
      /      26000.55 3.10-4; /Fe
assign=ground dirt 1.0;      /zone 1
      air      airl 1.0      t      /zone 2
      /concrete conc 2.34
/
/ block v (solver)
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
  ievt=0 iitm=200 oitm=50 isct=4 ibr=0 ibt=0 ibb=0
  norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0
/ energy grp (4 of 12) for the 6.2 MeV photon/s src. use whenfcsrc=ana:
  source= 0,0,0,1,f0
/ fine mesh location on the x axis (r) of the point source:
  sourcx= 1, f0
/ fine mesh location on the z axis of the point source:
  sourcy= 152z, 1, f0
  fcsrc=raytr
  fcrray=10000
  fcctr=25
  t
/
/
/ * * * * block vi (edits) * * * *
  pted=1 zned=1 igrped=3
/ use (j-1)NX + 1 j=jm=51;NX=708; i=im=102,203,304,405,506,607,708
  points=35502, 35603, 35704, 35805, 35906, 36007, 36108
/ Resp fcns in Air Kerma/unit Fluence in pGy/cm^2 for 12 energy groups:
  rsfe=23.025, 21.075, 19.1, 17.1 15.1, 13.1,
  11.03 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

```

3      0      0
ANS 6.6.1-1987 Problem I.2 THREEDANT 1 gamma/s N-16 (6.2 MeV), pt, isotropic
1828.8 cm above ground, in conc bldg detectors 91.44 cm above ground and
horizontally at 6096 cm and 1.524e5 cm 7ans6612.inp PARTISN
/ geometry - X-Y-Z
/ cross sections - MENDFG, xslibb.mendfg
/ mixing - isotopes mixed to make materials named air and ground
/ solver - S16-P4, source in group 4, fcsrc=ptana
/ edits - card input supplied
/
/ block i
  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=3 nzone=3
  im=19 it=390 jm=11 jt=87 km=8 kt=24
  maxscm=44000000 maxlcm=220000000 t
/
/ block ii (geometry)
  xmesh=-1524, -1402, -5,5, 1402, 1524, 6046,6146, 15190,15290, 30430,30530
        60910,61010, 91390,91490, 121870,121970, 152350,152450
  xints= 1, 20, 1, 20, 1, 10, 1, 40,1, 50,1, 60,1, 60,1, 60,1, 60,1
  ymesh=-60.96, 0.0, 86.44,96.44, 1824,1834, 1890, 3000, 6000, 12000,
        18000, 30000
  yints= 2, 2, 1, 40, 1, 1, 10, 6, 6, 6, 12
  zmesh=-30000, -6000, -2286, -2164, 0.0, 2164, 2286, 6000, 30000
  zints= 6, 3, 1, 2, 2, 1, 3, 6
  zones= 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=1-6, j=11-1, i=1-19:
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /first face of model
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=7-9, j=11-1, i=1-19:
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /second face of model
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=10, j=11-1, i=1-19:
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /third face of model
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=11-12
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fourth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
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2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=13-14
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fifth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=15,
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /sixth face of model

```

```

3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=16-18,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /seventh of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=19-24,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /last face of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; t

/
/ block iii (cross sections)
lib=xslibb savbxs=1 /first cp xslibb.mendfg xslibb
t
/
/ block iv (mixing)
matspec=atdens /atomic density= atoms/b*cm
matls=dirt "1001.50" 9.77-3 /H
"8016.50" 3.48-2 /O
"13027.50" 4.88-3 /Al

```

```

        "14000.50" 1.16-2; /Si
    air1 "8016.50" 1.07-5 /O
        "7014.50" 4.02-5; /N
    conc "1001.50" 7.86-3 /H
        "8016.50" 4.38-2 /O
        "11023.50" 1.05-3 /Na
        "12000.50" 1.40-4 /Mg
        "13027.50" 2.39-3 /Al
        "14000.50" 1.58-2 /Si
        "19000.50" 6.90-4 /K
        "20000.50" 2.92-3 /Ca
        "26000.55" 2.10-4; /Fe
    assign=ground dirt 1.0; /zone 1
        air air1 1.0; /zone 2
        concrete conc 1.0 t /zone 3
/
/ block v (solver)
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
    ievt=0 iitm=200 oitm=60 isct=4 ibb=0 ibt=0 ibl=0 ibr=0 ibback=0
    norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0 ibfrnt=0
/ energy grp (4 of 12) for the 6.2 MeV photon/s src. use whenfcsrc=ana:
    source= 0,0,0,1,f0
/ fine mesh location on the x axis of the point source:
    sourcx= 21z, 1, f0
/ fine mesh location on the y axis of the point source:
    sourcy= 45z, 1, f0
/ fine mesh location on the z axis of the point source:
    sourcez= 11z, 1, f0
    /fcsrc=ptana
    /fcxpos=0 /source position in cm
    /fcypos=1829 /source position in cm
    /fczpos=0 /source position in cm
    t
/
/ * * * * block vi (edits) * * * *
    pted=1 zned=1 igrped=3
/ use i+(j-1)NX+(k-1)NXNY; j=jt=5; k=kt=12 NX=IT=390; NY=JT=87
/ i=im=54, 95, 146, 207, 268, 329, 390
    points=374844, 374885, 374936, 374997, 375058, 375119, 375180 /j=5
        395092, 395124, 395165, 395216, 395277, 395338, 395399, 395460 /j=57
        397432, 397464, 397505, 397556, 397617, 397678, 397739, 397800 /j=63

```

399772,399804,399845,399896,399957,400018,400079,400140 /j=69
402112,402144,402185,402236,402297,402358,402419,402480 /j=75
406792,406824,406865,406916,406977,407038,407099,407160 /j=87
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1
11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t


```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=10, j=11-1, i=1-19:
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /third face of model
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=11-12
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fourth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=13-14
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fifth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=15,
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /sixth face of model

```

```

3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=16-18,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /seventh of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=19-24,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /last face of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

/
/ block iii (cross sections)
lib=xslibb savbxs=1 /first cp xslibb.mendfg xslibb
t
/
/ block iv (mixing)
matspec=atdens /atomic density= atoms/b*cm
matls=dirt "1001.50" 9.77-3 /H
"8016.50" 3.48-2 /O
"13027.50" 4.88-3 /Al

```

```

        "14000.50" 1.16-2; /Si
    airl "8016.50" 1.07-5 /O
        "7014.50" 4.02-5; /N
    conc "1001.50" 7.86-3 /H
        "8016.50" 4.38-2 /O
        "11023.50" 1.05-3 /Na
        "12000.50" 1.40-4 /Mg
        "13027.50" 2.39-3 /Al
        "14000.50" 1.58-2 /Si
        "19000.50" 6.90-4 /K
        "20000.50" 2.92-3 /Ca
        "26000.55" 2.10-4; /Fe
    assign=ground dirt 1.0; /zone 1
        air airl 1.0; /zone 2
        concrete conc 1.0 t /zone 3
/
/ block v (solver)
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
    ievt=0 iitm=200 oitm=60 isct=4 ibb=0 ibt=0 ibl=0 ibr=0 ibback=0
    norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0 ibfint=0
/ energy grp (4 of 12) for the 6.2 Mev photon/s src.
    source= 0,0,0,1,f0
/ fine mesh location on the x axis of the point source:
    sourcx= 21z, 1, f0
/ fine mesh location on the y axis of the point source:
    sourcy= 45z, 1, f0
/ fine mesh location on the z axis of the point source:
    sourcz= 11z, 1, f0
    fcsrc=raytr
    fcnray=10000
    fcncr=25
    /fcxpos=0 /source position in cm
    /fcypos=1829 /source position in cm
    /fczpos=0 /source position in cm
    t
/
/ * * * block vi (edits) * * *
    pted=1 zned=1 igrped=3
/ use i+(j-1)NX+(k-1)NXNY; j=jt=5; k=kt=12 NX=IT=390; NY=JT=87
/ i=im=54, 95, 146, 207, 268, 329, 390
    points=374844, 374885, 374936, 374997, 375058, 375119, 375180 /j=5

```

395092,395124,395165,395216,395277,395338,395399,395460 /j=57
397432,397464,397505,397556,397617,397678,397739,397800 /j=63
399772,399804,399845,399896,399957,400018,400079,400140 /j=69
402112,402144,402185,402236,402297,402358,402419,402480 /j=75
406792,406824,406865,406916,406977,407038,407099,407160 /j=87
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm² for 12 energy groups
rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1
11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

3      0      0
ANS 6.6.1-1987 Problem I.2 THREEDANT 1 gamma/s N-16 (6.2 MeV), pt, isotropic
1828.8 cm above ground, in conc bldg detectors 91.44 cm above ground and
horizontally at 6096 cm and 1.524e5 cm 9ans6612.inp PARTISN makes uncflux file
/ geometry - X-Y-Z
/ cross sections - MENDFG, xslibb.mendfg
/ mixing - isotopes mixed to make materials named air and ground
/ solver - S16-P4, source in group 4, fcsrc=raytr
/ edits - card input supplied
/
/ block i
  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=3 nzone=3
  im=19 it=390 jm=11 jt=87 km=8 kt=24
  maxscm=44000000 maxlcm=220000000 t
/
/ block ii (geometry)
  xmesh=-1524, -1402, -5,5, 1402, 1524, 6046,6146, 15190,15290, 30430,30530
        60910,61010, 91390,91490, 121870,121970, 152350,152450
  xints= 1, 20, 1, 20, 1, 10, 1, 40,1, 50,1, 60,1, 60,1, 60,1, 60,1
  ymesh=-60.96, 0.0, 86.44,96.44, 1824,1834, 1890, 3000, 6000, 12000,
        18000, 30000
  yints= 2, 2, 1, 40, 1, 1, 10, 6, 6, 6, 12
  zmesh=-30000, -6000, -2286, -2164, 0.0, 2164, 2286, 6000, 30000
  zints= 6, 3, 1, 2, 2, 1, 3, 6
  zones= 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=1-6, j=11-1, i=1-19:
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /first face of model
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=7-9, j=11-1, i=1-19:
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /second face of model
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=10, j=11-1, i=1-19:
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /third face of model
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=11-12
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fourth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=13-14
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /fifth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=15,
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2; /sixth face of model

```

```

3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=16-18,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /seventh of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=19-24,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /last face of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

/
/ block iii (cross sections)
lib=xslibb savbxs=1 /first cp xslibb.mendfg xslibb
t
/
/ block iv (mixing)
matspec=atdens /atomic density= atoms/b*cm
matls=dirt "1001.50" 9.77-3 /H
"8016.50" 3.48-2 /O
"13027.50" 4.88-3 /Al

```

```

        "14000.50" 1.16-2; /Si
    airl "8016.50" 1.07-5 /O
        "7014.50" 4.02-5; /N
    conc "1001.50" 7.86-3 /H
        "8016.50" 4.38-2 /O
        "11023.50" 1.05-3 /Na
        "12000.50" 1.40-4 /Mg
        "13027.50" 2.39-3 /Al
        "14000.50" 1.58-2 /Si
        "19000.50" 6.90-4 /K
        "20000.50" 2.92-3 /Ca
        "26000.55" 2.10-4; /Fe
    assign=ground dirt 1.0; /zone 1
        air airl 1.0; /zone 2
        concrete conc 1.0 t /zone 3
/
/ block v (solver)
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
fcrstrt=2
/fcrstrt=1
/fcntr=0
ievt=0 iitm=200 oitm=60 isct=4 ibb=0 ibt=0 ibl=0 ibr=0 ibback=0
norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0 ibfrnt=0
/ energy grp (4 of 12) for the 6.2 MeV photon/s src.
source= 0,0,0,1,f0
/ fine mesh location on the x axis of the point source:
sourcx= 21z, 1, f0
/ fine mesh location on the y axis of the point source:
sourcy= 45z, 1, f0
/ fine mesh location on the z axis of the point source:
sourcz= 11z, 1, f0
fcsrc=raytr
fcrray=10000
fcntr=25
/fcxpos=0 /source position in cm
/fcypos=1829 /source position in cm
/fczpos=0 /source position in cm
t
/
/ * * * * block vi (edits) * * * *
pted=1 zned=1 igrped=3

```

```

/ use i+(j-1)NX+(k-1)NXNY; j=jt=5; k=kt=12 NX=IT=390; NY=JT=87
/ i=im=54, 95, 146, 207, 268, 329, 390
  points=374844, 374885, 374936, 374997, 375058, 375119, 375180 /j=5
        395092, 395124, 395165, 395216, 395277, 395338, 395399, 395460 /j=57
        397432, 397464, 397505, 397556, 397617, 397678, 397739, 397800 /j=63
        399772, 399804, 399845, 399896, 399957, 400018, 400079, 400140 /j=69
        402112, 402144, 402185, 402236, 402297, 402358, 402419, 402480 /j=75
        406792, 406824, 406865, 406916, 406977, 407038, 407099, 407160 /j=87
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
  rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1
      11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

[illegible]

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=10, j=11-1, i=1-19:
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2; /third face of model
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=11-12
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2; /fourth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=13-14
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2; /fifth face of model
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=15,
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2; /sixth face of model

```

```

3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=16-18,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /seventh of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=19-24,
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /last face of model
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

/
/ block iii (cross sections)
  lib=xslibb savbxs=1      /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=dirt      "1001.50"  9.77-3      /H
                  "8016.50"  3.48-2      /O
                  "13027.50" 4.88-3      /Al

```

```

        "14000.50"  1.16-2;    /Si
    airl  "8016.50"   1.07-5    /O
        "7014.50"   4.02-5;    /N
    conc  "1001.50"   7.86-3    /H
        "8016.50"   4.38-2    /O
        "11023.50"  1.05-3    /Na
        "12000.50"  1.40-4    /Mg
        "13027.50"  2.39-3    /Al
        "14000.50"  1.58-2    /Si
        "19000.50"  6.90-4    /K
        "20000.50"  2.92-3    /Ca
        "26000.55"  2.10-4;    /Fe
    assign=ground dirt 1.0;    /zone 1
        air      airl 1.0;    /zone 2
        concrete conc 1.0 t    /zone 3
/
/ block v (solver)
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
/ fcrstrt=2
fcrstrt=1
fcnt=0
ievt=0 iitm=200 oitm=60 isct=4 ibb=0 ibt=0 ibl=0 ibr=0 ibback=0
norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0 ibfrnt=0
/ energy grp (4 of 12) for the 6.2 MeV photon/s src.
source= 0,0,0,1,f0
/ fine mesh location on the x axis of the point source:
sourcx= 21z, 1, f0
/ fine mesh location on the y axis of the point source:
sourcy= 45z, 1, f0
/ fine mesh location on the z axis of the point source:
sourcz= 11z, 1, f0
fcsrc=raytr
fcrray=10000
/ fcnt=25
/ fcxpos=0      /source position in cm
/ fcypos=1829   /source position in cm
/ fczpos=0      /source position in cm
t
/
/ * * * * block vi (edits) * * * *
pted=1 zned=1 igrped=3

```

```

/ use i+(j-1)NX+(k-1)NXNY; j=jt=5; k=kt=12 NX=IT=390; NY=JT=87
/ i=im=54, 95, 146, 207, 268, 329, 390
  points=374844, 374885, 374936, 374997, 375058, 375119, 375180 /j=5
        395092,395124,395165,395216,395277,395338,395399,395460 /j=57
        397432,397464,397505,397556,397617,397678,397739,397800 /j=63
        399772,399804,399845,399896,399957,400018,400079,400140 /j=69
        402112,402144,402185,402236,402297,402358,402419,402480 /j=75
        406792,406824,406865,406916,406977,407038,407099,407160 /j=87
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
  rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1
        11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

```

*****
*
*      generalized input module run on O3      with solver version 10-15-01      beta release 2.64      machine asci01
*
*****
*
*      ...listing of cards in the input stream...
*
*      1.      3      0      0
*      2.  ANS 6.6.1-1987 Problem I.2 THREEDANT 1 gamma/s N-16 (6.2 MeV), pt, isotropic
*      3.  1828.8 cm above ground, in conc bldg detectors 91.44 cm above ground and
*      4.  horizontally at 6096 cm and 1.524e5 cm 10ans6612.inp PARTISN
*      5.  / geometry - X-Y-Z
*      6.  / cross sections - MENDFG, xslibb.mendfg
*      7.  / mixing - isotopes mixed to make materials named air and ground
*      8.  / solver - S16-P4, source in group 4, fcsrc=raytr
*      9.  / edits - card input supplied
*      10. /
*      11. / block i
*      12.  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=3 nzone=3
*      13.  im=19 it=390 jm=11 jt=87 km=8 kt=24
*      14.  maxscm=44000000 maxlcm=220000000 t
*      15. /
*      16. / block ii (geometry)
*      17.  xmesh= -1524, -1402, -5,5, 1402, 1524, 6046,6146, 15190,15290, 30430,30530
*      18.  60910,61010, 91390,91490, 121870,121970, 152350,152450
*      19.  xints= 1, 20, 1, 20, 1, 10, 1, 40,1, 50,1, 60,1, 60,1, 60,1
*      20.  ymesh= -60.96, 0.0, 86.44,96.44, 1824,1834, 1890, 3000, 6000, 12000,
*      21.  18000, 30000
*      22.  yints= 2, 2, 1, 40, 1, 1, 10, 6, 6, 6, 12
*      23.  zmesh= -30000, -6000, -2286, -2164, 0.0, 2164, 2286, 6000, 30000
*      24.  zints= 6, 3, 1, 2, 2, 1, 3, 6
*      25.  zones= 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1; /k=1-6, j=11-1, i=1-19:
*      26.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /first face of model
*      27.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
*      28.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
*      29.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
*      30.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
*      31.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
*      32.  2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```



```

* 119.          2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; t
* 120. /
* 121. / block iii (cross sections)
* 122.   lib=xslibb savbxs=1   /first cp xslibb.mendfg xslibb
* 123.   t
* 124. /
* 125. / block iv (mixing)
* 126.   matspec=atdens   /atomic density= atoms/b*cm
* 127.   matls=dirt      "1001.50"  9.77-3   /H
* 128.                   "8016.50"  3.48-2   /O
* 129.                   "13027.50"  4.88-3   /Al
* 130.                   "14000.50"  1.16-2;  /Si
* 131.   airl           "8016.50"  1.07-5   /O
* 132.                   "7014.50"  4.02-5;  /N
* 133.   conc           "1001.50"  7.86-3   /H
* 134.                   "8016.50"  4.38-2   /O
* 135.                   "11023.50"  1.05-3   /Na
* 136.                   "12000.50"  1.40-4   /Mg
* 137.                   "13027.50"  2.39-3   /Al
* 138.                   "14000.50"  1.58-2   /Si
* 139.                   "19000.50"  6.90-4   /K
* 140.                   "20000.50"  2.92-3   /Ca
* 141.                   "26000.55"  2.10-4;  /Fe
* 142.   assign=ground   dirt 1.0;          /zone 1
* 143.                   air   airl 1.0;     /zone 2
* 144.                   concrete conc 1.0 t  /zone 3
* 145. /
* 146. / block v (solver)
* 147. /   norm is 24 hr/day*365 day/yr
* 148. /   first collision source is FCSRC, location is in sourcy,
* 149. /   energy spectrum is in source
* 150. /fcrstrt=2
* 151. fcrstrt=1
* 152. fcncr=0
* 153. ievt=0 iitm=200 oitm=60 isct=4 ibb=0 ibt=0 ibl=0 ibr=0 ibback=0
* 154. norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0 ibfrnt=0
* 155. / energy grp (4 of 12) for the 6.2 MeV photon/s src.
* 156.   source= 0,0,0,1,f0
* 157. / fine mesh location on the x axis of the point source:
* 158.   sourcx= 21z, 1, f0
* 159. / fine mesh location on the y axis of the point source:
* 160.   sourcy= 45z, 1, f0
* 161. / fine mesh location on the z axis of the point source:

```

```

*      162.      sourcz= 11z, 1, f0
*      163.      fcsrc=raytr
*      164.      fcrray=10000
*      165.      /fcntr=25
*      166.      /fcxpos=0      /source position in cm
*      167.      /fcypos=1829  /source position in cm
*      168.      /fczpos=0      /source position in cm
*      169.      t
*      170.      /
*      171.      / * * * * block vi (edits) * * * *
*      172.      pted=1  zned=1  igrped=3
*      173.      / use i+(j-1)NX+(k-1)NXNY; j=jt=5; k=kt=12 NX=IT=390; NY=JT=87
*      174.      / i=im=54, 95, 146, 207, 268, 329, 390
*      175.      points=374844, 374885, 374936, 374997, 375058, 375119, 375180 /j=5
*      176.      395092,395124,395165,395216,395277,395338,395399,395460 /j=57
*      177.      397432,397464,397505,397556,397617,397678,397739,397800 /j=63
*      178.      399772,399804,399845,399896,399957,400018,400079,400140 /j=69
*      179.      402112,402144,402185,402236,402297,402358,402419,402480 /j=75
*      180.      406792,406824,406865,406916,406977,407038,407099,407160 /j=87
*      181.      / Resp Fcns in Air Kerma/unit Fluence from ICRU-57
*      182.      / in pGy/cm^2 for 12 energy groups
*      183.      rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1
*      184.      11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t
*      185.
*
*****
1 *****
*****
*
*
*
*****
*****
*key start case input *
*****
*
*      3  nhead  number of title cards to follow
*      0  notty  0/1  no/yes  suppress on-line terminal output
*      0  nolist 0/1  no/yes  suppress input listing
*      0  restart 0/1 no/yes read td_restart file
*
*
*****
*

```

```

*
*      * ANS 6.6.1-1987 Problem I.2 THREEDANT 1 gamma/s N-16 (6.2 MeV), pt, isot *
*      * 1828.8 cm above ground, in conc bldg detectors 91.44 cm above ground an *
*      * horizontally at 6096 cm and 1.524e5 cm 10ans6612.inp PARTISN *
*      *
*      *****
*****
*key end  block i read*
*****
*****
1
*****
*****
*
*      ...block i - controls and dimensions...
*
*****
*
*      ...dimensions ...
*
14  igeom  14/15  x-y-z/r-z-theta
12  ngroup number of energy groups
16  isn    angular quadrature order
0   iquad  1/2/3/4/5/6/7 - source of quadrature constants (default=1)
      1 traditional built-in Pn set (1-D) or old twotran built-in set
      2 traditional built-in DPn constants (1-D)
      3 card input
      4 galerkin (based on triangular hybrid product set)
      5 hybrid product set (triangular arrangement)
      6 product set (rectangular arrangement)
      7 sncon file
99  niso   number of input isotopes (from isotxs, grupxs, or cards)
3   mt     number of permanent materials
3   nzone  number of zones
19  im     number of coarse mesh x intervals
390 it     number of fine mesh intervals
11  jm     number of coarse mesh y intervals
87  jt     number of fine mesh y intervals
8   km     number of coarse mesh z intervals
24  kt     number of fine mesh z intervals
*
*      ...storage...
*

```


xslibb/2004.50	mat=	5	scat=	3	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/2004.50	mat=	5	scat=	4	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3006.50	mat=	6	scat=	0	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3006.50	mat=	6	scat=	1	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3006.50	mat=	6	scat=	2	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3006.50	mat=	6	scat=	3	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3006.50	mat=	6	scat=	4	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3007.55	mat=	7	scat=	0	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3007.55	mat=	7	scat=	1	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/3007.55	mat=	7	scat=	2	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/96244.50	mat=	99	scat=	2	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/96244.50	mat=	99	scat=	3	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0
xslibb/96244.50	mat=	99	scat=	4	ngroup=	12	iht=	3	ihs=	4	ihm=	15	i2lp1=	0

bxslib has been prepared from **xslibb**

1

★

★

...block iii - cross section library...

★

★

★

```
...library source...
lib=xslibb
```

✱

✱

✱

...energy structure...

★

★

group		one	two	lower bound	upper bound	group		one	two	lower bound	upper bound
*	1	2.00000E+01	3.00000E+02	9.00000E+00	2.00000E+01	7	4.00000E+00	3.00000E+02	3.00000E+00	4.00000E+00	
*	2	9.00000E+00	3.00000E+02	8.00000E+00	9.00000E+00	8	3.00000E+00	3.00000E+02	2.00000E+00	3.00000E+00	
*	3	8.00000E+00	3.00000E+02	7.00000E+00	8.00000E+00	9	2.00000E+00	3.00000E+02	1.00000E+00	2.00000E+00	
*	4	7.00000E+00	3.00000E+02	6.00000E+00	7.00000E+00	10	1.00000E+00	3.00000E+02	5.00000E-01	1.00000E+00	
*	5	6.00000E+00	3.00000E+02	5.00000E+00	6.00000E+00	11	5.00000E-01	3.00000E+02	1.00000E-01	5.00000E-01	
*	6	5.00000E+00	3.00000E+02	4.00000E+00	5.00000E+00	12	1.00000E-01	3.00000E+02	1.00000E-02	1.00000E-01	

★

★

```
last neutron group(lng) is number 12
```

★

★

★

```
0 balxs -1/0/1 - adjust absorption/no/adjust self scatter to force xs balance
```

*
*
*
*
*
*
*
*
*

...edit position names...

position edname

1 chi
2 nusigf
3 total
4 abs

...isotope names and numbers from library...

number	name	number	name	number	name	number	name	number	name
1	1001.50	21	14000.50	41	36083.50	61	63151.55	81	92233.50
2	1002.55	22	15031.50	42	36084.50	62	63153.55	82	92234.50
3	1003.50	23	16032.50	43	36086.50	63	64000.35	83	92235.50
4	2003.50	24	17000.50	44	39089.50	64	67165.55	84	92236.50
5	2004.50	25	18000.35	45	40000.50	65	69169.55	85	92237.50
6	3006.50	26	19000.50	46	41093.50	66	73181.50	86	92238.50
7	3007.55	27	20000.50	47	42000.50	67	74000.55	87	92239.35
8	4007.35	28	22000.50	48	45103.50	68	74182.55	88	93237.55
9	4009.50	29	23000.50	49	45117.90	69	74183.55	89	94237.35
10	5010.50	30	24000.50	50	46119.90	70	74184.55	90	94238.50
11	5011.56	31	25055.50	51	47000.55	71	74186.55	91	94239.55
12	6000.50	32	26000.55	52	47107.50	72	75185.50	92	94240.50
13	6012.50	33	27059.50	53	47109.50	73	75187.50	93	94241.50
14	7014.50	34	28000.50	54	48000.50	74	77000.55	94	94242.50
15	7015.55	35	29000.50	55	50120.35	75	78000.35	95	95241.50
16	8016.50	36	31000.50	56	50998.99	76	79197.56	96	95242.50
17	9019.50	37	33075.35	57	50999.99	77	82000.50	97	95243.50
18	11023.50	38	36078.50	58	54000.35	78	83209.50	98	96242.50
19	12000.50	39	36080.50	59	56138.50	79	90232.50	99	96244.50
20	13027.50	40	36082.50	60	63000.35	80	91233.50		

*key end card libe read *

key end block iv read-mats

*

*

```

*
*                                     ... mixing instructions ...
*
*****
*
*      mix      comp      density      comp      density etc.
*      ---      ---      -----      ---      -----
*
*      matls
*      -----
*
*      1. dirt      1001.50  9.77000E-03, 8016.50  3.48000E-02, 13027.50  4.88000E-03, 14000.50  1.16000E-02,
*      2. air1      8016.50  1.07000E-05, 7014.50  4.02000E-05,
*      3. conc      1001.50  7.86000E-03, 8016.50  4.38000E-02, 11023.50  1.05000E-03, 12000.50  1.40000E-04,
*                  13027.50  2.39000E-03, 14000.50  1.58000E-02, 19000.50  6.90000E-04, 20000.50  2.92000E-03,
*                  26000.55  2.10000E-04,
*
*      assign
*      -----
*
*      1. ground    dirt      1.00000E+00,
*      2. air       air1      1.00000E+00,
*      3. concrete  conc      1.00000E+00,
*****
*key start mix card xs *
*****
*key end   mix card xs *
*****
*****
*key end   block v read-solvr*
*****
1*****
*****
*
*                                     ...input distributed source (isotropic component)...
*
*
*      --- distribution in energy ---
*
*      1  0.00000E+00   2  0.00000E+00   3  0.00000E+00   4  1.00000E+00   5  0.00000E+00
*      6  0.00000E+00   7  0.00000E+00   8  0.00000E+00   9  0.00000E+00  10  0.00000E+00
*      11 0.00000E+00  12  0.00000E+00
*
*

```

```

*      --- distribution in y-mesh ---
*      1  0.00000E+00  2  0.00000E+00  3  0.00000E+00  4  0.00000E+00  5  0.00000E+00
*      6  0.00000E+00  7  0.00000E+00  8  0.00000E+00  9  0.00000E+00 10  0.00000E+00
*     11  0.00000E+00 12  0.00000E+00 13  0.00000E+00 14  0.00000E+00 15  0.00000E+00
*     16  0.00000E+00 17  0.00000E+00 18  0.00000E+00 19  0.00000E+00 20  0.00000E+00
*     21  0.00000E+00 22  0.00000E+00 23  0.00000E+00 24  0.00000E+00 25  0.00000E+00
*     26  0.00000E+00 27  0.00000E+00 28  0.00000E+00 29  0.00000E+00 30  0.00000E+00
*     31  0.00000E+00 32  0.00000E+00 33  0.00000E+00 34  0.00000E+00 35  0.00000E+00
*     36  0.00000E+00 37  0.00000E+00 38  0.00000E+00 39  0.00000E+00 40  0.00000E+00
*     41  0.00000E+00 42  0.00000E+00 43  0.00000E+00 44  0.00000E+00 45  0.00000E+00
*     46  1.00000E+00 47  0.00000E+00 48  0.00000E+00 49  0.00000E+00 50  0.00000E+00
*     51  0.00000E+00 52  0.00000E+00 53  0.00000E+00 54  0.00000E+00 55  0.00000E+00

```

Spherical harmonics for each octant and angle

```

* octant=      1          2          3          4          5          6          7          8
* m
* 1 n

```

```

* 36 n
* 1  1.000000E+00  1.000000E+00  1.000000E+00  1.000000E+00  1.000000E+00  1.000000E+00  1.000000E+00  1.000000E+00
* 2 -1.334457E-01  1.334457E-01 -1.334457E-01  1.334457E-01 -1.334457E-01  1.334457E-01 -1.334457E-01  1.334457E-01
* 3 -1.334457E-01 -1.334457E-01  1.334457E-01  1.334457E-01 -1.334457E-01 -1.334457E-01  1.334457E-01  1.334457E-01
* 4 -9.820308E-01 -9.820308E-01 -9.820308E-01 -9.820308E-01  9.820308E-01  9.820308E-01  9.820308E-01  9.820308E-01
* 5 -4.732884E-01 -4.732884E-01 -4.732884E-01 -4.732884E-01 -4.732884E-01 -4.732884E-01 -4.732884E-01 -4.732884E-01
* 6  3.084395E-02 -3.084395E-02 -3.084395E-02  3.084395E-02  3.084395E-02 -3.084395E-02 -3.084395E-02  3.084395E-02
* 7 -8.197595E-01 -8.197595E-01 -8.197595E-01 -8.197595E-01 -8.197595E-01 -8.197595E-01 -8.197595E-01 -8.197595E-01
* 8  2.269815E-01  2.269815E-01 -2.269815E-01 -2.269815E-01 -2.269815E-01 -2.269815E-01  2.269815E-01  2.269815E-01
* 9  2.269815E-01 -2.269815E-01  2.269815E-01 -2.269815E-01 -2.269815E-01  2.269815E-01 -2.269815E-01  2.269815E-01
* 10 1.942277E-01 -1.942277E-01  1.942277E-01 -1.942277E-01  1.942277E-01 -1.942277E-01  1.942277E-01 -1.942277E-01
* 11 7.444237E-02  7.444237E-02 -7.444237E-02 -7.444237E-02  7.444237E-02  7.444237E-02 -7.444237E-02 -7.444237E-02
* 12 2.446111E-01 -2.446111E-01  2.446111E-01 -2.446111E-01  2.446111E-01 -2.446111E-01  2.446111E-01 -2.446111E-01
* 13 3.033435E-01  3.033435E-01 -3.033435E-01 -3.033435E-01  3.033435E-01  3.033435E-01 -3.033435E-01 -3.033435E-01
* 14 7.072370E-01  7.072370E-01  7.072370E-01  7.072370E-01 -7.072370E-01 -7.072370E-01 -7.072370E-01 -7.072370E-01
* 15 -6.772984E-02  6.772984E-02  6.772984E-02 -6.772984E-02 -6.772984E-02  6.772984E-02 -6.772984E-02  6.772984E-02
* 16 5.478235E-01  5.478235E-01  5.478235E-01  5.478235E-01 -5.478235E-01 -5.478235E-01 -5.478235E-01 -5.478235E-01
* 17 3.096083E-01  3.096083E-01  3.096083E-01  3.096083E-01  3.096083E-01  3.096083E-01  3.096083E-01  3.096083E-01
* 18 -4.047989E-02  4.047989E-02  4.047989E-02 -4.047989E-02 -4.047989E-02  4.047989E-02  4.047989E-02 -4.047989E-02
* 19 4.631913E-01  4.631913E-01  4.631913E-01  4.631913E-01  4.631913E-01  4.631913E-01  4.631913E-01  4.631913E-01
* 20 -1.070997E-01  1.070997E-01  1.070997E-01 -1.070997E-01 -1.070997E-01  1.070997E-01  1.070997E-01 -1.070997E-01
* 21 6.118065E-01  6.118065E-01  6.118065E-01  6.118065E-01  6.118065E-01  6.118065E-01  6.118065E-01  6.118065E-01
* 22 -3.669354E-01 -3.669354E-01  3.669354E-01  3.669354E-01  3.669354E-01  3.669354E-01 -3.669354E-01 -3.669354E-01
* 23 -2.497001E-01  2.497001E-01 -2.497001E-01  2.497001E-01  2.497001E-01 -2.497001E-01  2.497001E-01 -2.497001E-01

```

	n	xmesh	xint	deltax	ymesh	yint	deltay	zmesh	zint	deltaz
*	0	-1.524E+03			-6.096E+01			-3.000E+04		
*	1	-1.402E+03	1	1.220E+02	0.000E+00	2	3.048E+01	-6.000E+03	6	4.000E+03
*	2	-5.000E+00	20	6.985E+01	8.644E+01	2	4.322E+01	-2.286E+03	3	1.238E+03
*	3	5.000E+00	1	1.000E+01	9.644E+01	1	1.000E+01	-2.164E+03	1	1.220E+02
*	4	1.402E+03	20	6.985E+01	1.824E+03	40	4.319E+01	0.000E+00	2	1.082E+03
*	5	1.524E+03	1	1.220E+02	1.834E+03	1	1.000E+01	2.164E+03	2	1.082E+03
*	6	6.046E+03	10	4.522E+02	1.890E+03	1	5.600E+01	2.286E+03	1	1.220E+02
*	7	6.146E+03	1	1.000E+02	3.000E+03	10	1.110E+02	6.000E+03	3	1.238E+03
*	8	1.519E+04	40	2.261E+02	6.000E+03	6	5.000E+02	3.000E+04	6	4.000E+03
*	9	1.529E+04	1	1.000E+02	1.200E+04	6	1.000E+03			
*	10	3.043E+04	50	3.028E+02	1.800E+04	6	1.000E+03			
*	11	3.053E+04	1	1.000E+02	3.000E+04	12	1.000E+03			
*	12	6.091E+04	60	5.063E+02						
*	13	6.101E+04	1	1.000E+02						
*	14	9.139E+04	60	5.063E+02						
*	15	9.149E+04	1	1.000E+02						
*	16	1.219E+05	60	5.063E+02						

★

★

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★

★

★ ★

★

*key start mesh potential info *

★

```
* weight factor b: 1.00000E-01
```

```
* energy weighting function:      8.33333E-02
```

8.33333E-02

★ 8.33333E-02

★ 8.33333E-02

★ 8.33333E-02

8.33333E-02

★ 8.33333E-02

★ 8.33333E-02

★ 8.33333E-02

★ 8.33333E-02

```

*
*
*
*
* user input min potential:      4.16667E-02
* user input max source slope:   5.00000E-01
*
* initial max aspect ratio:      4.00000E+02
*
*****
1*****
*
*****
*key start storage map *
*****
*
* partisn storage summary...
*
* max words/PE allocated in alloc3d for this problem 26962307
*
* words/PE for the geom3d module      1792
* words/PE for the snpn3d module      7598
* words/PE for the fcsrc3d module     482
* words/PE for the bal3d module       286
* words/PE for the transport module   120
* words/PE for the xsec module        1964
* words/PE for the time module        0
* max words/PE for the meshpot3d module 1058
* words/cell for the diffusion3d module 101.1
* words/cell for the block module     946.1
*
* max cells/PE      25740
* min cells/PE      23400
* total cells       814320
*
* number of PE's used = 32
* PCE = 0.998, SN = 16
* ALB = 0.989
*
*****
1*****
*****

```

```

*
*
*      ... raytr calculation information ...
*
* number of histories, raytr calculation = 506400
* cpu time required = 3.875E+05 sec
* avg. raytr particle weight = 0.9874
* min raytr particle weight = 0.9655
* max raytr particle weight = 0.9999
*
*
*****
*****
1 *****
*****
*
*      ...iteration controls and criteria...
*
*****
*
*
*      ***iteration criteria***
*
*      transport inners
*      -----
*
*      criterion      quantity to test      value      action taken if value exceeded
*      -----
*      iitl - inner iteration count until near lambda      200      terminates inners
*              (i.e. fission source) convergence
*      iitm - inner iteration count when near lambda      200      terminates inners
*              (i.e. fission source) convergence
*      epsi - fractional ptwise flux change      1.00E-04      does another inner
*              per inner
*
*      diffusion sub-outers
*      -----
*
*      criterion      quantity to test      value      action taken if value exceeded
*      -----
*      oitmd - sub-outer iteration count      100      terminates sub-outers
*      eps - diffusion lambda-1.0 (see note below)      1.00E-04      does another sub-outer
*
*      note: eps, when the problem is finally converged, will equal epsi, the value shown above. however,

```

```

*          early in the iteration process, a larger value may be used to avoid unnecessary iterations.
*
*          final convergence criteria
*          -----
*
*          criterion      quantity to test      value      action taken if value exceeded
*          -----
*          oitm - outer iteration count      60      quits with error message
*          epsi - transport lambda-1.0      1.00E-04      does another outer
*
*****
1 *****
*****
*
*          ...flux and eigenvalue convergence as monitored by partisn...
*
*****
*key start iteration monitor *
*****
*
*          cpu time outer      diffusion      max ptwise      max ptwise      inners
*          (sec)      no. inners sub-outers      sourc multip lambda-1      flux change      fiss change converged
*          1111.7      0
*
*          -----
*
*          -- inner iteration summary for outer iteration no. 1 --
*
*          iter per max flux      at
*          group group      change      mesh
*          1 zero source in this group
*          2 zero source in this group
*          3 zero source in this group
*          **neg or zero transport flux*** 4      7      0.13E-04      13, 40, 12
*          **neg or zero transport flux*** 5      8      0.99E-05      29, 73, 11
*          **neg or zero transport flux*** 6      8      0.11E-04      24, 8, 13
*          **neg or zero transport flux*** 7      11      0.55E-04      24, 30, 11
*          **neg or zero transport flux*** 8      11      0.52E-04      12, 49, 11
*          **neg or zero transport flux*** 9      13      0.48E-04      25, 49, 8
*          10      13      0.52E-04      207, 1, 12

```

```

*
*      11   58   0.91E-04 268, 1, 14
*      12   49   0.87E-04 247, 75, 13
*
*
*  cpu time outer      diffusion      max ptwise      max ptwise      inners
*  (sec)      no. inners sub-outers  sourc multip lambda-1  flux change  fiss change converged
*124670.      1      181      0      1.000000000 -1.000000E+00  9.09269E-05  0.800000E+00  yes
*
*      **** some negative or zero transport fluxes ****
*
*      $$$$$$ all convergence criteria satisfied $$$$$$
*
*  particle balance = -9.32933E-05      total inners all outers = 181
*
*****
1
*****
*
*      ...group edit and balances upon convergence...
*
*****
*
*      ...title--- ANS 6.6.1-1987 Problem I.2 THREEDANT 1 gamma/s N-16 (6.2 MeV), pt, isot ...
*
*
*      ...system balance tables...(neutrons only)
*
*****
*key start balance table      *
*****
*
*
gp      source      fission source      absorption      in scatter      self scatter      out scatter      net leakage
*
1      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00
2      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00
3      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00      0.0000000E+00
4      1.0000000E+00      0.0000000E+00      -1.2613523E-01      0.0000000E+00      2.4652410E-02      8.3720309E-01      2.8896498E-01
5      0.0000000E+00      0.0000000E+00      -5.8157105E-03      5.3564120E-02      1.7018060E-03      4.4142201E-02      1.5305182E-02

```

6	0.0000000E+00	0.0000000E+00	-4.9131290E-03	5.9141206E-02	2.6904814E-03	4.9311482E-02	1.4805618E-02
7	0.0000000E+00	0.0000000E+00	-3.8057847E-03	7.0762555E-02	4.9947994E-03	5.9916558E-02	1.4705433E-02
8	0.0000000E+00	0.0000000E+00	-2.3223633E-03	9.7085595E-02	1.2014916E-02	8.3350712E-02	1.6085039E-02
9	0.0000000E+00	0.0000000E+00	-4.6863120E-04	1.7475953E-01	5.0009839E-02	1.5125977E-01	2.3916310E-02
10	0.0000000E+00	0.0000000E+00	5.4810532E-04	5.2150620E-01	2.4302985E-01	4.8288452E-01	3.8093574E-02
11	0.0000000E+00	0.0000000E+00	1.0183912E-01	7.3124913E-01	3.3017339E+00	5.5717380E-01	7.2301003E-02
12	0.0000000E+00	0.0000000E+00	5.3648679E-01	5.5717380E-01	9.5173994E-01	-3.3306691E-15	2.0714318E-02
tot	1.0000000E+00	0.0000000E+00	4.9541317E-01	2.2652421E+00	4.5925679E+00	2.2652421E+00	5.0489146E-01

*
*
*

gp	right leakage	horizontal leakage	top leakage	vertical leakage	back leakage	fr-back leakage	particle balance
1	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
2	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
3	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
4	5.5114895E-05	2.0341630E-01	4.3070704E-02	4.9949218E-02	1.7409412E-02	3.5599460E-02	-3.2840075E-05
5	2.1478190E-05	5.4676701E-03	4.4094568E-03	6.0252167E-03	1.8768183E-03	3.8122947E-03	-1.2611511E-03
6	2.0583946E-05	5.1876049E-03	4.2894497E-03	5.9105155E-03	1.8248755E-03	3.7074979E-03	-1.0612742E-03
7	2.0169216E-05	5.0126425E-03	4.2887486E-03	5.9930461E-03	1.8202453E-03	3.6997446E-03	-7.5819373E-04
8	2.0171983E-05	5.4965217E-03	4.6733786E-03	6.6073030E-03	1.9551457E-03	3.9812144E-03	-2.8626694E-04
9	2.0826468E-05	9.2780037E-03	6.7049381E-03	9.1854463E-03	2.6650655E-03	5.4528601E-03	2.9800452E-04
10	1.5134914E-05	2.0498318E-02	8.5736099E-03	1.0870952E-02	3.2756730E-03	6.7243042E-03	-3.8338010E-05
11	2.0960047E-05	4.0799340E-02	1.4268954E-02	2.0782381E-02	5.2236466E-03	1.0719282E-02	-8.8608407E-05
12	8.4319316E-06	1.0199511E-02	5.9557493E-03	6.3536815E-03	2.0329307E-03	4.1611248E-03	-4.9023082E-05
tot	2.0287159E-04	3.0535592E-01	9.6234989E-02	1.2167776E-01	3.8083812E-02	7.7857783E-02	-9.3293315E-05

*
*

gp	left leakage	bottom leakage	front leakage	nprod spectrum	time source
1	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
2	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
3	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
4	2.0336119E-01	6.8785136E-03	1.8190049E-02	0.0000000E+00	0.0000000E+00
5	5.4461919E-03	1.6157599E-03	1.9354764E-03	0.0000000E+00	0.0000000E+00
6	5.1670209E-03	1.6210658E-03	1.8826224E-03	0.0000000E+00	0.0000000E+00
7	4.9924733E-03	1.7042976E-03	1.8794993E-03	0.0000000E+00	0.0000000E+00
8	5.4763497E-03	1.9339244E-03	2.0260688E-03	0.0000000E+00	0.0000000E+00
9	9.2571772E-03	2.4805082E-03	2.7877945E-03	0.0000000E+00	0.0000000E+00
10	2.0483183E-02	2.2973420E-03	3.4486312E-03	0.0000000E+00	0.0000000E+00
11	4.0778380E-02	6.5134276E-03	5.4956356E-03	0.0000000E+00	0.0000000E+00
12	1.0191079E-02	3.9793220E-04	2.1281940E-03	0.0000000E+00	0.0000000E+00

```

*
* tot   3.0515304E-01    2.5442771E-02    3.9773971E-02    0.0000000E+00    0.0000000E+00
*
*****
1
*****
*****
*
*   Multigrid work units... Total=   120.00 WU.
*   By group...
*   1      0.00  2      0.00  3      0.00  4      0.00  5      0.00  6      0.00  7      0.00  8      0.00  9      0.00
*  10     13.00 11     58.00 12     49.00
*
*   Multigrid average convergence rate by group...
*   1 0.0000  2 0.0000  3 0.0000  4 0.0000  5 0.0000  6 0.0000  7 0.0000  8 0.0000  9 0.0000
*  10 0.0000 11 0.0000 12 0.0000

integral summary information
summary eigenvalue not used
summary integral-neutrons 5.0183849E+01
integral-source-i      neutron  1.0000000E+00
integral-time source-i  neutron  0.0000000E+00
integral-fission-i     neutron  0.0000000E+00
integral-absorption-i   neutron  4.9541317E-01
integral-in-scak-i      neutron  2.2652421E+00
integral-self-scak-i    neutron  4.5925679E+00
integral-out-scak-i     neutron  2.2652421E+00
integral-net lkage-i    neutron  5.0489146E-01
integral-right lkage-i   neutron  2.0287159E-04
integral-horizontal lkage-i neutron  3.0535592E-01
integral-top lkage-i    neutron  9.6234989E-02
integral-vertical lkage-i neutron  1.2167776E-01
integral-back lkage-i    neutron  3.8083812E-02
integral-fr-back lkage-i neutron  7.7857783E-02
integral-particle bal-i  neutron -3.2776911E-03
1*****
*****
*
*
*   isotropic flux component for group   1 and plane   3
*
*****
*****

```


	x mesh	9	x mesh	10	x mesh	11	x mesh	12	x mesh	13	x mesh	14	x mesh	15	x mesh	16
11	4.379958E-13	4.513169E-13	4.928468E-13	4.184925E-13	5.568289E-13	5.333548E-13	5.872833E-13	5.385284E-13								
10	3.854347E-13	4.696657E-13	4.138131E-13	4.103426E-13	5.165565E-13	4.788719E-13	5.218866E-13	4.992819E-13								
9	3.607607E-13	4.523515E-13	3.321127E-13	4.109595E-13	4.180483E-13	4.447009E-13	5.274076E-13	4.919288E-13								
8	3.490283E-13	3.966656E-13	3.074762E-13	4.146675E-13	3.564663E-13	4.300099E-13	4.826624E-13	5.075796E-13								
7	3.853775E-13	2.978756E-13	3.099778E-13	4.055190E-13	3.645782E-13	4.385466E-13	4.499581E-13	4.919892E-13								
6	3.938162E-13	2.709525E-13	3.507768E-13	3.464973E-13	3.949505E-13	4.381929E-13	4.364135E-13	4.299619E-13								
5	3.657470E-13	2.723204E-13	3.809413E-13	2.942622E-13	4.017820E-13	4.370411E-13	4.159845E-13	3.564646E-13								
4	3.256855E-13	2.623155E-13	3.427210E-13	3.009510E-13	3.844940E-13	3.894277E-13	3.815848E-13	3.513106E-13								
3	2.838500E-13	2.668914E-13	2.757699E-13	3.498841E-13	3.611344E-13	3.534473E-13	3.575977E-13	3.271240E-13								
2	7.603469E-14	7.707662E-14	7.911530E-14	9.035344E-14	8.989711E-14	8.755418E-14	9.186955E-14	9.108146E-14								
1	6.201869E-15	6.165397E-15	6.320649E-15	6.506282E-15	6.715514E-15	6.916200E-15	7.016639E-15	7.187732E-15								
	x mesh	17	x mesh	18	x mesh	19	x mesh	20	x mesh	21	x mesh	22	x mesh	23	x mesh	24
11	5.562137E-13	5.887031E-13	5.258519E-13	5.265242E-13	4.882033E-13	4.086468E-13	4.513348E-13	4.671799E-13								
10	5.407546E-13	6.198240E-13	5.262776E-13	4.558257E-13	4.240044E-13	3.802622E-13	4.033820E-13	4.330290E-13								
9	5.238687E-13	5.910780E-13	5.316944E-13	4.004339E-13	4.013095E-13	3.605564E-13	3.907089E-13	3.997406E-13								
8	4.752096E-13	5.265279E-13	5.073215E-13	3.907295E-13	3.876099E-13	3.546003E-13	3.874054E-13	3.545510E-13								
7	4.130861E-13	5.122117E-13	4.815018E-13	4.107341E-13	3.847451E-13	3.362474E-13	3.560968E-13	3.350269E-13								
6	3.990989E-13	4.176741E-13	4.744016E-13	3.958727E-13	3.746640E-13	3.168299E-13	3.261304E-13	3.124024E-13								
5	4.006838E-13	3.955495E-13	4.503326E-13	3.825434E-13	3.642449E-13	3.058883E-13	3.109738E-13	3.033009E-13								
4	3.865185E-13	4.120808E-13	4.221716E-13	3.617967E-13	3.537519E-13	2.836930E-13	3.189851E-13	2.983653E-13								
3	3.944455E-13	3.913786E-13	4.150303E-13	3.314731E-13	3.281485E-13	2.701862E-13	3.288667E-13	2.803211E-13								
2	9.981386E-14	9.682620E-14	9.914555E-14	9.436819E-14	9.105084E-14	8.793099E-14	9.195064E-14	8.736508E-14								
1	7.293133E-15	7.380816E-15	7.494251E-15	7.507698E-15	7.529735E-15	7.589811E-15	7.689127E-15	7.870135E-15								
	x mesh	25	x mesh	26	x mesh	27	x mesh	28	x mesh	29	x mesh	30	x mesh	31	x mesh	32
11	5.296190E-13	4.821974E-13	5.331218E-13	4.893305E-13	5.266616E-13	5.469413E-13	5.779048E-13	6.242804E-13								
10	4.897793E-13	4.110335E-13	5.219398E-13	4.429764E-13	5.336573E-13	4.481098E-13	5.403874E-13	6.134813E-13								
9	4.181034E-13	3.926492E-13	4.772086E-13	4.117353E-13	5.565636E-13	3.867364E-13	4.687421E-13	5.153679E-13								
8	3.950215E-13	3.871982E-13	4.643651E-13	4.034618E-13	5.568123E-13	3.567420E-13	4.053163E-13	4.919999E-13								
7	3.556177E-13	3.771823E-13	4.232485E-13	4.101760E-13	4.656356E-13	4.053504E-13	3.844043E-13	4.612497E-13								
6	3.434796E-13	3.519375E-13	3.864169E-13	3.929564E-13	4.305091E-13	4.155302E-13	3.879698E-13	4.270468E-13								
5	3.376280E-13	3.208904E-13	3.926520E-13	4.057654E-13	4.035284E-13	4.434672E-13	3.557484E-13	4.314078E-13								
4	3.409001E-13	3.389836E-13	3.940533E-13	4.187834E-13	3.938190E-13	4.765318E-13	3.573463E-13	4.005436E-13								
3	3.635580E-13	3.537388E-13	3.956669E-13	3.855930E-13	3.991187E-13	4.967732E-13	3.713881E-13	3.833460E-13								
2	9.695387E-14	9.849831E-14	1.038867E-13	1.057613E-13	1.086921E-13	1.153954E-13	1.127094E-13	1.124965E-13								
1	8.104312E-15	8.216054E-15	8.193622E-15	8.291675E-15	8.549354E-15	8.761906E-15	8.714882E-15	8.756065E-15								

	x mesh	33	x mesh	34	x mesh	35	x mesh	36	x mesh	37	x mesh	38	x mesh	39	x mesh	40
*																
*																
*	11	5.918109E-13	4.899398E-13	4.923079E-13	4.719567E-13	5.544474E-13	4.864325E-13	5.233729E-13	5.923219E-13							
*	10	5.908069E-13	4.438797E-13	4.418444E-13	4.639940E-13	4.896772E-13	5.154676E-13	4.376707E-13	5.469639E-13							
*	9	6.038550E-13	4.653926E-13	4.374589E-13	4.977200E-13	4.361898E-13	4.993979E-13	4.304936E-13	4.663148E-13							
*	8	5.559443E-13	5.332450E-13	4.219957E-13	4.982536E-13	3.950753E-13	4.586623E-13	4.594828E-13	4.844776E-13							
*	7	4.881739E-13	5.951323E-13	3.974309E-13	4.863742E-13	4.038821E-13	4.191288E-13	4.652932E-13	5.522548E-13							
*	6	4.434594E-13	6.188183E-13	3.853611E-13	4.307793E-13	4.480706E-13	3.707449E-13	4.377915E-13	5.107078E-13							
*	5	4.134953E-13	5.727329E-13	4.210660E-13	4.078400E-13	4.749755E-13	3.532391E-13	4.357661E-13	5.198313E-13							
*	4	4.145358E-13	5.090701E-13	4.756741E-13	3.824999E-13	5.022660E-13	4.408188E-13	4.789047E-13	5.277430E-13							
*	3	4.202631E-13	3.917183E-13	4.774166E-13	3.229999E-13	5.281963E-13	6.480684E-13	5.586179E-13	6.737749E-13							
*	2	1.215036E-13	1.120481E-13	1.194176E-13	1.062882E-13	1.225632E-13	1.544988E-13	1.483034E-13	1.551511E-13							
*	1	8.857408E-15	8.636584E-15	8.394886E-15	8.576314E-15	8.793141E-15	8.770413E-15	8.921813E-15	9.010650E-15							
*																
*																
	x mesh	41	x mesh	42	x mesh	43	x mesh	44	x mesh	45	x mesh	46	x mesh	47	x mesh	48
*																
*																
*	11	5.245416E-13	6.366559E-13	1.022497E-12	1.204762E-12	1.324830E-12	2.542050E-12	1.829785E-12	9.837684E-13							
*	10	5.014898E-13	5.040680E-13	8.967207E-13	1.414399E-12	1.664516E-12	2.661334E-12	1.920473E-12	8.571006E-13							
*	9	4.915582E-13	4.500163E-13	7.828092E-13	1.577326E-12	2.100568E-12	2.853184E-12	1.988168E-12	7.653443E-13							
*	8	5.565828E-13	4.804489E-13	7.320556E-13	1.726456E-12	2.554756E-12	3.132003E-12	2.043305E-12	6.967164E-13							
*	7	6.745612E-13	6.983572E-13	7.645442E-13	1.875979E-12	3.041605E-12	3.500264E-12	2.108186E-12	6.532030E-13							
*	6	8.180289E-13	9.891893E-13	9.533606E-13	2.039441E-12	3.052517E-12	3.926278E-12	2.206130E-12	6.112681E-13							
*	5	9.126731E-13	1.136619E-12	1.154517E-12	2.151013E-12	3.773179E-12	4.205223E-12	2.293068E-12	5.905127E-13							
*	4	9.150164E-13	1.289052E-12	1.457652E-12	2.323856E-12	3.990740E-12	4.494039E-12	2.404692E-12	5.880221E-13							
*	3	9.139726E-13	1.454802E-12	1.945161E-12	2.656241E-12	4.279767E-12	4.948156E-12	2.623138E-12	5.757266E-13							
*	2	1.754371E-13	2.296273E-13	3.066473E-13	3.780628E-13	5.368423E-13	6.187501E-13	3.661124E-13	1.406580E-13							
*	1	8.913295E-15	9.069563E-15	9.580018E-15	1.000437E-14	1.080110E-14	1.112435E-14	1.022657E-14	9.560851E-15							
*																
*																
	x mesh	49	x mesh	50	x mesh	51	x mesh	52	x mesh	53	x mesh	54	x mesh	55	x mesh	56
*																
*																
*	11	1.008104E-12	6.194070E-13	8.397116E-13	8.726764E-13	1.057100E-12	1.144076E-12	1.181114E-12	1.434177E-12							
*	10	1.044108E-12	5.990311E-13	8.230765E-13	9.603454E-13	1.114444E-12	1.284892E-12	1.170838E-12	1.363974E-12							
*	9	1.015812E-12	6.283183E-13	7.780176E-13	1.054695E-12	1.214035E-12	1.307502E-12	1.276452E-12	1.300104E-12							
*	8	9.863705E-13	6.581486E-13	7.225450E-13	1.139121E-12	1.301838E-12	1.464092E-12	1.371434E-12	1.355874E-12							
*	7	9.338553E-13	6.859633E-13	6.899649E-13	1.195546E-12	1.374326E-12	1.565704E-12	1.531295E-12	1.411747E-12							
*	6	8.954323E-13	6.922878E-13	6.905905E-13	1.230932E-12	1.475714E-12	1.572371E-12	1.647154E-12	1.532577E-12							
*	5	8.660941E-13	6.881291E-13	7.016995E-13	1.247483E-12	1.545951E-12	1.601464E-12	1.681032E-12	1.628910E-12							
*	4	8.061346E-13	7.126796E-13	6.993089E-13	1.266615E-12	1.598207E-12	1.678011E-12	1.710986E-12	1.677275E-12							
*	3	7.259875E-13	7.458587E-13	6.977145E-13	1.292676E-12	1.701427E-12	1.756132E-12	1.795266E-12	1.739684E-12							
*	2	1.526338E-13	1.591582E-13	1.519890E-13	2.131690E-13	2.616506E-13	2.674267E-13	2.689371E-13	2.652221E-13							
*	1	9.508545E-15	9.446673E-15	9.440783E-15	9.666423E-15	9.959222E-15	9.797191E-15	9.769823E-15	9.891145E-15							
*																
*																
	x mesh	57	x mesh	58	x mesh	59	x mesh	60	x mesh	61	x mesh	62	x mesh	63	x mesh	64

11	1.517647E-12	1.418678E-12	1.232175E-12	1.048217E-12	1.178832E-12	1.356023E-12	1.334235E-12	1.313091E-12
10	1.490166E-12	1.443039E-12	1.330956E-12	1.129391E-12	1.079249E-12	1.244544E-12	1.321264E-12	1.298835E-12
9	1.462287E-12	1.429025E-12	1.373908E-12	1.243624E-12	1.103242E-12	1.150272E-12	1.260361E-12	1.277677E-12
8	1.435429E-12	1.450344E-12	1.370452E-12	1.305048E-12	1.179977E-12	1.155596E-12	1.199913E-12	1.242508E-12
7	1.472122E-12	1.467465E-12	1.382735E-12	1.321863E-12	1.249091E-12	1.203281E-12	1.216985E-12	1.199845E-12
6	1.519772E-12	1.532800E-12	1.414972E-12	1.332097E-12	1.267785E-12	1.240097E-12	1.265740E-12	1.242213E-12
5	1.536184E-12	1.601851E-12	1.455116E-12	1.326689E-12	1.277712E-12	1.255105E-12	1.308339E-12	1.276622E-12
4	1.602818E-12	1.628799E-12	1.527863E-12	1.376424E-12	1.272519E-12	1.242778E-12	1.307522E-12	1.335257E-12
3	1.657958E-12	1.685303E-12	1.651368E-12	1.468885E-12	1.319289E-12	1.213127E-12	1.279008E-12	1.393789E-12
2	2.506638E-13	2.553622E-13	2.568374E-13	2.378898E-13	2.188291E-13	2.023386E-13	2.076444E-13	2.238307E-13
1	9.636378E-15	9.676400E-15	9.682635E-15	9.521409E-15	9.368289E-15	9.197349E-15	9.277404E-15	9.216281E-15
x mesh 65 x mesh 66 x mesh 67 x mesh 68 x mesh 69 x mesh 70 x mesh 71 x mesh 72								
11	1.339773E-12	1.314993E-12	1.289017E-12	1.225583E-12	1.242981E-12	1.315312E-12	1.257836E-12	1.193631E-12
10	1.305742E-12	1.348531E-12	1.299985E-12	1.236955E-12	1.200748E-12	1.257305E-12	1.323317E-12	1.231266E-12
9	1.272482E-12	1.313200E-12	1.344340E-12	1.253633E-12	1.187759E-12	1.188570E-12	1.279585E-12	1.312341E-12
8	1.233024E-12	1.259592E-12	1.331577E-12	1.315052E-12	1.192676E-12	1.149370E-12	1.194095E-12	1.297816E-12
7	1.224987E-12	1.201035E-12	1.279990E-12	1.347874E-12	1.249651E-12	1.129927E-12	1.121325E-12	1.221896E-12
6	1.206466E-12	1.198614E-12	1.185751E-12	1.327549E-12	1.324694E-12	1.169832E-12	1.071673E-12	1.113446E-12
5	1.213327E-12	1.196726E-12	1.163177E-12	1.251504E-12	1.384796E-12	1.213081E-12	1.059585E-12	1.051737E-12
4	1.269380E-12	1.211205E-12	1.155985E-12	1.190626E-12	1.357219E-12	1.309416E-12	1.097300E-12	1.009515E-12
3	1.358631E-12	1.286111E-12	1.193042E-12	1.121708E-12	1.250402E-12	1.382515E-12	1.238981E-12	1.012808E-12
2	2.263570E-13	2.159784E-13	2.070182E-13	1.938675E-13	1.985256E-13	2.204563E-13	2.174470E-13	1.880884E-13
1	9.135118E-15	9.112871E-15	8.955582E-15	8.857977E-15	8.740107E-15	8.787883E-15	8.719828E-15	8.608337E-15
x mesh 73 x mesh 74 x mesh 75 x mesh 76 x mesh 77 x mesh 78 x mesh 79 x mesh 80								
11	1.217725E-12	1.222179E-12	1.167839E-12	1.113534E-12	1.103031E-12	1.109132E-12	1.101349E-12	1.089427E-12
10	1.189454E-12	1.226117E-12	1.207178E-12	1.149040E-12	1.101006E-12	1.107754E-12	1.105355E-12	1.089968E-12
9	1.203635E-12	1.195152E-12	1.225729E-12	1.185080E-12	1.132380E-12	1.096840E-12	1.113061E-12	1.103026E-12
8	1.271248E-12	1.185016E-12	1.209316E-12	1.217392E-12	1.166239E-12	1.115210E-12	1.103332E-12	1.117270E-12
7	1.293909E-12	1.211276E-12	1.184780E-12	1.215350E-12	1.197009E-12	1.151211E-12	1.100913E-12	1.107319E-12
6	1.257091E-12	1.264150E-12	1.176186E-12	1.195332E-12	1.211670E-12	1.176211E-12	1.134730E-12	1.088674E-12
5	1.186423E-12	1.286214E-12	1.193962E-12	1.176227E-12	1.211243E-12	1.191342E-12	1.151779E-12	1.095675E-12
4	1.110664E-12	1.245839E-12	1.230711E-12	1.166134E-12	1.192309E-12	1.200831E-12	1.161259E-12	1.116397E-12
3	9.912695E-13	1.147418E-12	1.238440E-12	1.192761E-12	1.165407E-12	1.189777E-12	1.178197E-12	1.138953E-12
2	1.717923E-13	1.861337E-13	2.022301E-13	1.996075E-13	1.937092E-13	1.964318E-13	1.950378E-13	1.907045E-13
1	8.465680E-15	8.430492E-15	8.391640E-15	8.317093E-15	8.270487E-15	8.148551E-15	8.136790E-15	8.000205E-15
x mesh 81 x mesh 82 x mesh 83 x mesh 84 x mesh 85 x mesh 86 x mesh 87 x mesh 88								

*	11	1.081129E-12	1.056822E-12	1.062074E-12	1.053742E-12	1.035453E-12	1.042975E-12	1.007985E-12	9.907535E-13
*	10	1.085272E-12	1.064693E-12	1.036564E-12	1.053408E-12	1.040406E-12	1.024157E-12	1.029056E-12	9.933380E-13
*	9	1.078695E-12	1.078494E-12	1.048967E-12	1.024599E-12	1.039860E-12	1.024378E-12	1.019025E-12	1.009903E-12
*	8	1.097253E-12	1.069594E-12	1.066564E-12	1.031959E-12	1.016895E-12	1.021750E-12	1.013011E-12	1.012863E-12
*	7	1.118405E-12	1.089923E-12	1.063370E-12	1.048039E-12	1.013713E-12	1.007380E-12	1.009609E-12	1.002253E-12
*	6	1.109621E-12	1.116733E-12	1.087997E-12	1.056677E-12	1.030673E-12	9.979042E-13	9.958591E-13	9.997713E-13
*	5	1.085361E-12	1.124452E-12	1.111768E-12	1.068268E-12	1.041198E-12	1.004301E-12	9.796966E-13	9.986514E-13
*	4	1.083333E-12	1.101528E-12	1.121694E-12	1.091846E-12	1.051960E-12	1.021997E-12	9.812270E-13	9.786087E-13
*	3	1.093039E-12	1.075043E-12	1.097719E-12	1.119789E-12	1.079669E-12	1.045174E-12	1.007370E-12	9.603128E-13
*	2	1.870080E-13	1.819099E-13	1.821273E-13	1.869781E-13	1.844891E-13	1.777995E-13	1.753208E-13	1.678871E-13
*	1	7.981904E-15	7.856888E-15	7.840037E-15	7.743069E-15	7.677990E-15	7.624709E-15	7.549252E-15	7.510998E-15
*		x mesh 89	x mesh 90	x mesh 91	x mesh 92	x mesh 93	x mesh 94	x mesh 95	x mesh 96
*	11	9.984547E-13	9.706460E-13	9.615595E-13	9.570786E-13	9.451350E-13	9.365766E-13	9.290770E-13	9.225532E-13
*	10	9.860624E-13	9.816129E-13	9.608608E-13	9.558264E-13	9.442044E-13	9.341240E-13	9.249149E-13	9.225399E-13
*	9	9.843522E-13	9.801244E-13	9.687980E-13	9.482315E-13	9.478111E-13	9.363563E-13	9.252077E-13	9.177734E-13
*	8	9.950619E-13	9.727624E-13	9.716060E-13	9.598584E-13	9.360733E-13	9.391214E-13	9.322399E-13	9.187004E-13
*	7	1.002773E-12	9.834967E-13	9.586780E-13	9.644138E-13	9.469537E-13	9.296861E-13	9.376609E-13	9.173190E-13
*	6	9.898574E-13	9.899509E-13	9.709362E-13	9.492476E-13	9.540565E-13	9.311571E-13	9.268610E-13	9.234730E-13
*	5	9.902766E-13	9.827948E-13	9.800724E-13	9.513086E-13	9.445780E-13	9.384092E-13	9.093958E-13	9.286480E-13
*	4	9.880502E-13	9.797318E-13	9.776437E-13	9.539489E-13	9.433928E-13	9.386642E-13	9.167842E-13	9.202960E-13
*	3	9.693131E-13	9.757598E-13	9.735449E-13	9.681427E-13	9.428367E-13	9.365043E-13	9.313443E-13	9.130663E-13
*	2	1.643460E-13	1.669077E-13	1.657397E-13	1.656003E-13	1.631926E-13	1.607839E-13	1.605388E-13	1.575497E-13
*	1	7.404953E-15	7.332240E-15	7.260753E-15	7.201227E-15	7.163230E-15	7.080584E-15	7.045468E-15	6.944701E-15
*		x mesh 97	x mesh 98	x mesh 99	x mesh 100	x mesh 101	x mesh 102	x mesh 103	x mesh 104
*	11	9.050306E-13	8.881130E-13	8.724001E-13	8.550484E-13	8.379337E-13	8.245161E-13	8.086776E-13	7.963818E-13
*	10	9.109508E-13	8.891729E-13	8.737377E-13	8.557252E-13	8.391580E-13	8.223077E-13	8.100594E-13	7.949170E-13
*	9	9.107329E-13	8.953098E-13	8.744149E-13	8.566148E-13	8.392939E-13	8.246577E-13	8.089983E-13	7.951197E-13
*	8	9.085803E-13	8.951451E-13	8.778388E-13	8.576847E-13	8.390814E-13	8.239067E-13	8.092639E-13	7.964711E-13
*	7	9.085242E-13	8.960261E-13	8.763719E-13	8.607120E-13	8.401241E-13	8.245371E-13	8.082725E-13	7.943288E-13
*	6	9.004419E-13	8.997042E-13	8.772561E-13	8.605083E-13	8.423272E-13	8.240029E-13	8.112901E-13	7.921425E-13
*	5	9.003806E-13	8.928383E-13	8.832181E-13	8.557628E-13	8.482483E-13	8.191094E-13	8.151740E-13	7.913965E-13
*	4	9.087841E-13	8.875939E-13	8.829220E-13	8.582848E-13	8.443034E-13	8.248018E-13	8.084298E-13	7.979645E-13
*	3	9.103934E-13	8.904039E-13	8.753641E-13	8.635911E-13	8.408250E-13	8.280338E-13	8.084670E-13	7.944357E-13
*	2	1.559651E-13	1.543911E-13	1.508258E-13	1.494511E-13	1.461193E-13	1.430310E-13	1.411671E-13	1.377869E-13
*	1	6.845570E-15	6.753017E-15	6.651396E-15	6.571657E-15	6.432278E-15	6.352232E-15	6.209366E-15	6.132896E-15
*		x mesh 105	x mesh 106	x mesh 107	x mesh 108	x mesh 109	x mesh 110	x mesh 111	x mesh 112
*	11	7.799576E-13	7.642408E-13	7.517593E-13	7.374992E-13	7.320107E-13	7.228370E-13	7.152430E-13	7.020452E-13

*	10	7.821547E-13	7.655297E-13	7.521869E-13	7.375200E-13	7.279032E-13	7.217615E-13	7.134114E-13	7.045462E-13
*	9	7.808363E-13	7.698950E-13	7.519216E-13	7.391237E-13	7.267486E-13	7.189478E-13	7.119287E-13	7.045303E-13
*	8	7.806567E-13	7.686920E-13	7.567207E-13	7.388691E-13	7.278904E-13	7.167589E-13	7.098172E-13	7.023261E-13
*	7	7.833561E-13	7.682476E-13	7.577198E-13	7.412292E-13	7.287723E-13	7.165834E-13	7.069990E-13	7.013678E-13
*	6	7.825768E-13	7.683963E-13	7.573221E-13	7.449086E-13	7.282012E-13	7.181003E-13	7.060492E-13	6.978994E-13
*	5	7.807299E-13	7.712105E-13	7.539025E-13	7.488174E-13	7.299913E-13	7.174727E-13	7.071045E-13	6.964509E-13
*	4	7.781298E-13	7.704665E-13	7.565617E-13	7.454213E-13	7.338905E-13	7.185589E-13	7.080275E-13	6.962287E-13
*	3	7.825403E-13	7.669999E-13	7.582742E-13	7.454199E-13	7.350282E-13	7.232237E-13	7.087806E-13	6.987286E-13
*	2	1.362294E-13	1.337330E-13	1.316671E-13	1.303445E-13	1.275023E-13	1.267030E-13	1.237173E-13	1.220811E-13
*	1	5.985448E-15	5.939171E-15	5.829733E-15	5.756666E-15	5.623367E-15	5.556850E-15	5.485504E-15	5.391335E-15
*		x mesh 113	x mesh 114	x mesh 115	x mesh 116	x mesh 117	x mesh 118	x mesh 119	x mesh 120
*	11	6.926255E-13	6.829073E-13	6.738711E-13	6.699182E-13	6.608845E-13	6.514685E-13	6.419603E-13	6.338075E-13
*	10	6.926269E-13	6.838994E-13	6.735855E-13	6.671886E-13	6.609411E-13	6.524285E-13	6.426038E-13	6.326975E-13
*	9	6.946468E-13	6.839177E-13	6.761294E-13	6.668724E-13	6.598008E-13	6.515715E-13	6.415226E-13	6.323603E-13
*	8	6.951018E-13	6.861932E-13	6.760201E-13	6.688822E-13	6.617903E-13	6.524795E-13	6.427811E-13	6.304770E-13
*	7	6.932039E-13	6.864955E-13	6.766581E-13	6.686453E-13	6.612648E-13	6.525562E-13	6.445470E-13	6.327873E-13
*	6	6.928360E-13	6.853816E-13	6.788274E-13	6.682488E-13	6.603882E-13	6.528914E-13	6.427373E-13	6.344955E-13
*	5	6.906015E-13	6.844566E-13	6.814704E-13	6.679533E-13	6.604083E-13	6.518185E-13	6.444147E-13	6.319728E-13
*	4	6.904083E-13	6.828426E-13	6.783752E-13	6.717955E-13	6.596940E-13	6.515426E-13	6.424017E-13	6.330137E-13
*	3	6.869913E-13	6.834804E-13	6.761712E-13	6.697780E-13	6.631462E-13	6.507257E-13	6.428098E-13	6.343398E-13
*	2	1.260791E-13	1.183001E-13	1.176249E-13	1.157874E-13	1.147052E-13	1.125534E-13	1.109264E-13	1.094191E-13
*	1	5.317088E-15	5.230544E-15	5.162851E-15	5.099475E-15	5.017995E-15	4.930628E-15	4.858091E-15	4.785571E-15
*		x mesh 121	x mesh 122	x mesh 123	x mesh 124	x mesh 125	x mesh 126	x mesh 127	x mesh 128
*	11	6.226400E-13	6.103006E-13	5.969055E-13	5.838202E-13	5.719167E-13	5.597310E-13	5.474147E-13	5.341846E-13
*	10	6.232945E-13	6.115523E-13	5.986058E-13	5.847024E-13	5.708546E-13	5.570158E-13	5.453983E-13	5.346079E-13
*	9	6.239407E-13	6.125204E-13	6.004786E-13	5.878204E-13	5.726916E-13	5.585616E-13	5.445066E-13	5.309784E-13
*	8	6.205987E-13	6.123328E-13	6.029941E-13	5.872830E-13	5.735191E-13	5.610276E-13	5.478289E-13	5.328349E-13
*	7	6.199554E-13	6.083990E-13	5.992923E-13	5.898746E-13	5.754958E-13	5.601736E-13	5.454376E-13	5.362984E-13
*	6	6.234268E-13	6.106342E-13	5.971973E-13	5.869047E-13	5.748614E-13	5.615808E-13	5.489264E-13	5.328360E-13
*	5	6.221079E-13	6.134033E-13	5.984597E-13	5.855823E-13	5.746208E-13	5.606795E-13	5.489567E-13	5.379226E-13
*	4	6.218787E-13	6.116001E-13	6.003310E-13	5.873927E-13	5.744598E-13	5.609299E-13	5.466396E-13	5.357407E-13
*	3	6.213523E-13	6.104854E-13	5.995641E-13	5.870071E-13	5.747943E-13	5.629925E-13	5.481073E-13	5.326291E-13
*	2	1.076329E-13	1.057669E-13	1.040437E-13	1.020329E-13	9.985448E-14	9.803003E-14	9.613617E-14	9.388925E-14
*	1	4.701144E-15	4.622393E-15	4.567189E-15	4.469073E-15	4.395527E-15	4.319718E-15	4.259945E-15	4.183337E-15
*		x mesh 129	x mesh 130	x mesh 131	x mesh 132	x mesh 133	x mesh 134	x mesh 135	x mesh 136
*	11	5.226806E-13	5.104608E-13	4.993380E-13	4.884963E-13	4.801478E-13	4.741331E-13	4.666425E-13	4.600332E-13
*	10	5.233795E-13	5.122274E-13	5.009810E-13	4.907599E-13	4.799217E-13	4.708962E-13	4.624562E-13	4.552938E-13

*	9	5.199175E-13	5.108627E-13	5.016165E-13	4.909669E-13	4.809556E-13	4.721901E-13	4.637334E-13	4.553535E-13
*	8	5.181723E-13	5.080010E-13	4.993104E-13	4.901038E-13	4.822447E-13	4.719371E-13	4.631591E-13	4.572186E-13
*	7	5.235967E-13	5.092070E-13	4.963547E-13	4.881791E-13	4.799091E-13	4.711044E-13	4.633655E-13	4.549845E-13
*	6	5.202736E-13	5.103775E-13	5.007702E-13	4.889600E-13	4.783694E-13	4.694826E-13	4.615249E-13	4.534607E-13
*	5	5.209017E-13	5.066226E-13	4.992508E-13	4.909045E-13	4.800211E-13	4.700997E-13	4.604164E-13	4.529823E-13
*	4	5.243036E-13	5.099213E-13	4.965520E-13	4.868632E-13	4.803957E-13	4.715421E-13	4.609721E-13	4.528654E-13
*	3	5.219343E-13	5.109116E-13	5.004115E-13	4.881451E-13	4.749806E-13	4.672015E-13	4.621049E-13	4.550662E-13
*	2	9.188755E-14	9.019612E-14	8.825488E-14	8.684109E-14	8.495340E-14	8.302064E-14	8.177581E-14	8.041522E-14
*	1	4.128878E-15	4.040650E-15	3.977556E-15	3.893738E-15	3.836696E-15	3.763351E-15	3.723145E-15	3.663374E-15
*		x mesh 137	x mesh 138	x mesh 139	x mesh 140	x mesh 141	x mesh 142	x mesh 143	x mesh 144
*	11	4.509001E-13	4.443796E-13	4.357755E-13	4.287236E-13	4.249002E-13	4.217439E-13	4.197065E-13	4.176364E-13
*	10	4.504932E-13	4.438397E-13	4.379500E-13	4.318233E-13	4.255086E-13	4.206015E-13	4.165338E-13	4.145468E-13
*	9	4.470558E-13	4.404627E-13	4.361487E-13	4.323836E-13	4.257744E-13	4.201667E-13	4.181108E-13	4.130556E-13
*	8	4.493535E-13	4.417759E-13	4.337602E-13	4.276228E-13	4.252505E-13	4.214841E-13	4.162983E-13	4.137255E-13
*	7	4.493784E-13	4.427272E-13	4.374453E-13	4.291736E-13	4.223939E-13	4.173866E-13	4.134100E-13	4.129158E-13
*	6	4.483845E-13	4.434004E-13	4.367774E-13	4.305352E-13	4.257235E-13	4.204416E-13	4.145209E-13	4.085137E-13
*	5	4.445666E-13	4.420920E-13	4.374428E-13	4.346181E-13	4.213157E-13	4.190491E-13	4.196457E-13	4.103018E-13
*	4	4.446063E-13	4.388897E-13	4.349908E-13	4.306392E-13	4.263131E-13	4.186846E-13	4.140284E-13	4.113799E-13
*	3	4.464470E-13	4.378334E-13	4.317321E-13	4.279407E-13	4.243832E-13	4.191150E-13	4.155282E-13	4.092340E-13
*	2	7.931337E-14	7.745267E-14	7.645461E-14	7.516748E-14	7.431981E-14	7.316549E-14	7.211633E-14	7.118637E-14
*	1	3.609984E-15	3.543929E-15	3.485769E-15	3.422280E-15	3.377113E-15	3.306243E-15	3.266656E-15	3.210836E-15
*		x mesh 145	x mesh 146	x mesh 147	x mesh 148	x mesh 149	x mesh 150	x mesh 151	x mesh 152
*	11	4.153341E-13	4.137273E-13	4.088758E-13	4.045845E-13	3.978062E-13	3.904162E-13	3.817296E-13	3.747964E-13
*	10	4.126758E-13	4.125940E-13	4.108583E-13	4.035104E-13	3.973430E-13	3.921655E-13	3.843298E-13	3.757998E-13
*	9	4.101913E-13	4.086941E-13	4.070805E-13	4.028696E-13	3.983830E-13	3.898558E-13	3.837110E-13	3.768337E-13
*	8	4.105575E-13	4.096828E-13	4.067979E-13	4.016603E-13	3.952238E-13	3.909729E-13	3.838263E-13	3.747443E-13
*	7	4.119628E-13	4.097905E-13	4.072696E-13	4.030902E-13	3.969355E-13	3.893439E-13	3.809169E-13	3.767045E-13
*	6	4.052201E-13	4.047340E-13	4.063460E-13	4.032630E-13	3.987857E-13	3.919328E-13	3.840200E-13	3.742234E-13
*	5	4.055263E-13	4.028045E-13	4.007369E-13	4.022170E-13	3.989958E-13	3.941184E-13	3.827707E-13	3.777001E-13
*	4	4.074087E-13	4.040331E-13	4.011550E-13	3.986689E-13	3.977965E-13	3.932609E-13	3.854348E-13	3.769237E-13
*	3	4.054611E-13	4.034346E-13	4.016232E-13	3.990316E-13	3.948014E-13	3.912416E-13	3.866497E-13	3.789045E-13
*	2	7.022606E-14	6.966657E-14	6.874081E-14	6.771889E-14	6.654251E-14	6.538481E-14	6.409537E-14	6.246049E-14
*	1	3.162981E-15	3.139440E-15	3.083906E-15	3.001382E-15	2.902559E-15	2.828173E-15	2.754304E-15	2.666821E-15
*		x mesh 153	x mesh 154	x mesh 155	x mesh 156	x mesh 157	x mesh 158	x mesh 159	x mesh 160
*	11	3.695364E-13	3.614662E-13	3.503089E-13	3.421990E-13	3.334825E-13	3.215776E-13	3.122812E-13	3.031060E-13
*	10	3.672613E-13	3.587723E-13	3.537783E-13	3.452583E-13	3.330031E-13	3.236215E-13	3.147543E-13	3.040741E-13
*	9	3.690977E-13	3.599610E-13	3.510979E-13	3.432426E-13	3.372581E-13	3.260241E-13	3.140342E-13	3.052271E-13

*	8	3.688924E-13	3.616217E-13	3.522905E-13	3.434090E-13	3.343268E-13	3.262981E-13	3.165108E-13	3.065589E-13
*	7	3.693265E-13	3.597087E-13	3.531944E-13	3.451690E-13	3.356455E-13	3.261192E-13	3.167180E-13	3.068226E-13
*	6	3.683570E-13	3.636522E-13	3.534737E-13	3.449125E-13	3.380608E-13	3.281668E-13	3.178406E-13	3.068332E-13
*	5	3.662246E-13	3.596354E-13	3.594410E-13	3.433769E-13	3.353498E-13	3.327479E-13	3.176922E-13	3.077975E-13
*	4	3.689885E-13	3.589865E-13	3.523078E-13	3.483662E-13	3.379116E-13	3.290674E-13	3.204056E-13	3.099809E-13
*	3	3.701544E-13	3.604623E-13	3.518971E-13	3.429854E-13	3.379050E-13	3.311271E-13	3.206096E-13	3.116478E-13
*	2	6.114865E-14	5.936811E-14	5.781279E-14	5.638195E-14	5.497539E-14	5.360390E-14	5.231105E-14	5.076507E-14
*	1	2.594822E-15	2.521785E-15	2.441123E-15	2.388833E-15	2.309431E-15	2.259201E-15	2.179733E-15	2.123392E-15
*		x mesh 161	x mesh 162	x mesh 163	x mesh 164	x mesh 165	x mesh 166	x mesh 167	x mesh 168
*	11	2.950861E-13	2.866659E-13	2.782293E-13	2.713293E-13	2.618929E-13	2.519119E-13	2.423750E-13	2.323048E-13
*	10	2.946868E-13	2.858039E-13	2.785011E-13	2.715622E-13	2.636105E-13	2.547191E-13	2.446276E-13	2.352379E-13
*	9	2.977069E-13	2.883544E-13	2.787024E-13	2.709495E-13	2.638224E-13	2.546126E-13	2.472378E-13	2.391013E-13
*	8	2.966774E-13	2.877544E-13	2.794641E-13	2.714861E-13	2.630061E-13	2.552746E-13	2.478571E-13	2.386204E-13
*	7	2.979495E-13	2.894234E-13	2.798229E-13	2.699975E-13	2.628375E-13	2.551992E-13	2.465299E-13	2.391500E-13
*	6	2.969527E-13	2.884610E-13	2.801079E-13	2.737649E-13	2.644218E-13	2.542216E-13	2.463485E-13	2.382531E-13
*	5	2.980995E-13	2.899254E-13	2.784211E-13	2.728770E-13	2.663531E-13	2.588224E-13	2.449630E-13	2.387800E-13
*	4	2.982327E-13	2.879242E-13	2.806583E-13	2.722324E-13	2.632344E-13	2.579990E-13	2.502827E-13	2.390882E-13
*	3	3.007169E-13	2.895425E-13	2.804515E-13	2.719014E-13	2.656516E-13	2.560122E-13	2.474302E-13	2.419573E-13
*	2	4.909177E-14	4.754404E-14	4.580558E-14	4.447915E-14	4.306723E-14	4.200823E-14	4.053687E-14	3.941550E-14
*	1	2.059345E-15	2.010487E-15	1.941543E-15	1.888453E-15	1.828073E-15	1.783075E-15	1.728596E-15	1.686623E-15
*		x mesh 169	x mesh 170	x mesh 171	x mesh 172	x mesh 173	x mesh 174	x mesh 175	x mesh 176
*	11	2.230408E-13	2.153743E-13	2.091322E-13	2.032137E-13	1.980724E-13	1.937871E-13	1.876073E-13	1.817233E-13
*	10	2.248559E-13	2.150943E-13	2.072633E-13	2.017456E-13	1.960861E-13	1.908879E-13	1.873169E-13	1.825747E-13
*	9	2.278210E-13	2.178238E-13	2.075203E-13	2.004872E-13	1.944182E-13	1.897597E-13	1.867297E-13	1.813695E-13
*	8	2.312142E-13	2.212595E-13	2.102471E-13	2.020238E-13	1.946030E-13	1.881497E-13	1.834693E-13	1.805585E-13
*	7	2.310053E-13	2.225343E-13	2.142476E-13	2.043184E-13	1.964592E-13	1.895220E-13	1.832139E-13	1.776997E-13
*	6	2.297591E-13	2.225075E-13	2.138618E-13	2.057097E-13	1.974771E-13	1.923410E-13	1.852477E-13	1.776645E-13
*	5	2.285802E-13	2.241786E-13	2.111287E-13	2.065529E-13	1.953525E-13	1.910347E-13	1.855297E-13	1.815256E-13
*	4	2.300199E-13	2.218335E-13	2.138338E-13	2.047876E-13	1.967203E-13	1.895922E-13	1.837280E-13	1.800103E-13
*	3	2.349660E-13	2.236674E-13	2.134555E-13	2.049898E-13	1.976039E-13	1.896942E-13	1.825610E-13	1.774020E-13
*	2	3.815204E-14	3.699233E-14	3.550984E-14	3.417282E-14	3.287541E-14	3.175963E-14	3.059161E-14	2.955605E-14
*	1	1.629364E-15	1.582511E-15	1.520761E-15	1.471757E-15	1.423395E-15	1.374981E-15	1.329993E-15	1.287592E-15
*		x mesh 177	x mesh 178	x mesh 179	x mesh 180	x mesh 181	x mesh 182	x mesh 183	x mesh 184
*	11	1.782927E-13	1.728945E-13	1.653178E-13	1.576794E-13	1.523139E-13	1.480723E-13	1.452859E-13	1.409327E-13
*	10	1.758999E-13	1.690194E-13	1.646620E-13	1.601570E-13	1.541641E-13	1.474347E-13	1.422440E-13	1.377181E-13
*	9	1.756077E-13	1.708422E-13	1.647098E-13	1.573237E-13	1.515240E-13	1.474442E-13	1.428950E-13	1.384605E-13
*	8	1.773140E-13	1.708239E-13	1.635633E-13	1.587872E-13	1.524336E-13	1.465310E-13	1.407161E-13	1.366748E-13

*	7	1.733524E-13	1.699158E-13	1.661080E-13	1.596203E-13	1.525006E-13	1.461955E-13	1.414802E-13	1.366927E-13
*	6	1.731047E-13	1.680086E-13	1.633886E-13	1.594178E-13	1.554067E-13	1.495752E-13	1.420861E-13	1.358471E-13
*	5	1.726821E-13	1.704612E-13	1.630399E-13	1.573198E-13	1.516874E-13	1.497594E-13	1.455152E-13	1.381343E-13
*	4	1.749922E-13	1.698070E-13	1.644605E-13	1.585336E-13	1.517873E-13	1.462973E-13	1.429843E-13	1.391408E-13
*	3	1.720673E-13	1.683490E-13	1.656747E-13	1.604386E-13	1.537377E-13	1.478139E-13	1.407580E-13	1.355900E-13
*	2	2.881257E-14	2.790305E-14	2.730509E-14	2.663231E-14	2.577256E-14	2.493274E-14	2.403208E-14	2.316959E-14
*	1	1.248573E-15	1.208202E-15	1.177729E-15	1.142347E-15	1.106116E-15	1.078645E-15	1.049900E-15	1.021872E-15
*		x mesh 185	x mesh 186	x mesh 187	x mesh 188	x mesh 189	x mesh 190	x mesh 191	x mesh 192
*	11	1.372163E-13	1.327916E-13	1.283685E-13	1.251237E-13	1.217878E-13	1.181929E-13	1.139108E-13	1.101298E-13
*	10	1.340080E-13	1.311698E-13	1.284559E-13	1.253699E-13	1.217713E-13	1.184290E-13	1.149933E-13	1.109255E-13
*	9	1.329372E-13	1.291901E-13	1.251916E-13	1.230822E-13	1.211878E-13	1.192414E-13	1.158495E-13	1.111616E-13
*	8	1.332963E-13	1.294794E-13	1.257644E-13	1.211712E-13	1.187306E-13	1.158631E-13	1.155021E-13	1.133949E-13
*	7	1.316578E-13	1.272835E-13	1.240601E-13	1.211459E-13	1.178995E-13	1.151611E-13	1.123263E-13	1.098476E-13
*	6	1.317123E-13	1.277141E-13	1.235971E-13	1.188867E-13	1.159548E-13	1.138911E-13	1.116693E-13	1.088357E-13
*	5	1.309718E-13	1.265128E-13	1.234392E-13	1.200530E-13	1.152183E-13	1.121166E-13	1.098736E-13	1.073495E-13
*	4	1.340177E-13	1.281194E-13	1.234535E-13	1.189696E-13	1.156637E-13	1.123995E-13	1.091779E-13	1.068231E-13
*	3	1.319735E-13	1.292192E-13	1.257807E-13	1.220260E-13	1.168793E-13	1.118833E-13	1.085843E-13	1.058687E-13
*	2	2.242576E-14	2.169932E-14	2.109609E-14	2.054104E-14	1.994416E-14	1.935961E-14	1.868578E-14	1.826309E-14
*	1	9.928831E-16	9.671205E-16	9.402505E-16	9.162851E-16	8.897768E-16	8.686506E-16	8.434003E-16	8.233556E-16
*		x mesh 193	x mesh 194	x mesh 195	x mesh 196	x mesh 197	x mesh 198	x mesh 199	x mesh 200
*	11	1.063946E-13	1.024234E-13	9.977242E-14	9.798596E-14	9.574159E-14	9.373311E-14	9.038595E-14	8.728706E-14
*	10	1.066575E-13	1.030264E-13	9.982828E-14	9.682156E-14	9.331399E-14	9.124300E-14	8.991315E-14	8.798964E-14
*	9	1.067997E-13	1.038527E-13	1.015040E-13	9.842269E-14	9.400449E-14	9.108686E-14	8.896462E-14	8.629304E-14
*	8	1.090213E-13	1.037642E-13	9.970916E-14	9.732016E-14	9.604237E-14	9.331053E-14	9.010771E-14	8.650971E-14
*	7	1.071600E-13	1.052779E-13	1.026447E-13	9.858444E-14	9.436135E-14	9.058575E-14	8.877991E-14	8.741947E-14
*	6	1.061273E-13	1.028866E-13	9.936245E-14	9.699148E-14	9.579896E-14	9.391473E-14	9.003655E-14	8.590679E-14
*	5	1.049486E-13	1.017465E-13	1.007553E-13	9.504712E-14	9.240300E-14	8.977497E-14	8.946553E-14	8.931028E-14
*	4	1.044643E-13	1.016106E-13	9.857534E-14	9.588247E-14	9.296369E-14	9.001528E-14	8.714405E-14	8.576928E-14
*	3	1.036281E-13	1.011861E-13	9.822017E-14	9.503768E-14	9.181146E-14	8.978041E-14	8.774168E-14	8.587863E-14
*	2	1.782203E-14	1.741046E-14	1.689464E-14	1.642310E-14	1.587880E-14	1.549119E-14	1.501646E-14	1.462846E-14
*	1	8.021735E-16	7.828314E-16	7.595429E-16	7.390562E-16	7.148099E-16	7.003480E-16	6.746949E-16	6.617552E-16
*		x mesh 201	x mesh 202	x mesh 203	x mesh 204	x mesh 205	x mesh 206	x mesh 207	x mesh 208
*	11	8.440992E-14	8.211305E-14	8.034452E-14	7.876853E-14	7.800661E-14	7.497449E-14	7.358424E-14	7.285792E-14
*	10	8.592114E-14	8.287560E-14	8.020093E-14	7.754936E-14	7.558054E-14	7.354130E-14	7.283571E-14	7.146896E-14
*	9	8.403547E-14	8.223646E-14	8.067812E-14	7.888990E-14	7.658534E-14	7.394494E-14	7.246913E-14	7.120393E-14
*	8	8.413627E-14	8.142449E-14	7.927857E-14	7.758327E-14	7.648726E-14	7.428525E-14	7.358076E-14	7.248520E-14
*	7	8.557335E-14	8.326064E-14	7.934040E-14	7.689195E-14	7.500215E-14	7.370106E-14	7.284388E-14	7.160388E-14

*	6	8.262783E-14	8.099127E-14	8.091536E-14	7.893525E-14	7.605584E-14	7.307390E-14	7.177986E-14	7.072380E-14
*	5	8.410490E-14	8.036589E-14	7.863665E-14	7.653001E-14	7.592655E-14	7.609524E-14	7.132939E-14	7.070486E-14
*	4	8.473272E-14	8.283486E-14	7.983562E-14	7.672403E-14	7.438931E-14	7.317779E-14	7.280592E-14	7.208138E-14
*	3	8.255488E-14	8.038488E-14	7.948036E-14	7.895749E-14	7.671180E-14	7.350952E-14	7.194879E-14	7.025930E-14
*	2	1.419419E-14	1.381619E-14	1.343441E-14	1.313514E-14	1.285859E-14	1.259564E-14	1.226759E-14	1.218747E-14
*	1	6.368370E-16	6.181889E-16	6.027717E-16	5.851659E-16	5.687288E-16	5.534742E-16	5.300639E-16	5.398185E-16
*		x mesh 209	x mesh 210	x mesh 211	x mesh 212	x mesh 213	x mesh 214	x mesh 215	x mesh 216
*	11	7.132975E-14	7.036324E-14	7.016801E-14	6.907170E-14	6.833747E-14	6.622892E-14	6.383681E-14	6.189114E-14
*	10	7.124909E-14	6.949550E-14	6.856492E-14	6.780525E-14	6.674238E-14	6.643502E-14	6.614597E-14	6.463545E-14
*	9	6.994354E-14	6.913958E-14	6.808213E-14	6.750978E-14	6.623592E-14	6.564448E-14	6.461481E-14	6.310173E-14
*	8	7.042979E-14	6.854334E-14	6.675632E-14	6.589601E-14	6.568214E-14	6.490162E-14	6.382485E-14	6.256033E-14
*	7	7.025386E-14	6.852300E-14	6.770383E-14	6.657906E-14	6.516028E-14	6.366881E-14	6.298919E-14	6.271354E-14
*	6	6.879780E-14	6.799185E-14	6.660680E-14	6.589434E-14	6.483458E-14	6.447960E-14	6.377023E-14	6.283829E-14
*	5	6.865405E-14	6.715533E-14	6.560782E-14	6.461045E-14	6.595817E-14	6.288411E-14	6.191409E-14	6.124430E-14
*	4	7.017590E-14	6.759138E-14	6.545454E-14	6.430522E-14	6.337691E-14	6.327004E-14	6.240252E-14	6.159266E-14
*	3	6.868011E-14	6.763981E-14	6.666267E-14	6.550131E-14	6.425967E-14	6.231377E-14	6.132279E-14	6.114955E-14
*	2	1.188884E-14	1.154266E-14	1.121055E-14	1.097384E-14	1.084614E-14	1.062211E-14	1.036959E-14	1.019825E-14
*	1	5.161336E-16	5.117708E-16	4.869077E-16	4.822443E-16	4.606807E-16	4.551603E-16	4.372702E-16	4.303650E-16
*		x mesh 217	x mesh 218	x mesh 219	x mesh 220	x mesh 221	x mesh 222	x mesh 223	x mesh 224
*	11	6.053211E-14	5.899216E-14	5.818245E-14	5.723508E-14	5.642242E-14	5.579696E-14	5.454117E-14	5.391129E-14
*	10	6.223671E-14	5.976483E-14	5.769464E-14	5.642155E-14	5.536432E-14	5.473333E-14	5.457744E-14	5.378209E-14
*	9	6.217002E-14	6.114262E-14	5.994739E-14	5.846639E-14	5.618964E-14	5.483614E-14	5.366384E-14	5.297591E-14
*	8	6.092030E-14	6.021687E-14	5.872453E-14	5.772401E-14	5.702067E-14	5.621920E-14	5.526158E-14	5.443153E-14
*	7	6.151234E-14	6.024609E-14	5.807394E-14	5.634538E-14	5.541680E-14	5.464262E-14	5.426979E-14	5.373977E-14
*	6	6.092692E-14	5.870681E-14	5.823304E-14	5.763907E-14	5.636154E-14	5.525922E-14	5.321367E-14	5.199198E-14
*	5	6.205753E-14	6.107241E-14	5.733353E-14	5.614848E-14	5.498590E-14	5.557602E-14	5.711116E-14	5.241620E-14
*	4	6.005136E-14	5.937402E-14	5.864540E-14	5.737664E-14	5.580033E-14	5.375933E-14	5.327802E-14	5.345291E-14
*	3	6.103970E-14	5.975114E-14	5.787468E-14	5.610765E-14	5.527943E-14	5.490489E-14	5.327013E-14	5.217267E-14
*	2	1.001143E-14	9.876876E-15	9.586679E-15	9.412170E-15	9.158713E-15	8.958590E-15	8.772093E-15	8.579363E-15
*	1	4.140163E-16	4.055073E-16	3.911982E-16	3.847907E-16	3.716052E-16	3.631598E-16	3.524742E-16	3.417489E-16
*		x mesh 225	x mesh 226	x mesh 227	x mesh 228	x mesh 229	x mesh 230	x mesh 231	x mesh 232
*	11	5.328469E-14	5.248796E-14	5.140368E-14	4.996497E-14	4.870997E-14	4.762903E-14	4.688562E-14	4.612878E-14
*	10	5.275390E-14	5.173553E-14	5.067662E-14	5.051765E-14	4.995775E-14	4.917180E-14	4.777041E-14	4.657202E-14
*	9	5.199364E-14	5.099707E-14	5.058308E-14	4.970425E-14	4.883168E-14	4.807441E-14	4.732867E-14	4.703350E-14
*	8	5.256010E-14	5.112301E-14	5.012144E-14	4.896243E-14	4.809186E-14	4.730377E-14	4.701057E-14	4.622373E-14
*	7	5.355486E-14	5.277771E-14	5.173307E-14	5.069791E-14	4.924453E-14	4.776147E-14	4.668364E-14	4.548660E-14
*	6	5.199927E-14	5.158469E-14	5.097361E-14	4.998866E-14	4.909685E-14	4.876637E-14	4.814717E-14	4.671568E-14

*	5	5.114487E-14	5.048329E-14	4.974463E-14	5.019475E-14	4.847679E-14	4.690675E-14	4.650331E-14	4.801027E-14
*	4	5.291217E-14	5.190869E-14	5.025444E-14	4.865816E-14	4.824090E-14	4.744836E-14	4.663685E-14	4.582267E-14
*	3	5.085524E-14	5.025071E-14	5.067795E-14	5.047674E-14	4.950227E-14	4.781804E-14	4.594332E-14	4.523210E-14
*	2	8.464273E-15	8.262218E-15	8.132720E-15	7.985997E-15	7.908709E-15	7.709231E-15	7.548244E-15	7.354239E-15
*	1	3.353032E-16	3.254650E-16	3.175418E-16	3.085740E-16	3.013488E-16	2.925374E-16	2.850401E-16	2.753524E-16
*		x mesh 233	x mesh 234	x mesh 235	x mesh 236	x mesh 237	x mesh 238	x mesh 239	x mesh 240
*	11	4.585715E-14	4.494797E-14	4.405270E-14	4.438314E-14	4.408231E-14	4.338205E-14	4.257192E-14	4.153779E-14
*	10	4.546355E-14	4.441539E-14	4.420044E-14	4.372816E-14	4.331328E-14	4.271331E-14	4.154138E-14	4.132536E-14
*	9	4.661388E-14	4.589099E-14	4.454456E-14	4.341257E-14	4.276146E-14	4.200742E-14	4.190598E-14	4.119334E-14
*	8	4.555969E-14	4.485427E-14	4.423230E-14	4.386506E-14	4.357243E-14	4.325114E-14	4.227108E-14	4.114919E-14
*	7	4.482684E-14	4.425725E-14	4.397575E-14	4.322653E-14	4.252624E-14	4.202930E-14	4.182526E-14	4.165495E-14
*	6	4.564954E-14	4.459698E-14	4.348732E-14	4.261898E-14	4.191735E-14	4.145896E-14	4.139508E-14	4.097429E-14
*	5	4.546506E-14	4.509544E-14	4.517738E-14	4.284600E-14	4.189551E-14	4.117446E-14	4.069861E-14	4.034007E-14
*	4	4.507361E-14	4.465529E-14	4.432071E-14	4.374826E-14	4.295676E-14	4.178461E-14	4.101029E-14	4.017509E-14
*	3	4.491273E-14	4.423593E-14	4.357121E-14	4.299184E-14	4.227541E-14	4.211058E-14	4.153228E-14	4.101852E-14
*	2	7.205118E-15	7.085989E-15	6.941417E-15	6.877429E-15	6.704229E-15	6.593049E-15	6.490650E-15	6.361793E-15
*	1	2.696221E-16	2.608643E-16	2.553601E-16	2.473966E-16	2.420474E-16	2.340934E-16	2.298070E-16	2.223627E-16
*		x mesh 241	x mesh 242	x mesh 243	x mesh 244	x mesh 245	x mesh 246	x mesh 247	x mesh 248
*	11	4.033764E-14	3.958611E-14	3.898340E-14	3.814105E-14	3.727319E-14	3.677202E-14	3.633599E-14	3.591624E-14
*	10	4.093452E-14	4.012396E-14	3.946581E-14	3.867141E-14	3.779871E-14	3.715164E-14	3.673020E-14	3.624710E-14
*	9	4.042767E-14	3.959442E-14	3.856045E-14	3.808328E-14	3.814918E-14	3.759954E-14	3.710703E-14	3.646806E-14
*	8	4.017845E-14	3.911093E-14	3.873055E-14	3.821702E-14	3.761992E-14	3.707144E-14	3.626789E-14	3.573116E-14
*	7	4.116340E-14	4.031443E-14	3.891225E-14	3.819968E-14	3.733845E-14	3.651488E-14	3.620072E-14	3.592413E-14
*	6	4.036219E-14	3.958516E-14	3.898118E-14	3.822846E-14	3.775430E-14	3.723557E-14	3.641133E-14	3.586273E-14
*	5	3.985100E-14	3.953064E-14	3.847371E-14	3.773037E-14	3.703579E-14	3.727756E-14	3.702534E-14	3.539416E-14
*	4	3.974943E-14	3.913827E-14	3.844031E-14	3.777759E-14	3.703133E-14	3.643745E-14	3.607585E-14	3.586196E-14
*	3	4.045911E-14	3.965140E-14	3.867243E-14	3.780528E-14	3.706500E-14	3.644691E-14	3.580860E-14	3.530852E-14
*	2	6.284985E-15	6.180642E-15	6.096145E-15	5.959676E-15	5.832950E-15	5.727469E-15	5.618984E-15	5.514825E-15
*	1	2.193775E-16	2.109445E-16	2.085713E-16	2.005619E-16	1.974669E-16	1.901558E-16	1.883880E-16	1.805035E-16
*		x mesh 249	x mesh 250	x mesh 251	x mesh 252	x mesh 253	x mesh 254	x mesh 255	x mesh 256
*	11	3.561769E-14	3.513338E-14	3.457030E-14	3.398917E-14	3.353365E-14	3.316649E-14	3.304043E-14	3.257126E-14
*	10	3.548661E-14	3.505558E-14	3.457825E-14	3.397142E-14	3.349320E-14	3.298763E-14	3.254780E-14	3.208946E-14
*	9	3.596132E-14	3.538529E-14	3.500168E-14	3.443949E-14	3.371167E-14	3.295541E-14	3.249762E-14	3.204272E-14
*	8	3.589608E-14	3.573948E-14	3.535795E-14	3.490867E-14	3.401982E-14	3.336797E-14	3.288132E-14	3.243150E-14
*	7	3.552350E-14	3.515277E-14	3.463009E-14	3.393981E-14	3.398329E-14	3.381212E-14	3.328705E-14	3.282934E-14
*	6	3.519652E-14	3.457288E-14	3.429250E-14	3.425826E-14	3.387237E-14	3.338903E-14	3.279065E-14	3.191124E-14
*	5	3.557751E-14	3.480944E-14	3.412559E-14	3.373131E-14	3.336319E-14	3.297302E-14	3.245208E-14	3.360440E-14

*	4	3.530145E-14	3.489155E-14	3.427431E-14	3.369204E-14	3.328897E-14	3.294405E-14	3.241296E-14	3.188724E-14
*	3	3.479520E-14	3.433465E-14	3.414723E-14	3.404412E-14	3.366746E-14	3.329620E-14	3.265870E-14	3.187426E-14
*	2	5.424238E-15	5.331385E-15	5.254053E-15	5.167531E-15	5.104297E-15	5.025940E-15	4.997747E-15	4.876343E-15
*	1	1.797240E-16	1.716018E-16	1.711187E-16	1.635025E-16	1.633573E-16	1.562878E-16	1.559596E-16	1.496406E-16
*		x mesh 257	x mesh 258	x mesh 259	x mesh 260	x mesh 261	x mesh 262	x mesh 263	x mesh 264
*	11	3.194638E-14	3.113511E-14	3.071747E-14	3.027067E-14	2.979581E-14	2.956578E-14	2.915682E-14	2.875148E-14
*	10	3.164695E-14	3.111049E-14	3.065492E-14	3.022251E-14	2.979027E-14	2.928447E-14	2.875894E-14	2.827748E-14
*	9	3.160207E-14	3.110858E-14	3.060974E-14	3.016355E-14	2.976456E-14	2.930499E-14	2.878325E-14	2.825805E-14
*	8	3.161479E-14	3.108908E-14	3.059360E-14	3.011470E-14	2.968818E-14	2.930833E-14	2.879870E-14	2.828821E-14
*	7	3.206807E-14	3.113591E-14	3.057303E-14	3.009886E-14	2.961939E-14	2.925954E-14	2.881060E-14	2.831972E-14
*	6	3.176821E-14	3.177592E-14	3.136471E-14	3.090861E-14	3.024844E-14	2.941064E-14	2.878756E-14	2.834862E-14
*	5	3.144667E-14	3.100369E-14	3.051177E-14	3.007757E-14	3.021956E-14	3.099710E-14	2.971517E-14	2.835723E-14
*	4	3.182980E-14	3.140439E-14	3.091054E-14	3.088595E-14	3.007984E-14	2.970118E-14	2.917053E-14	2.871887E-14
*	3	3.135658E-14	3.094100E-14	3.049895E-14	3.000803E-14	2.991315E-14	2.950440E-14	2.923588E-14	2.907555E-14
*	2	4.787673E-15	4.707748E-15	4.637140E-15	4.542404E-15	4.467627E-15	4.384258E-15	4.311192E-15	4.235438E-15
*	1	1.488467E-16	1.428863E-16	1.415649E-16	1.364092E-16	1.349114E-16	1.302482E-16	1.279667E-16	1.238012E-16
*		x mesh 265	x mesh 266	x mesh 267	x mesh 268	x mesh 269	x mesh 270	x mesh 271	x mesh 272
*	11	2.834728E-14	2.790153E-14	2.726004E-14	2.682433E-14	2.664338E-14	2.620069E-14	2.573116E-14	2.539467E-14
*	10	2.791543E-14	2.748419E-14	2.729109E-14	2.716260E-14	2.696852E-14	2.655735E-14	2.611955E-14	2.560794E-14
*	9	2.783580E-14	2.746071E-14	2.701424E-14	2.677420E-14	2.652626E-14	2.615730E-14	2.573002E-14	2.529582E-14
*	8	2.778169E-14	2.741025E-14	2.698129E-14	2.678052E-14	2.647101E-14	2.611023E-14	2.569515E-14	2.529956E-14
*	7	2.778560E-14	2.735748E-14	2.693471E-14	2.675535E-14	2.644526E-14	2.605035E-14	2.565624E-14	2.527187E-14
*	6	2.781387E-14	2.734595E-14	2.688568E-14	2.667811E-14	2.642234E-14	2.600917E-14	2.560775E-14	2.522824E-14
*	5	2.784148E-14	2.734696E-14	2.687356E-14	2.658908E-14	2.640167E-14	2.599099E-14	2.558123E-14	2.519007E-14
*	4	2.824491E-14	2.773554E-14	2.722134E-14	2.657808E-14	2.636947E-14	2.596835E-14	2.556723E-14	2.515211E-14
*	3	2.840889E-14	2.779832E-14	2.727852E-14	2.692760E-14	2.670757E-14	2.609620E-14	2.554508E-14	2.510908E-14
*	2	4.172184E-15	4.095330E-15	4.052370E-15	3.961726E-15	3.942914E-15	3.864497E-15	3.807946E-15	3.730466E-15
*	1	1.219457E-16	1.180658E-16	1.162597E-16	1.105916E-16	1.129121E-16	1.095058E-16	1.076476E-16	1.045982E-16
*		x mesh 273	x mesh 274	x mesh 275	x mesh 276	x mesh 277	x mesh 278	x mesh 279	x mesh 280
*	11	2.510073E-14	2.457149E-14	2.412737E-14	2.368940E-14	2.326606E-14	2.256355E-14	2.216117E-14	2.189790E-14
*	10	2.487678E-14	2.428962E-14	2.381121E-14	2.336693E-14	2.301932E-14	2.293958E-14	2.250826E-14	2.211077E-14
*	9	2.502950E-14	2.468634E-14	2.420523E-14	2.375071E-14	2.348535E-14	2.312461E-14	2.238302E-14	2.180641E-14
*	8	2.482937E-14	2.437305E-14	2.390366E-14	2.347269E-14	2.300805E-14	2.281741E-14	2.271867E-14	2.249382E-14
*	7	2.484720E-14	2.441509E-14	2.394209E-14	2.351492E-14	2.306761E-14	2.265753E-14	2.226134E-14	2.186682E-14
*	6	2.484090E-14	2.442864E-14	2.399247E-14	2.354119E-14	2.312465E-14	2.269703E-14	2.229170E-14	2.188510E-14
*	5	2.483466E-14	2.442170E-14	2.402483E-14	2.355658E-14	2.314970E-14	2.272833E-14	2.231928E-14	2.188974E-14
*	4	2.480793E-14	2.441184E-14	2.402672E-14	2.358121E-14	2.316770E-14	2.275013E-14	2.235451E-14	2.191081E-14

*	3	2.475223E-14	2.438631E-14	2.401931E-14	2.360818E-14	2.320332E-14	2.278417E-14	2.239777E-14	2.196777E-14
*	2	3.666204E-15	3.599824E-15	3.543356E-15	3.476266E-15	3.419101E-15	3.356982E-15	3.300926E-15	3.239803E-15
*	1	1.026522E-16	9.984065E-17	9.743853E-17	9.519768E-17	9.259940E-17	9.060332E-17	8.759996E-17	8.589786E-17
*		x mesh 281	x mesh 282	x mesh 283	x mesh 284	x mesh 285	x mesh 286	x mesh 287	x mesh 288
*	11	2.175514E-14	2.140653E-14	2.109639E-14	2.082945E-14	2.053378E-14	1.998530E-14	1.954199E-14	1.915633E-14
*	10	2.173508E-14	2.139503E-14	2.082090E-14	2.047131E-14	2.019953E-14	2.012544E-14	1.984348E-14	1.948931E-14
*	9	2.139796E-14	2.106371E-14	2.093457E-14	2.072786E-14	2.044982E-14	2.019961E-14	1.985867E-14	1.942805E-14
*	8	2.206281E-14	2.168601E-14	2.119334E-14	2.060302E-14	2.009340E-14	1.985432E-14	1.956763E-14	1.933448E-14
*	7	2.145254E-14	2.104632E-14	2.081173E-14	2.076308E-14	2.066578E-14	2.039137E-14	2.013797E-14	1.969800E-14
*	6	2.149666E-14	2.106807E-14	2.069043E-14	2.033296E-14	2.005186E-14	1.973855E-14	1.950650E-14	1.922837E-14
*	5	2.152379E-14	2.108707E-14	2.070192E-14	2.032062E-14	2.004209E-14	1.971930E-14	1.947212E-14	1.921149E-14
*	4	2.153124E-14	2.111715E-14	2.071720E-14	2.032672E-14	2.002324E-14	1.972036E-14	1.944434E-14	1.918159E-14
*	3	2.154872E-14	2.115290E-14	2.075470E-14	2.034644E-14	2.000648E-14	1.970454E-14	1.941816E-14	1.913899E-14
*	2	3.172635E-15	3.107491E-15	3.046212E-15	2.980351E-15	2.924738E-15	2.876742E-15	2.832210E-15	2.786861E-15
*	1	8.323133E-17	8.168695E-17	7.908540E-17	7.795773E-17	7.538938E-17	7.451846E-17	7.178657E-17	7.095450E-17
*		x mesh 289	x mesh 290	x mesh 291	x mesh 292	x mesh 293	x mesh 294	x mesh 295	x mesh 296
*	11	1.878794E-14	1.844809E-14	1.820090E-14	1.792640E-14	1.781463E-14	1.755892E-14	1.731029E-14	1.708925E-14
*	10	1.908303E-14	1.873747E-14	1.822060E-14	1.770972E-14	1.731963E-14	1.701814E-14	1.674229E-14	1.653795E-14
*	9	1.884449E-14	1.847001E-14	1.811330E-14	1.777568E-14	1.736459E-14	1.702769E-14	1.673029E-14	1.649771E-14
*	8	1.917194E-14	1.878849E-14	1.840115E-14	1.807276E-14	1.770938E-14	1.707654E-14	1.673975E-14	1.646599E-14
*	7	1.917031E-14	1.854369E-14	1.816620E-14	1.779509E-14	1.749172E-14	1.734804E-14	1.702176E-14	1.671303E-14
*	6	1.899568E-14	1.887208E-14	1.850301E-14	1.810058E-14	1.777764E-14	1.743622E-14	1.681342E-14	1.646057E-14
*	5	1.895152E-14	1.860530E-14	1.824551E-14	1.784331E-14	1.750292E-14	1.719154E-14	1.802567E-14	1.668490E-14
*	4	1.893934E-14	1.862124E-14	1.827175E-14	1.787805E-14	1.751547E-14	1.718725E-14	1.687926E-14	1.673952E-14
*	3	1.890034E-14	1.863561E-14	1.830647E-14	1.793658E-14	1.754915E-14	1.720482E-14	1.689590E-14	1.658640E-14
*	2	2.742492E-15	2.704553E-15	2.653076E-15	2.601811E-15	2.540854E-15	2.490744E-15	2.440337E-15	2.403084E-15
*	1	6.852372E-17	6.785546E-17	6.522678E-17	6.484665E-17	6.224560E-17	6.167223E-17	5.888912E-17	5.889245E-17
*		x mesh 297	x mesh 298	x mesh 299	x mesh 300	x mesh 301	x mesh 302	x mesh 303	x mesh 304
*	11	1.665420E-14	1.639635E-14	1.582073E-14	1.556192E-14	1.529204E-14	1.503224E-14	1.474995E-14	1.447923E-14
*	10	1.644758E-14	1.628921E-14	1.622768E-14	1.602925E-14	1.577665E-14	1.551372E-14	1.506205E-14	1.473346E-14
*	9	1.626978E-14	1.603202E-14	1.575808E-14	1.550273E-14	1.527572E-14	1.503989E-14	1.481976E-14	1.449914E-14
*	8	1.624151E-14	1.601550E-14	1.576694E-14	1.548549E-14	1.524776E-14	1.502917E-14	1.477368E-14	1.449469E-14
*	7	1.646680E-14	1.608819E-14	1.576926E-14	1.548895E-14	1.522729E-14	1.500169E-14	1.478192E-14	1.450429E-14
*	6	1.619824E-14	1.595483E-14	1.575198E-14	1.549887E-14	1.522554E-14	1.497281E-14	1.476867E-14	1.451799E-14
*	5	1.618936E-14	1.594243E-14	1.573007E-14	1.550500E-14	1.523005E-14	1.496120E-14	1.475143E-14	1.452409E-14
*	4	1.644717E-14	1.619203E-14	1.596470E-14	1.574392E-14	1.532323E-14	1.496381E-14	1.473256E-14	1.451977E-14
*	3	1.622243E-14	1.591890E-14	1.568655E-14	1.547296E-14	1.539960E-14	1.522343E-14	1.495087E-14	1.474058E-14

*	2	2.349519E-15	2.304361E-15	2.260492E-15	2.230727E-15	2.185239E-15	2.152387E-15	2.103638E-15	2.075368E-15
*	1	5.629859E-17	5.607888E-17	5.363198E-17	5.357381E-17	5.113651E-17	5.106511E-17	4.891423E-17	4.891564E-17
*		x mesh 305	x mesh 306	x mesh 307	x mesh 308	x mesh 309	x mesh 310	x mesh 311	x mesh 312
*	11	1.417173E-14	1.391277E-14	1.362219E-14	1.332115E-14	1.302950E-14	1.293738E-14	1.265708E-14	1.242152E-14
*	10	1.424137E-14	1.393308E-14	1.365217E-14	1.336551E-14	1.304443E-14	1.275271E-14	1.247741E-14	1.222310E-14
*	9	1.443670E-14	1.418931E-14	1.390413E-14	1.361457E-14	1.331362E-14	1.300239E-14	1.254006E-14	1.224660E-14
*	8	1.425182E-14	1.398983E-14	1.371619E-14	1.341773E-14	1.313337E-14	1.283537E-14	1.271914E-14	1.247927E-14
*	7	1.425194E-14	1.400570E-14	1.375138E-14	1.345123E-14	1.315852E-14	1.287274E-14	1.258631E-14	1.229540E-14
*	6	1.425957E-14	1.400799E-14	1.377424E-14	1.349129E-14	1.318940E-14	1.289653E-14	1.262740E-14	1.233465E-14
*	5	1.426781E-14	1.401069E-14	1.377716E-14	1.351946E-14	1.320937E-14	1.291355E-14	1.264148E-14	1.236829E-14
*	4	1.427273E-14	1.402312E-14	1.377409E-14	1.353372E-14	1.323758E-14	1.293385E-14	1.265283E-14	1.238932E-14
*	3	1.450467E-14	1.415590E-14	1.378057E-14	1.354305E-14	1.327672E-14	1.297591E-14	1.267416E-14	1.241533E-14
*	2	2.034596E-15	2.021313E-15	1.968920E-15	1.939047E-15	1.900220E-15	1.860610E-15	1.811414E-15	1.775838E-15
*	1	4.688292E-17	4.669181E-17	4.485589E-17	4.458770E-17	4.300206E-17	4.259938E-17	4.104662E-17	4.045939E-17
*		x mesh 313	x mesh 314	x mesh 315	x mesh 316	x mesh 317	x mesh 318	x mesh 319	x mesh 320
*	11	1.220901E-14	1.221251E-14	1.205256E-14	1.175014E-14	1.151812E-14	1.138985E-14	1.121098E-14	1.095744E-14
*	10	1.199801E-14	1.181544E-14	1.163324E-14	1.151540E-14	1.129505E-14	1.114790E-14	1.100367E-14	1.087434E-14
*	9	1.200398E-14	1.180193E-14	1.162155E-14	1.144731E-14	1.128432E-14	1.110980E-14	1.096601E-14	1.080867E-14
*	8	1.223112E-14	1.199708E-14	1.181035E-14	1.164918E-14	1.129943E-14	1.109231E-14	1.092898E-14	1.077570E-14
*	7	1.205493E-14	1.180795E-14	1.160504E-14	1.146861E-14	1.161600E-14	1.146542E-14	1.129118E-14	1.111574E-14
*	6	1.207446E-14	1.183515E-14	1.160855E-14	1.140957E-14	1.123607E-14	1.106649E-14	1.089023E-14	1.071943E-14
*	5	1.208469E-14	1.185219E-14	1.161818E-14	1.140727E-14	1.122530E-14	1.106141E-14	1.088010E-14	1.070932E-14
*	4	1.226485E-14	1.207406E-14	1.184076E-14	1.162156E-14	1.126390E-14	1.105339E-14	1.087536E-14	1.069896E-14
*	3	1.214944E-14	1.189225E-14	1.164826E-14	1.143744E-14	1.137174E-14	1.123628E-14	1.106367E-14	1.088088E-14
*	2	1.735255E-15	1.702295E-15	1.664176E-15	1.637216E-15	1.604780E-15	1.577430E-15	1.549964E-15	1.521874E-15
*	1	3.911369E-17	3.856902E-17	3.727031E-17	3.662797E-17	3.567916E-17	3.492633E-17	3.407095E-17	3.312846E-17
*		x mesh 321	x mesh 322	x mesh 323	x mesh 324	x mesh 325	x mesh 326	x mesh 327	x mesh 328
*	11	1.060045E-14	1.037565E-14	1.014791E-14	1.002790E-14	9.943786E-15	9.746107E-15	9.549509E-15	9.354220E-15
*	10	1.080574E-14	1.058238E-14	1.035343E-14	1.013897E-14	9.949337E-15	9.757638E-15	9.447648E-15	9.203307E-15
*	9	1.063065E-14	1.042290E-14	1.020344E-14	9.980825E-15	9.788292E-15	9.595080E-15	9.529639E-15	9.382458E-15
*	8	1.062729E-14	1.043605E-14	1.023128E-14	1.000279E-14	9.806212E-15	9.604834E-15	9.426372E-15	9.235848E-15
*	7	1.097144E-14	1.075802E-14	1.028087E-14	1.002936E-14	9.824149E-15	9.623739E-15	9.433517E-15	9.250290E-15
*	6	1.056117E-14	1.047418E-14	1.058502E-14	1.023526E-14	1.002305E-14	9.821249E-15	9.622231E-15	9.383087E-15
*	5	1.054372E-14	1.040123E-14	1.027090E-14	1.006772E-14	9.855389E-15	9.659763E-15	9.459053E-15	9.466423E-15
*	4	1.053252E-14	1.038253E-14	1.025105E-14	1.008433E-14	9.865472E-15	9.672958E-15	9.472487E-15	9.277002E-15
*	3	1.070363E-14	1.050817E-14	1.021622E-14	1.008593E-14	9.891933E-15	9.688736E-15	9.495682E-15	9.297139E-15
*	2	1.489957E-15	1.478890E-15	1.441304E-15	1.422906E-15	1.397104E-15	1.369229E-15	1.345123E-15	1.318239E-15

*	1	3.256256E-17	3.167351E-17	3.127303E-17	3.033052E-17	2.989847E-17	2.894007E-17	2.861777E-17	2.766752E-17
*		x mesh 329	x mesh 330	x mesh 331	x mesh 332	x mesh 333	x mesh 334	x mesh 335	x mesh 336
*	11	9.225389E-15	9.113039E-15	8.931670E-15	8.634641E-15	8.403687E-15	8.224464E-15	8.078506E-15	8.053536E-15
*	10	9.103123E-15	8.965896E-15	8.778029E-15	8.711489E-15	8.584017E-15	8.392519E-15	8.232120E-15	8.086298E-15
*	9	9.291287E-15	9.155571E-15	8.955828E-15	8.763094E-15	8.594542E-15	8.366708E-15	8.082790E-15	7.930124E-15
*	8	9.134088E-15	9.013961E-15	8.820822E-15	8.619859E-15	8.445321E-15	8.320890E-15	8.249831E-15	8.079875E-15
*	7	9.149283E-15	9.032599E-15	8.842474E-15	8.643918E-15	8.453471E-15	8.287628E-15	8.120911E-15	7.943150E-15
*	6	9.152482E-15	9.051233E-15	8.861610E-15	8.667455E-15	8.472376E-15	8.294622E-15	8.133381E-15	7.966653E-15
*	5	9.874328E-15	9.725348E-15	8.874925E-15	8.680419E-15	8.486029E-15	8.303406E-15	8.134208E-15	7.983418E-15
*	4	9.151921E-15	9.075443E-15	9.050476E-15	8.858837E-15	8.657843E-15	8.474636E-15	8.294749E-15	8.127347E-15
*	3	9.169341E-15	9.070278E-15	8.892529E-15	8.718932E-15	8.520592E-15	8.334346E-15	8.154536E-15	8.005186E-15
*	2	1.297833E-15	1.287021E-15	1.261640E-15	1.237439E-15	1.209032E-15	1.180903E-15	1.154510E-15	1.129677E-15
*	1	2.769819E-17	2.706109E-17	2.663998E-17	2.577923E-17	2.532527E-17	2.445323E-17	2.398815E-17	2.314492E-17
*		x mesh 337	x mesh 338	x mesh 339	x mesh 340	x mesh 341	x mesh 342	x mesh 343	x mesh 344
*	11	7.969222E-15	7.697845E-15	7.570401E-15	7.433736E-15	7.422847E-15	7.350921E-15	7.238076E-15	7.093379E-15
*	10	7.958783E-15	7.831581E-15	7.598264E-15	7.432481E-15	7.305365E-15	7.190369E-15	7.216478E-15	7.104010E-15
*	9	7.801538E-15	7.670718E-15	7.671704E-15	7.576903E-15	7.443144E-15	7.313234E-15	7.208210E-15	7.097392E-15
*	8	7.866291E-15	7.664065E-15	7.542259E-15	7.427020E-15	7.303525E-15	7.167408E-15	7.051349E-15	6.951150E-15
*	7	7.792852E-15	7.659289E-15	7.533221E-15	7.416419E-15	7.298841E-15	7.171026E-15	7.037849E-15	6.934909E-15
*	6	7.796003E-15	7.658250E-15	7.526069E-15	7.409347E-15	7.287012E-15	7.172983E-15	7.037386E-15	7.048403E-15
*	5	7.801430E-15	7.657951E-15	7.522640E-15	7.405414E-15	7.280556E-15	7.168748E-15	7.042246E-15	6.913160E-15
*	4	7.818564E-15	7.660603E-15	7.522096E-15	7.400295E-15	7.278205E-15	7.162490E-15	7.041993E-15	6.915828E-15
*	3	7.989064E-15	7.825502E-15	7.669160E-15	7.539168E-15	7.415484E-15	7.283185E-15	7.036620E-15	6.919329E-15
*	2	1.107815E-15	1.086559E-15	1.064303E-15	1.044953E-15	1.027412E-15	1.018670E-15	9.939277E-16	9.760043E-16
*	1	2.298167E-17	2.214478E-17	2.196932E-17	2.114663E-17	2.102419E-17	2.024869E-17	2.007772E-17	1.933865E-17
*		x mesh 345	x mesh 346	x mesh 347	x mesh 348	x mesh 349	x mesh 350	x mesh 351	x mesh 352
*	11	6.929536E-15	6.765213E-15	6.615940E-15	6.444441E-15	6.235481E-15	6.239859E-15	6.137544E-15	6.028092E-15
*	10	6.932823E-15	6.651663E-15	6.500605E-15	6.398046E-15	6.365519E-15	6.243339E-15	6.130161E-15	6.025400E-15
*	9	6.983790E-15	6.823022E-15	6.651083E-15	6.500173E-15	6.368029E-15	6.250071E-15	6.132437E-15	6.022304E-15
*	8	6.834587E-15	6.809414E-15	6.664981E-15	6.513007E-15	6.369122E-15	6.248485E-15	6.130155E-15	6.024409E-15
*	7	6.827022E-15	6.705967E-15	6.554217E-15	6.404697E-15	6.255207E-15	6.128849E-15	6.009622E-15	5.903842E-15
*	6	6.948878E-15	6.840309E-15	6.627624E-15	6.424683E-15	6.271277E-15	6.135951E-15	6.011727E-15	5.904459E-15
*	5	6.802340E-15	6.700924E-15	6.899505E-15	6.959950E-15	6.283090E-15	6.140700E-15	6.014153E-15	5.904427E-15
*	4	6.794038E-15	6.691877E-15	6.576311E-15	6.456507E-15	6.424213E-15	6.276790E-15	6.142163E-15	6.028413E-15
*	3	6.789538E-15	6.676567E-15	6.568761E-15	6.456364E-15	6.317432E-15	6.167510E-15	6.028190E-15	5.907449E-15
*	2	9.579286E-16	9.394163E-16	9.230611E-16	9.055095E-16	8.887185E-16	8.670682E-16	8.496033E-16	8.303205E-16
*	1	1.909613E-17	1.843933E-17	1.830211E-17	1.760765E-17	1.744651E-17	1.675502E-17	1.674837E-17	1.599262E-17

		x mesh 353	x mesh 354	x mesh 355	x mesh 356	x mesh 357	x mesh 358	x mesh 359	x mesh 360
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*	11	5.913322E-15	5.794382E-15	5.672226E-15	5.650681E-15	5.505456E-15	5.309776E-15	5.208462E-15	5.110122E-15
*	10	5.916316E-15	5.801190E-15	5.682242E-15	5.456857E-15	5.365533E-15	5.322809E-15	5.233390E-15	5.223916E-15
*	9	5.798243E-15	5.690966E-15	5.576508E-15	5.561247E-15	5.452015E-15	5.332145E-15	5.219407E-15	5.113464E-15
*	8	5.920184E-15	5.814949E-15	5.703256E-15	5.586236E-15	5.466374E-15	5.345480E-15	5.230314E-15	5.023715E-15
*	7	5.910592E-15	5.810272E-15	5.681950E-15	5.481460E-15	5.362716E-15	5.247141E-15	5.128189E-15	5.119627E-15
*	6	5.797065E-15	5.692788E-15	5.589118E-15	5.490602E-15	5.373702E-15	5.259369E-15	5.141772E-15	5.028509E-15
*	5	5.797838E-15	5.693291E-15	5.587113E-15	5.494105E-15	5.382507E-15	5.264428E-15	5.152377E-15	5.033042E-15
*	4	5.918481E-15	5.813026E-15	5.633546E-15	5.492016E-15	5.390514E-15	5.271192E-15	5.159366E-15	5.042443E-15
*	3	5.800136E-15	5.695316E-15	5.662339E-15	5.604096E-15	5.511219E-15	5.395823E-15	5.281059E-15	5.164463E-15
*	2	8.170479E-16	8.003150E-16	7.870523E-16	7.697829E-16	7.590816E-16	7.419962E-16	7.272444E-16	7.102073E-16
*	1	1.599219E-17	1.528945E-17	1.527364E-17	1.450039E-17	1.462327E-17	1.387431E-17	1.392411E-17	1.328405E-17
*									
*		x mesh 361	x mesh 362	x mesh 363	x mesh 364	x mesh 365	x mesh 366	x mesh 367	x mesh 368
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*	11	5.027645E-15	4.959893E-15	4.907858E-15	4.800521E-15	4.728409E-15	4.638390E-15	4.577413E-15	4.542031E-15
*	10	5.128290E-15	5.036739E-15	4.997666E-15	4.999337E-15	4.858359E-15	4.743973E-15	4.651789E-15	4.549564E-15
*	9	5.016937E-15	4.924759E-15	4.792638E-15	4.730138E-15	4.772880E-15	4.737959E-15	4.655716E-15	4.557671E-15
*	8	4.911455E-15	4.820350E-15	4.786482E-15	4.758838E-15	4.685469E-15	4.623286E-15	4.552633E-15	4.466444E-15
*	7	5.023562E-15	4.926541E-15	4.839524E-15	4.757391E-15	4.675963E-15	4.608504E-15	4.469214E-15	4.374252E-15
*	6	4.924514E-15	4.822940E-15	4.733933E-15	4.652534E-15	4.570545E-15	4.494791E-15	4.450771E-15	4.466499E-15
*	5	4.929296E-15	4.827084E-15	4.731811E-15	4.651757E-15	4.569603E-15	4.489831E-15	4.421185E-15	4.363215E-15
*	4	4.932955E-15	4.831577E-15	4.734853E-15	4.649978E-15	4.569832E-15	4.487686E-15	4.414266E-15	4.352840E-15
*	3	5.034577E-15	4.836566E-15	4.741456E-15	4.650151E-15	4.568815E-15	4.486280E-15	4.406984E-15	4.337590E-15
*	2	7.024165E-16	6.792794E-16	6.662378E-16	6.526491E-16	6.421494E-16	6.299692E-16	6.191731E-16	6.073780E-16
*	1	1.334986E-17	1.274026E-17	1.271150E-17	1.223834E-17	1.217017E-17	1.176553E-17	1.164621E-17	1.121773E-17
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*	11	4.443461E-15	4.275406E-15	4.196591E-15	4.109125E-15	4.014121E-15	3.873257E-15	3.741422E-15	3.665766E-15
*	10	4.471161E-15	4.466501E-15	4.309522E-15	4.114710E-15	4.025555E-15	3.970013E-15	3.924406E-15	3.841511E-15
*	9	4.462588E-15	4.374690E-15	4.364216E-15	4.303218E-15	4.127089E-15	4.033154E-15	3.934650E-15	3.849484E-15
*	8	4.370698E-15	4.275344E-15	4.108300E-15	4.121913E-15	4.129980E-15	4.044674E-15	3.946410E-15	3.857068E-15
*	7	4.284571E-15	4.202449E-15	4.200633E-15	4.121565E-15	4.040261E-15	3.960258E-15	3.870649E-15	3.779668E-15
*	6	4.385818E-15	4.296567E-15	4.207570E-15	4.125082E-15	4.045087E-15	3.907736E-15	3.795158E-15	3.708688E-15
*	5	4.292158E-15	4.206779E-15	4.119269E-15	4.035577E-15	3.956720E-15	4.126601E-15	4.175463E-15	3.717062E-15
*	4	4.289218E-15	4.209427E-15	4.123397E-15	4.039119E-15	3.958394E-15	3.880205E-15	3.802354E-15	3.807095E-15
*	3	4.279080E-15	4.210053E-15	4.129673E-15	4.044955E-15	3.962884E-15	3.881902E-15	3.806677E-15	3.727354E-15
*	2	5.988301E-16	5.881796E-16	5.775777E-16	5.658701E-16	5.545842E-16	5.421991E-16	5.310665E-16	5.192735E-16
*	1	1.110681E-17	1.075509E-17	1.055166E-17	1.029541E-17	1.010009E-17	9.834501E-18	9.616395E-18	9.409081E-18

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* 9 3.781516E-15 3.784515E-15 3.616611E-15 3.479892E-15 3.409328E-15 3.362205E-15 3.338000E-15 3.275788E-15
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* 2 5.076413E-16 4.962898E-16 4.858033E-16 4.752992E-16 4.648116E-16 4.533185E-16 4.417828E-16 4.296159E-16
* 1 9.171719E-18 8.953854E-18 8.806058E-18 8.661212E-18 8.426909E-18 7.881746E-18 7.317250E-18 6.711935E-18
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* 5 3.060025E-15 2.993434E-15 2.944396E-15 2.897531E-15 2.851247E-15 2.819345E-15
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* 3 3.139865E-15 3.071300E-15 3.008443E-15 2.956657E-15 2.913907E-15 2.885464E-15
* 2 4.176316E-16 4.054712E-16 3.945851E-16 3.853732E-16 3.787849E-16 3.743637E-16
* 1 6.048477E-18 5.228339E-18 4.655541E-18 4.307261E-18 4.175411E-18 4.091658E-18

```

1*****

```

*      ...interface file rtflux written..

```

```

*
*      ...interface file sncons written..

```

```

PARTISN solver iteration time      = 124822.577 seconds
mesh analysis and adjustments      = 153.223 seconds
first collision source              = 624.975 seconds
outer source setup                  = 1256.305 seconds
inner source setup                  = 800.890 seconds
transport sweeps                    = 121088.267 seconds

```

```

transport synthetic acceleration =      0.000 seconds
diffusion synthetic acceleration =    549.502 seconds
diffusion source                 =      0.000 seconds
diffusion solve                  =    159.007 seconds
relaxation                       =     70.425 seconds
interpolation                    =      0.000 seconds
particle balance                  =      5.333 seconds

Transport Grind Time              =    2771.454 nanoseconds
Diffusion Grind Time             =    5623.324 nanoseconds

```

```

*
*****
1 *****
*****
*
*               edit run on 03           with solver version 10-15-01     beta release 2.64     machine ascii01
*
*****
*
*               ...mass edit...
*               (by solver zones)
*
*   zone      1   mass edit   (zone volume = 5.63175E+11 cm**3)
*   isotope   library position  isotope name  atomic weight  number density  isotope mass
*   1         1              1001.50         1.01          9.77000E-03    9.20830E+06 kg
*   2         16             8016.50         15.99          3.48000E-02    5.20548E+08 kg
*   3         20             13027.50        26.98          4.88000E-03    1.23136E+08 kg
*   4         21             14000.50        28.09          1.16000E-02    3.04677E+08 kg
*   zone      1   total mass = 9.57570E+08 kg    average density = 1.70 g/cm**3
*
*   zone      2   mass edit   (zone volume = 2.77150E+14 cm**3)
*   isotope   library position  isotope name  atomic weight  number density  isotope mass
*   1         14             7014.50         14.00          4.02000E-05    2.59072E+08 kg
*   2         16             8016.50         15.99          1.07000E-05    7.87655E+07 kg
*   zone      2   total mass = 3.37837E+08 kg    average density = 0.00 g/cm**3
*
*   zone      3   mass edit   (zone volume = 3.40152E+09 cm**3)
*   isotope   library position  isotope name  atomic weight  number density  isotope mass
*   1         1              1001.50         1.01          7.86000E-03    4.47441E+04 kg
*   2         16             8016.50         15.99          4.38000E-02    3.95717E+06 kg
*   3         18             11023.50        22.99          1.05000E-03    1.36349E+05 kg

```

```

*           4           19           12000.50           24.31           1.40000E-04           1.92200E+04 kg
*           5           20           13027.50           26.98           2.39000E-03           3.64245E+05 kg
*           6           21           14000.50           28.09           1.58000E-02           2.50650E+06 kg
*           7           26           19000.50           39.10           6.90000E-04           1.52383E+05 kg
*           8           27           20000.50           40.08           2.92000E-03           6.61027E+05 kg
*           9           32           26000.55           55.85           2.10000E-04           6.62432E+04 kg
*
*      zone      3      total mass = 7.90788E+06 kg      average density = 2.32 g/cm**3
*
*      total mass = 1.30331E+09 kg      total volume = 2.77716E+14 cm**3      average density = 0.00 g/cm**3
*      (excluding voids)

```

```

0*****
*****

```

```

*
*      ...edit output...

```

```

*
*      ...block vi - edit specification data...

```

```

*****
*key start edit output *
*****

```

```

*****
*
*      cross section balancing (balxs.ne.0)
*      or
*      transport correction (trcor=diag, cesaro, or bhs)
*      will NOT be reflected in edits
*
*****

```

```

*      ...input control integers...

```

```

*      1 pted      0/1      no/yes - point edits desired

```

```

*
*      1  zned      0/1      no/yes - zone edits desired
*
*      0  ajed      0/1      direct/adjoint edit(use rtflux/atflux file)
*
*      3  igrped    0/1/2/3  print totals only/print broad groups only/same as 1/print all groups and totals
*      0  byvolp    0/1      no/yes - multiply point reaction rates by mesh volumes
*      0  rzflux    0/1/2/3  no/write the rzflux file/+xvzflux/+print
*      0  rzmflx    0/1      no/yes - write the rzmflx file (zone average flux moments file)
*

```

...floating parameters...

```

*      0.000000E+00  power      0/p      no/normalize all results, including flux files, to p megawatts
*      2.100000E+02  mevper     mev per fission (default: 210 mev)
*

```

...energy related edit information...

```

*      12  number of fine neutron groups
*      0   number of fine gamma groups
*      12  total number of fine groups
*      12  total number of broad groups
*

```

...space related edit information...

```

*      47  number of points to edit
*      1672 number of zones to edit
*      0   0/1 no/yes density factors were input
*      1   0/1/2/3 no/solver/edit/both zones mass edit
*              (requires atomic weights to be present)
*

```

```

*****
*****

```

****point translation from 1d to 3d

point	i	j	k	avg. radii	avg. y	avg. z	volume
374844	54	5	12	6.096000E+03	9.144000E+01	-5.410000E+02	1.082000E+06
374885	95	5	12	1.524000E+04	9.144000E+01	-5.410000E+02	1.082000E+06

374936	146	5	12	3.048000E+04	9.144000E+01	-5.410000E+02	1.082000E+06
374997	207	5	12	6.096000E+04	9.144000E+01	-5.410000E+02	1.082000E+06
375058	268	5	12	9.144000E+04	9.144000E+01	-5.410000E+02	1.082000E+06
375119	329	5	12	1.219200E+05	9.144000E+01	-5.410000E+02	1.082000E+06
375180	390	5	12	1.524000E+05	9.144000E+01	-5.410000E+02	1.082000E+06
395092	22	57	12	-2.273737E-13	2.944500E+03	-5.410000E+02	1.201020E+06
395124	54	57	12	6.096000E+03	2.944500E+03	-5.410000E+02	1.201020E+07
395165	95	57	12	1.524000E+04	2.944500E+03	-5.410000E+02	1.201020E+07
395216	146	57	12	3.048000E+04	2.944500E+03	-5.410000E+02	1.201020E+07
395277	207	57	12	6.096000E+04	2.944500E+03	-5.410000E+02	1.201020E+07
395338	268	57	12	9.144000E+04	2.944500E+03	-5.410000E+02	1.201020E+07
395399	329	57	12	1.219200E+05	2.944500E+03	-5.410000E+02	1.201020E+07
395460	390	57	12	1.524000E+05	2.944500E+03	-5.410000E+02	1.201020E+07
397432	22	63	12	-2.273737E-13	5.750000E+03	-5.410000E+02	5.410000E+06
397464	54	63	12	6.096000E+03	5.750000E+03	-5.410000E+02	5.410000E+07
397505	95	63	12	1.524000E+04	5.750000E+03	-5.410000E+02	5.410000E+07
397556	146	63	12	3.048000E+04	5.750000E+03	-5.410000E+02	5.410000E+07
397617	207	63	12	6.096000E+04	5.750000E+03	-5.410000E+02	5.410000E+07
397678	268	63	12	9.144000E+04	5.750000E+03	-5.410000E+02	5.410000E+07
397739	329	63	12	1.219200E+05	5.750000E+03	-5.410000E+02	5.410000E+07
397800	390	63	12	1.524000E+05	5.750000E+03	-5.410000E+02	5.410000E+07
399772	22	69	12	-2.273737E-13	1.150000E+04	-5.410000E+02	1.082000E+07
399804	54	69	12	6.096000E+03	1.150000E+04	-5.410000E+02	1.082000E+08
399845	95	69	12	1.524000E+04	1.150000E+04	-5.410000E+02	1.082000E+08
399896	146	69	12	3.048000E+04	1.150000E+04	-5.410000E+02	1.082000E+08
399957	207	69	12	6.096000E+04	1.150000E+04	-5.410000E+02	1.082000E+08
400018	268	69	12	9.144000E+04	1.150000E+04	-5.410000E+02	1.082000E+08
400079	329	69	12	1.219200E+05	1.150000E+04	-5.410000E+02	1.082000E+08
400140	390	69	12	1.524000E+05	1.150000E+04	-5.410000E+02	1.082000E+08
402112	22	75	12	-2.273737E-13	1.750000E+04	-5.410000E+02	1.082000E+07
402144	54	75	12	6.096000E+03	1.750000E+04	-5.410000E+02	1.082000E+08
402185	95	75	12	1.524000E+04	1.750000E+04	-5.410000E+02	1.082000E+08
402236	146	75	12	3.048000E+04	1.750000E+04	-5.410000E+02	1.082000E+08
402297	207	75	12	6.096000E+04	1.750000E+04	-5.410000E+02	1.082000E+08
402358	268	75	12	9.144000E+04	1.750000E+04	-5.410000E+02	1.082000E+08
402419	329	75	12	1.219200E+05	1.750000E+04	-5.410000E+02	1.082000E+08
402480	390	75	12	1.524000E+05	1.750000E+04	-5.410000E+02	1.082000E+08
406792	22	87	12	-2.273737E-13	2.950000E+04	-5.410000E+02	1.082000E+07
406824	54	87	12	6.096000E+03	2.950000E+04	-5.410000E+02	1.082000E+08
406865	95	87	12	1.524000E+04	2.950000E+04	-5.410000E+02	1.082000E+08
406916	146	87	12	3.048000E+04	2.950000E+04	-5.410000E+02	1.082000E+08
406977	207	87	12	6.096000E+04	2.950000E+04	-5.410000E+02	1.082000E+08
407038	268	87	12	9.144000E+04	2.950000E+04	-5.410000E+02	1.082000E+08

[illegible]

```
...zone edit for broad group 1 ...
```

zone	volume	rspfl
1	1.7849E+08	0.00000E+00
2	2.0439E+09	0.00000E+00
3	1.4630E+07	0.00000E+00

4	2.0439E+09	0.00000E+00
5	1.7849E+08	0.00000E+00
6	6.6159E+09	0.00000E+00
7	1.4630E+08	0.00000E+00
8	1.3232E+10	0.00000E+00
9	1.4630E+08	0.00000E+00
10	2.2150E+10	0.00000E+00

...point edit for the sum of the neutron groups ...

... response functions ...

point	av rad	rspfl
*****	6.0960E+03	1.66432E-09
*****	1.5240E+04	3.15678E-10
*****	3.0480E+04	1.21764E-10
*****	6.0960E+04	2.19895E-11
*****	9.1440E+04	5.29517E-12
*****	1.2192E+05	1.59401E-12
*****	1.5240E+05	4.03536E-13
*****	-2.2737E-13	9.54694E-07
*****	6.0960E+03	3.17491E-08
*****	1.5240E+04	5.03531E-09
*****	3.0480E+04	1.58079E-10
*****	6.0960E+04	2.72541E-11
*****	9.1440E+04	6.69949E-12
*****	1.2192E+05	1.84223E-12
*****	1.5240E+05	4.78732E-13
*****	-2.2737E-13	9.92992E-08
*****	6.0960E+03	2.17868E-08
*****	1.5240E+04	3.87922E-09
*****	3.0480E+04	8.81890E-10
*****	6.0960E+04	5.99845E-11
*****	9.1440E+04	7.71838E-12
*****	1.2192E+05	1.99642E-12
*****	1.5240E+05	5.12322E-13
*****	-2.2737E-13	1.27120E-08
*****	6.0960E+03	7.91657E-09
*****	1.5240E+04	2.91837E-09
*****	3.0480E+04	8.27679E-10

```

***** 6.0960E+04 1.30897E-10
***** 9.1440E+04 1.67143E-11
***** 1.2192E+05 4.91459E-12
***** 1.5240E+05 9.28643E-13
***** -2.2737E-13 2.59221E-09
***** 6.0960E+03 3.83944E-09
***** 1.5240E+04 2.09669E-09
***** 3.0480E+04 6.66396E-10
***** 6.0960E+04 8.94743E-11
***** 9.1440E+04 1.81207E-11
***** 1.2192E+05 7.48632E-12
***** 1.5240E+05 1.12207E-12
***** -2.2737E-13 1.99695E-10
***** 6.0960E+03 7.81651E-10
***** 1.5240E+04 7.53327E-10
***** 3.0480E+04 2.92373E-10
***** 6.0960E+04 5.86358E-11
***** 9.1440E+04 1.55553E-11
***** 1.2192E+05 4.49738E-12
***** 1.5240E+05 9.78959E-13

```

...zone edit for the sum of the neutron groups ...

... response functions ...

zone	volume	rspfl
1	1.7849E+08	1.21173E-02
2	2.0439E+09	1.23026E-01
3	1.4630E+07	7.44592E-04
4	2.0439E+09	1.34877E-01
5	1.7849E+08	1.45126E-02
6	6.6159E+09	3.74849E-01
7	1.4630E+08	6.85576E-03
8	1.3232E+10	4.97828E-01
9	1.4630E+08	3.84167E-03
10	2.2150E+10	3.78934E-01
11	1.4630E+08	1.56360E-03
12	4.4447E+10	2.34880E-01
13	1.4630E+08	3.24406E-04

14	4.4447E+10	5.32023E-02
15	1.4630E+08	8.37483E-05
16	4.4447E+10	1.45803E-02
17	1.4630E+08	2.46553E-05
18	4.4447E+10	4.31219E-03
19	1.4630E+08	6.32015E-06
20	2.5310E+08	1.69987E-01
21	2.8982E+09	1.51784E+00
22	2.0746E+07	7.58378E-03
23	2.8982E+09	1.61699E+00
24	2.5310E+08	1.91402E-01
25	9.3812E+09	4.62613E+00
26	2.0746E+08	8.29808E-02
27	1.8762E+10	6.03550E+00
28	2.0746E+08	4.42896E-02
29	3.1409E+10	4.32033E+00
30	2.0746E+08	1.78142E-02
31	6.3025E+10	2.69651E+00
32	2.0746E+08	3.76257E-03
33	6.3025E+10	6.19517E-01
34	2.0746E+08	9.81073E-04
35	6.3025E+10	1.71063E-01
36	2.0746E+08	2.90338E-04
37	6.3025E+10	5.11529E-02
38	2.0746E+08	7.94239E-05
39	2.9280E+07	1.91979E-02
40	3.3528E+08	1.78886E-01
41	2.4000E+06	8.94581E-04
42	3.3528E+08	1.90699E-01
43	2.9280E+07	2.19205E-02
44	1.0853E+09	5.38012E-01
45	2.4000E+07	9.78086E-03
46	2.1706E+09	6.95453E-01
47	2.4000E+07	5.17137E-03
48	3.6336E+09	5.02168E-01
49	2.4000E+07	2.07290E-03
50	7.2912E+09	3.13195E-01
51	2.4000E+07	4.36960E-04
52	7.2912E+09	7.19152E-02
53	2.4000E+07	1.13918E-04
54	7.2912E+09	1.98489E-02
55	2.4000E+07	3.37231E-05
56	7.2912E+09	5.93319E-03

57	2.4000E+07	9.16610E-06
58	5.0583E+09	2.60493E+00
59	5.7922E+10	2.99653E+01
60	4.1461E+08	1.94886E-01
61	5.7922E+10	3.32626E+01
62	5.0583E+09	3.15139E+00
63	1.8749E+11	9.10852E+01
64	4.1461E+09	1.69135E+00
65	3.7498E+11	1.17910E+02
66	4.1461E+09	9.59275E-01
67	6.2773E+11	9.40889E+01
68	4.1461E+09	3.85236E-01
69	1.2596E+12	5.78121E+01
70	4.1461E+09	8.01681E-02
71	1.2596E+12	1.31579E+01
72	4.1461E+09	2.07348E-02
73	1.2596E+12	3.60344E+00
74	4.1461E+09	6.08272E-03
75	1.2596E+12	1.06848E+00
76	4.1461E+09	1.63508E-03
77	2.9280E+07	1.36283E-02
78	3.3528E+08	1.72674E-01
79	2.4000E+06	1.20986E-03
80	3.3528E+08	1.96672E-01
81	2.9280E+07	1.76741E-02
82	1.0853E+09	5.61878E-01
83	2.4000E+07	1.07389E-02
84	2.1706E+09	7.28459E-01
85	2.4000E+07	5.96765E-03
86	3.6336E+09	5.86613E-01
87	2.4000E+07	2.38051E-03
88	7.2912E+09	3.55530E-01
89	2.4000E+07	4.90006E-04
90	7.2912E+09	8.03008E-02
91	2.4000E+07	1.26076E-04
92	7.2912E+09	2.18167E-02
93	2.4000E+07	3.66832E-05
94	7.2912E+09	6.42465E-03
95	2.4000E+07	9.85741E-06
96	1.6397E+08	7.80265E-02
97	1.8776E+09	9.90329E-01
98	1.3440E+07	6.93750E-03
99	1.8776E+09	1.13151E+00

100	1.6397E+08	1.01242E-01
101	6.0776E+09	3.19232E+00
102	1.3440E+08	6.07831E-02
103	1.2155E+10	4.10515E+00
104	1.3440E+08	3.35234E-02
105	2.0348E+10	3.29724E+00
106	1.3440E+08	1.33803E-02
107	4.0831E+10	1.99696E+00
108	1.3440E+08	2.74792E-03
109	4.0831E+10	4.50388E-01
110	1.3440E+08	7.06974E-04
111	4.0831E+10	1.22380E-01
112	1.3440E+08	2.05504E-04
113	4.0831E+10	3.60504E-02
114	1.3440E+08	5.52976E-05
115	3.2501E+09	1.35543E+01
116	3.7216E+10	1.64269E+02
117	2.6640E+08	1.16083E+00
118	3.7216E+10	1.70432E+02
119	3.2501E+09	1.46856E+01
120	1.2047E+11	4.41145E+02
121	2.6640E+09	7.53497E+00
122	4.2093E+11	3.90417E+02
123	2.6640E+09	2.10347E+00
124	4.0333E+11	1.29858E+02
125	2.6640E+09	2.78360E-01
126	8.0932E+11	4.12247E+01
127	2.6640E+09	5.64978E-02
128	8.0932E+11	9.23684E+00
129	2.6640E+09	1.44373E-02
130	8.0932E+11	2.49654E+00
131	2.6640E+09	4.18209E-03
132	8.0932E+11	7.32717E-01
133	2.6640E+09	1.11424E-03
134	8.7840E+09	4.75155E+01
135	1.0058E+11	5.58729E+02
136	7.2000E+08	4.32428E+00
137	1.0058E+11	5.77595E+02
138	8.7840E+09	5.03190E+01
139	3.2558E+11	1.61982E+03
140	7.2000E+09	2.92971E+01
141	6.5117E+11	1.80817E+03
142	7.2000E+09	1.29175E+01

143	1.0901E+12	1.07389E+03
144	7.2000E+09	3.39083E+00
145	2.1874E+12	3.81976E+02
146	7.2000E+09	3.43445E-01
147	2.1874E+12	4.49793E+01
148	7.2000E+09	4.87884E-02
149	2.1874E+12	7.65148E+00
150	7.2000E+09	1.23428E-01
151	2.1874E+12	2.14684E+00
152	7.2000E+09	3.22982E-03
153	1.7568E+10	6.66510E+01
154	2.0117E+11	7.51308E+02
155	1.4400E+09	5.35874E+00
156	2.0117E+11	7.83585E+02
157	1.7568E+10	7.23841E+01
158	6.5117E+11	2.33487E+03
159	1.4400E+10	4.54844E+01
160	1.3023E+12	3.00496E+03
161	1.4400E+10	2.26077E+01
162	2.1802E+12	2.03997E+03
163	1.4400E+10	7.67824E+00
164	4.3747E+12	1.07348E+03
165	1.4400E+10	1.28564E+00
166	4.3747E+12	1.85532E+02
167	1.4400E+10	2.42074E-01
168	4.3747E+12	3.82806E+01
169	1.4400E+10	5.49754E-02
170	4.3747E+12	8.85595E+00
171	1.4400E+10	1.23617E-02
172	1.7568E+10	3.61486E+01
173	2.0117E+11	4.10468E+02
174	1.4400E+09	2.30016E+00
175	2.0117E+11	4.28263E+02
176	1.7568E+10	3.83216E+01
177	6.5117E+11	1.39500E+03
178	1.4400E+10	2.82469E+01
179	1.3023E+12	2.09671E+03
180	1.4400E+10	1.78247E+01
181	2.1802E+12	1.71433E+03
182	1.4400E+10	6.71883E+00
183	4.3747E+12	9.30601E+02
184	1.4400E+10	1.24527E+00
185	4.3747E+12	2.06781E+02

186	1.4400E+10	3.31006E-01
187	4.3747E+12	5.40218E+01
188	1.4400E+10	7.62221E-02
189	4.3747E+12	1.23280E+01
190	1.4400E+10	1.73853E-02
191	3.5136E+10	3.28396E+01
192	4.0234E+11	3.73994E+02
193	2.8800E+09	2.34301E+00
194	4.0234E+11	3.90110E+02
195	3.5136E+10	3.64055E+01
196	1.3023E+12	1.37470E+03
197	2.8800E+10	2.79436E+01
198	2.6047E+12	2.25142E+03
199	2.8800E+10	2.12370E+01
200	4.3603E+12	2.30213E+03
201	2.8800E+10	1.00302E+01
202	8.7494E+12	1.53074E+03
203	2.8800E+10	2.04598E+00
204	8.7494E+12	3.25972E+02
205	2.8800E+10	5.05245E-01
206	8.7494E+12	9.08500E+01
207	2.8800E+10	1.65647E-01
208	8.7494E+12	2.98992E+01
209	2.8800E+10	4.84804E-02
210	2.7621E+07	1.81374E-02
211	3.1629E+08	3.31937E-01
212	2.2641E+06	3.01761E-03
213	3.1629E+08	3.40259E-01
214	2.7621E+07	2.00443E-02
215	1.0238E+09	3.64569E-01
216	2.2641E+07	3.37345E-03
217	2.0476E+09	2.12320E-01
218	2.2641E+07	1.46533E-03
219	3.4278E+09	1.03687E-01
220	2.2641E+07	3.68530E-04
221	6.8782E+09	5.03518E-02
222	2.2641E+07	6.26990E-05
223	6.8782E+09	1.00343E-02
224	2.2641E+07	1.51869E-05
225	6.8782E+09	2.58657E-03
226	2.2641E+07	4.23172E-06
227	6.8782E+09	7.29310E-04
228	2.2641E+07	1.03609E-06

★
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1637	1.4400E+09	1.74642E+00
1638	2.0117E+11	3.85552E+02
1639	1.7568E+10	3.38253E+01
1640	6.5117E+11	1.28152E+03
1641	1.4400E+10	2.58311E+01
1642	1.3023E+12	1.95915E+03
1643	1.4400E+10	1.68407E+01

```

*
*      1644 2.1802E+12  1.64130E+03
*      1645 1.4400E+10  6.34532E+00
*      1646 4.3747E+12  8.85089E+02
*      1647 1.4400E+10  1.19629E+00
*      1648 4.3747E+12  2.05426E+02
*      1649 1.4400E+10  3.37956E-01
*      1650 4.3747E+12  5.49680E+01
*      1651 1.4400E+10  7.89605E-02
*      1652 4.3747E+12  1.26864E+01
*      1653 1.4400E+10  1.85371E-02
*      1654 3.5136E+10  3.14340E+01
*      1655 4.0234E+11  3.56763E+02
*      1656 2.8800E+09  1.61004E+00
*      1657 4.0234E+11  3.59521E+02
*      1658 3.5136E+10  3.29702E+01
*      1659 1.3023E+12  1.30383E+03
*      1660 2.8800E+10  2.68228E+01
*      1661 2.6047E+12  2.14672E+03
*      1662 2.8800E+10  2.03105E+01
*      1663 4.3603E+12  2.21331E+03
*      1664 2.8800E+10  9.67382E+00
*      1665 8.7494E+12  1.48056E+03
*      1666 2.8800E+10  1.98122E+00
*      1667 8.7494E+12  3.11849E+02
*      1668 2.8800E+10  4.78031E-01
*      1669 8.7494E+12  8.76460E+01
*      1670 2.8800E+10  1.63030E-01
*      1671 8.7494E+12  3.00576E+01
*      1672 2.8800E+10  5.07439E-02
*
*      -----
*      sum 2.7772E+14  1.60297E+05
1*****
*
*
*
*      run highlights
*
*****
*key start run highlights *
*****
*
*
*
*      *****
*
*      *
*      all modules are tentatively go.
*      interface file geodst written.
*

```

```
* xslibb asc prepared from bxslib *  
* **full path name is used x-sections *  
* bxslib prepared from xslibb asc *  
* interface mixing files written. *  
* interface file asgmat written *  
* xs files macrxs,snxedt written. *  
* interface file solinp written. *  
* interface file editit written. *  
* start solver execution. *  
* **negative or zero transport fluxes** *  
* all convergence criteria met. *  
* interface file rtflux written. *  
* interface file sncons written. *  
* start edit execution. *  
* edits completed. *  
*  
*****
```

```
...execution terminated...
```

```

3      0      0
THREEDANT isotropic point source, 25 cm above floor, in center corridor;
detectors @ y=508cm, D1 @ x=229cm and z=6990cm, D2 @ x=4995 cm and z=6990cm
2mod2.in
/ geometry      - X-Y-Z
/ cross sections - MENDF5G, xslibb.mendfg
/ mixing        - isotopes mixed to make materials named air
/              and ground
/ solver        - S16-P4, first collision source=ptana
/ edits         - card input supplied
/
/ block i
  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=2 nzone=2
  im=15 it=226 jm=6 jt=20 km=9 kt=225
  maxscm=80000000 maxlcm=150000000 t
/
/ block ii (geometry)
  xmesh= -20, 0, 224, 234, 457, 477,
         4744, 4764, 4988, 4998, 5221, 5241
         9508, 9528, 9985, 10005
  xints= 1,3,1,3,1,100,1,3,1,3,1,100,1,6,1
  ymesh= -20, 0, 50, 498, 518, 610, 630
  yints= 1,2,10,1,5,1
  zmesh= -20, 0, 457, 477, 3368, 3378,
         6268, 6288, 6745, 6765
  zints= 1,10,1,100,1,100,1,10,1
  zones= 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=-20-0
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=0-457
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=457-477
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;

```

2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=477-3368
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=3368-3378
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1;
2 1 1 1 2 1 2 1 1 1 2 1 2 1;
2 1 1 1 2 1 2 1 1 1 2 1 2 1;
2 1 1 1 2 1 2 1 1 1 2 1 2 1;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6268-6288
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6288-6745
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6745-6765
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

      2 2 2 2 2 2 2 2 2 2 2 2 2 2; \
      2 2 2 2 2 2 2 2 2 2 2 2 2 2; t
/
/ block iii (cross sections)
  lib=xslibb savbxs=1      /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=airl      "8016.50" 9.6533-6      /O
                  "7014.50" 4.1425-5;     /N
  conc           "1001.50" 1.4660-1,      /H
                  "8016.50" 5.1465-2,      /O
                  "11023.50" 8.5857-4,     /Na
                  "12000.50" 1.0828-4,     /Mg
                  "13027.50" 1.6651-3,     /Al
                  "14000.50" 1.0575-2,     /Si
                  "19000.50" 3.3176-4,     /K
                  "20000.50" 1.3696-3,     /Ca
                  "26000.55" 1.0435-4;     /Fe
  assign=air      airl 1.0;                /zone 1
                  concrete conc 1.0 t      /zone 2
/
/ * * * * block v (solver) * * * *
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
  ievt=0 isct=4 ibr=0 ibt=0 ibb=0 ibfrnt=0 ibback=0 iitm=200 oitm=50
  norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0
/ energy grps (12) for source term
  source=4.40939-8, 4.40939-8, 2.35945-4, 4.75076-4, 7.14207-4,1.91294-3,
          5.56546-3, 1.75850-2, 5.11491-2, 4.03269-2, 1.22591-2, 2.92139-5
/ fine mesh location on the x axis of the point source:
  sourcx= 113z, 1, f0
/ fine mesh location on the y axis of the point source:
  sourcy= 2z, 1, f0
/ fine mesh location on the z axis of the point source:
  sourcz= 112z, 1, f0
  /fcsrc=ptana
  /fcxpos=4993 /position of source in x in cm
  /fcypos=3373 /position of source in x in cm
  /fczpos=25   /position of source in x in cm
  t

```

```

/
/ * * * * block vi (edits) * * * *
  pted=1  zned=1  igrped=3
/ for detectors use point=i +(j-1)NX + (k-1)NXNY; NX=IT=226; NY=JT=20
/ fine mesh points i=5, 43, 76, 114
/ fine mesh points j=8, 14, 19
/ fine mesh points k=224
  points= 1009547, 1010903, 1012033  /i=5, lowest ht to highest
          1009585, 1010941, 1012071  /i=43
          1009618, 1010974, 1012104  /i=76
          1009656, 1011012, 1012142  /i=114
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
  rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1,
        11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

```

3      0      0
THREEDANT isotropic point source, 25 cm above floor, in center corridor;
detectors @ y=508cm, D1 @ x=229cm and z=6990cm, D2 @ x=4995 cm and z=6990cm
3mod2.in
/ geometry      - X-Y-Z
/ cross sections - MENDF5G, xslibb.mendfg
/ mixing        - isotopes mixed to make materials named air
/              and ground
/ solver        - S16-P4, first collision source=raytr
/ edits         - card input supplied
/
/ block i
  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=2 nzone=2
  im=15 it=226 jm=6 jt=20 km=9 kt=225
  maxscm=80000000 maxlcm=150000000 t
/
/ block ii (geometry)
  xmesh= -20, 0, 224, 234, 457, 477,
         4744, 4764, 4988, 4998, 5221, 5241
         9508, 9528, 9985, 10005
  xints= 1,3,1,3,1,100,1,3,1,3,1,100,1,6,1
  ymesh= -20, 0, 50, 498, 518, 610, 630
  yints= 1,2,10,1,5,1
  zmesh= -20, 0, 457, 477, 3368, 3378,
         6268, 6288, 6745, 6765
  zints= 1,10,1,100,1,100,1,10,1
  zones= 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=-20-0
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=0-457
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=457-477
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;

```

```
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=477-3368
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 1;
2 1 1 1 2 1 2 1 1 2 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 1;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 1;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=3368-3378
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 ; /z=3378-6268
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 ;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 ;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 ;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2 ;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 ;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6268-6288
2 1 1 1 2 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 2 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 2 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 2 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6288-6745
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
/z=6745-6765

```

        2 2 2 2 2 2 2 2 2 2 2 2 2 2;
        2 2 2 2 2 2 2 2 2 2 2 2 2 2; t
/
/ block iii (cross sections)
  lib=xslibb savbxs=1    /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=airl      "8016.50" 9.6533-6      /O
                  "7014.50" 4.1425-5;     /N
  conc           "1001.50" 1.4660-1,      /H
                  "8016.50" 5.1465-2,      /O
                  "11023.50" 8.5857-4,     /Na
                  "12000.50" 1.0828-4,     /Mg
                  "13027.50" 1.6651-3,     /Al
                  "14000.50" 1.0575-2,     /Si
                  "19000.50" 3.3176-4,     /K
                  "20000.50" 1.3696-3,     /Ca
                  "26000.55" 1.0435-4;     /Fe
  assign=air      airl 1.0;                /zone 1
                  concrete conc 1.0 t      /zone 2
/
/ * * * * block v (solver) * * * *
/ norm is 24 hr/day*365 day/yr
/ first collision source is FCSRC, location is in sourcy,
/ energy spectrum is in source
  ievt=0 isct=4 ibr=0 ibt=0 ibb=0 ibfrnt=0 ibback=0 iitm=200 oitm=50
  norm=1.0 fluxp=1 xsct=0 sourcp=1 balp=0
/ energy grps (12) for source term
  source=4.40939-8, 4.40939-8, 2.35945-4, 4.75076-4, 7.14207-4, 1.91294-3,
          5.56546-3, 1.75850-2, 5.11491-2, 4.03269-2, 1.22591-2, 2.92139-5
/ fine mesh location on the x axis of the point source:
  sourcx= 113z, 1, f0
/ fine mesh location on the y axis of the point source:
  sourcy= 2z, 1, f0
/ fine mesh location on the z axis of the point source:
  sourcez= 112z, 1, f0
  fcsrc=raytr
  fcncray=10000
  fcncr=25
  /fcxpos=4993 /position of source in x in cm
  /fcypos=3373 /position of source in y in cm

```

```

      /fczpos=25      /position of source in x in cm
      t
/
/ * * * * block vi (edits) * * * *
      pted=1 zned=1 igrped=3
/ for detectors use point=i +(j-1)NX + (k-1)NXNY; NX=IT=226; NY=JT=20
/ fine mesh points i=5, 43, 76, 114
/ fine mesh points j=8, 14, 19
/ fine mesh points k=224
      points= 1009547, 1010903, 1012033 /i=5, lowest ht to highest
              1009585, 1010941, 1012071 /i=43
              1009618, 1010974, 1012104 /i=76
              1009656, 1011012, 1012142 /i=114
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
      rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1,
           11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

```

3      0      0
THREEDANT isotropic point source, 25 cm above floor, in center corridor;
detectors @ y=508cm, D1 @ x=229cm and z=6990cm, D2 @ x=4995 cm and z=6990cm
4mod2.in
/ geometry      - X-Y-Z
/ cross sections - MENDF5G, xslibb.mendfg
/ mixing        - isotopes mixed to make materials named air
/              and ground
/ solver        - S16-P4, first collision source=raytr fcrstrt=2
/ edits         - card input supplied
/
/ block i
  igeom=x-y-z, ngroup=12, isn=16 niso=99 mt=2 nzone=2
  im=15 it=226 jm=6 jt=20 km=9 kt=225
  maxscm=80000000 maxlcm=150000000 t
/
/ block ii (geometry)
  xmesh= -20, 0, 224, 234, 457, 477,
         4744, 4764, 4988, 4998, 5221, 5241
         9508, 9528, 9985, 10005
  xints= 1,3,1,3,1,100,1,3,1,3,1,100,1,6,1
  ymesh= -20, 0, 50, 498, 518, 610, 630
  yints= 1,2,10,1,5,1
  zmesh= -20, 0, 457, 477, 3368, 3378,
         6268, 6288, 6745, 6765
  zints= 1,10,1,100,1,100,1,10,1
  zones= 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=-20-0
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=0-457
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

         2 2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=457-477
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
         2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;

```

```
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;
```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;  /z=477-3368
2 1 1 1 1 2 1 1 1 1 2 1 2 1 2;
2 1 1 1 1 2 1 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=3368-3378
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2;    /z=3378-6268
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 1 1 1 2 1 2 1 1 1 2 1 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6268-6288
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 1 2 2 2 1 2;
2 1 1 1 2 2 2 1 1 2 2 2 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6288-6745
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 1 1 1 1 1 1 1 1 1 1 1 1 1 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2;

2 2 2 2 2 2 2 2 2 2 2 2 2 2; /z=6745-6765
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;
2 2 2 2 2 2 2 2 2 2 2 2 2 2;

```

      2 2 2 2 2 2 2 2 2 2 2 2 2 2;
      2 2 2 2 2 2 2 2 2 2 2 2 2 2; t
/
/ block iii (cross sections)
  lib=xslibb savbxs=1    /first cp xslibb.mendfg xslibb
  t
/
/ block iv (mixing)
  matspec=atdens /atomic density= atoms/b*cm
  matls=airl      "8016.50" 9.6533-6      /O
                  "7014.50" 4.1425-5;     /N
  conc           "1001.50" 1.4660-1,      /H
                  "8016.50" 5.1465-2,      /O
                  "11023.50" 8.5857-4,     /Na
                  "12000.50" 1.0828-4,     /Mg
                  "13027.50" 1.6651-3,     /Al
                  "14000.50" 1.0575-2,     /Si
                  "19000.50" 3.3176-4,     /K
                  "20000.50" 1.3696-3,     /Ca
                  "26000.55" 1.0435-4;     /Fe
  assign=air      airl 1.0;                /zone 1
                  concrete conc 1.0 t      /zone 2
/
/ * * * block v (solver) * * *
/  norm is 24 hr/day*365 day/yr
/  first collision source is FCSRC, location is in sourcy,
/  energy spectrum is in source
  fcrstrt=2
  ievt=0 isct=4 ibr=0 ibt=0 ibb=0 ibfrnt=0 ibback=0 iitm=200 oitm=50
  norm=1.0 fluxp=1 xsectp=0 sourcp=1 balp=0
/ energy grps (12) for source term
  source=4.40939-8, 4.40939-8, 2.35945-4, 4.75076-4, 7.14207-4, 1.91294-3,
          5.56546-3, 1.75850-2, 5.11491-2, 4.03269-2, 1.22591-2, 2.92139-5
/ fine mesh location on the x axis of the point source:
  sourcx= 113z, 1, f0
/ fine mesh location on the y axis of the point source:
  sourcy= 2z, 1, f0
/ fine mesh location on the z axis of the point source:
  sourcez= 112z, 1, f0
  fcsrc=raytr
  fcrray=10000
  fcctr=25
  /fcxpos=4993 /position of source in x in cm

```

```

/fcypos=3373 /position of source in x in cm
/fczpos=25   /position of source in x in cm
t
/
/ * * * * block vi (edits) * * * *
  pted=1 zned=1 igrped=3
/ for detectors use point=i +(j-1)NX + (k-1)NXNY; NX=IT=226; NY=JT=20
/ fine mesh points i=5, 43, 76, 114
/ fine mesh points j=8, 14, 19
/ fine mesh points k=224
  points= 1009547, 1010903, 1012033 /i=5, lowest ht to highest
          1009585, 1010941, 1012071 /i=43
          1009618, 1010974, 1012104 /i=76
          1009656, 1011012, 1012142 /i=114
/ Resp Fcns in Air Kerma/unit Fluence from ICRU-57
/ in pGy/cm^2 for 12 energy groups
  rsfe=23.025, 21.075, 19.1, 17.1, 15.1, 13.1,
        11.03, 8.755, 6.075, 3.46, 1.3736, 0.8410 t

```

APPENDIX B: Source Term CSAS1X Input/Output Files and Development Data

```

0.....
*
*
*      SCALE4.4a  Bulletin  Board
*      -----
*
*
*      Welcome to the configuration controlled version of SCALE-4.4a.
*      Any problems can be reported via email to <scalehelp@ornl.gov>.
*
*
*.....

```

```

1      primary module access and input record ( scale driver - 96/03/13 - 10:32:44 )
-      module csasix will be called
      Source term search for Dantsys calcs srcterm3 based on LANL/student input
      27n-18couple
      multiregion
      uranium 1 den=18.74 1.0 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 end
      end comp
      spherical end
      1 8.741 noexterm0d
      end zone
      more data sxf=15
      end more
      end data

0      secondary module o0o008 has been called.
0      module o0o008 is finished. completion code      0. cpu time used      0.08 (seconds).
0      secondary module o0o002 has been called.
0      module o0o002 is finished. completion code      0. cpu time used      1.66 (seconds).
0      secondary module o0o001 has been called.
0      module o0o001 is finished. completion code      0. cpu time used      0.25 (seconds).
0      module csasix is finished. completion code      0. cpu time used      2.07 (seconds).
0 the following data cards precede an - card

```

1	CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAA22222A	SSSSSSSSSSSS	11	XX	XX				
	CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAA222222A	SSSSSSSSSSSS	111	XX	XX				
	CC	SS	SS	AA	AA	SS	SS	1111	XX	XX	
	CC	SS		AA		AA	SS	11	XX	XX	
	CC	SS		AA		AA	SS	11	XX	XX	
	CC	SSSSSSSSSSSS	AAAAA222222A	SSSSSSSSSSSS	11			11	XXX		
	CC	SSSSSSSSSSSS	AAAAA222222A	SSSSSSSSSSSS	11			11	XXX		
	CC		SS	AA		AA	SS	11	XX	XX	
	CC		SS	AA		AA	SS	11	XX	XX	
	CC	CC	SS	SS	AA	AA	SS	SS	11	XX	XX
	CCCCCCCCCCCC	SSSSSSSSSSSS	AA	AA	SSSSSSSSSSSS	11111111	XX			XX	
	CCCCCCCCCCCC	SSSSSSSSSSSS	AA	AA	SSSSSSSSSSSS	11111111	XX			XX	

[illegible]

1	cccccccccc	cccccccccc	cccccccccc	cccccccccc	11	xx	xx				
	cccccccccc	cccccccccc	cccccccccc	cccccccccc	111	xx	xx				
--	cc	ss	ss	aa	aa	ss	ss	1111	xx	xx	
cc		ss		aa		aa	ss	ss	11	xx	xx
cc		ss		aa		aa	ss	ss	11	xx	xx
cc		cccccccccc		cccccccccc		cccccccccc	cccccccccc	11		xxx	
cc		cccccccccc		cccccccccc		cccccccccc	cccccccccc	11		xxx	
cc			ss	aa		aa	ss	ss	11	xx	xx
cc			ss	aa		aa	ss	ss	11	xx	xx
cc	cc	ss	ss	aa	aa	ss	ss	11	xx	xx	
cccccccccccccc	cccccccccccccc	cccccccccccccc	aa	aa	cccccccccccccc	cccccccccccccc	cccccccccccccc	11111111	xx	xx	
cccccccccccccc	cccccccccccccc	cccccccccccccc	aa	aa	cccccccccccccc	cccccccccccccc	cccccccccccccc	11111111	xx	xx	

xx		xx	vv		vv	cccccccccccccc		
xx		xx	vv		vv	cccccccccccccc		
	xx		xx	vv		vv	cc	
	xx	xx		vv		vv	cc	
		xx	xx		vv	vv	cc	
			xxx		vv	vv	cc	
		xxx		vv		vv	cc	
		xx	xx		vv	vv	cc	
		xx		xx		vv	vv	cc
	xx		xx		vv	vv	cc	
		xx		xx		vv	vv	cc
xx			xx		vvv		cc	
xx			xx		v		cc	


```

0000000 11 // 2222222222 3333333333 // 0000000 2222222222
000000000 111 // 222222222222 333333333333 // 000000000 222222222222
00 00 1111 // 22 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
00 00 11 22 33 33 // 00 00 22 22
000000000 11111111 // 222222222222 333333333333 // 000000000 222222222222
0000000 11111111 // 222222222222 3333333333 // 0000000 222222222222

```

```

0000000 9999999999 2222222222 44 11 44
000000000 99999999999 222222222222 444 111 444
00 00 99 99 22 22 4444 1111 4444
00 00 99 99 22 22 44 44 11 44 44
00 00 99 99 22 22 44 44 11 44 44
00 00 99999999999 22 44 44 11 44 44
00 00 99999999999 22 44 44 11 44 44
00 00 99 22 444444444444 11 444444444444
00 00 99 22 444444444444 11 444444444444
00 00 99 22 44 44 11 44
000000000 99999999999 222222222222 44 11111111 44
0000000 99999999999 222222222222 44 11111111 44

```

```

##### CCCCCCCCCC AAAAAAAAAA 11 #####
##### CCCCCCCCCCCCCC AAAAAAAAAA 11 #####
SS SS CC CC AA AA 11
SS CC CC AA AA 11
SS CC CC AA AA 11
##### CC AAAAAAAAAA 11 #####
##### CC AAAAAAAAAA 11 #####
SS CC AA AA 11
SS CC AA AA 11
SS SS CC CC AA AA 11
##### CCCCCCCCCCCCCC AA AA 111111111111 #####
##### CCCCCCCCCCCCCC AA AA 111111111111 #####

```

```

.....
.....
.....
****
**** program verification information ****
****
**** code system: scale version: 4.4a ****
****
.....
.....
****
**** program: csas ****
****
**** creation date: 08_sep_2000 ****

```



```

rz          8.74 cm right boundary location
smod noextermod external moderator index

0  **** special parameters ****

lsn          8 order of angular quadrature
lim          20 inner iteration maximum
lcm          25 outer iteration maximum
szf 1.50000E+01 size factor for spatial mesh
eps 1.00000E-04 overall problem convergence
ptc 1.00000E-05 scalar flux convergence
bkl 1.42089E+00 buckling factor
lus          0 thermal upscatter scaling
bal          fine balance table print flag
dy 0.00000E+00 buckling height
dz 0.00000E+00 buckling depth
lgn          0 diffusion coefficient option
frd 491411 logical unit number to read flux guess
fwr -1 logical unit number to write flux guess
msh 2001 number of intervals for res. integrns
nlv          2 max lvalue for res. integrns
axs          0 logical unit number to write axian lib
nbu          0 logical unit number to write bal.tables
1
*****
***
***          source term search for dantays calcs srcterm4 based on oecd benchmark input ***
***
*****
***
***          ***** data library information *****
***
***          unit          volume
***          number          data set name          name          unit function
***          -----          -----          ----          -----
***
***          09          /vcc/scale4.4a/data/scale.rev16.sclib          standard composition library
***
***          00          /vcc/scale4.4a/data/scale.rev04.xn27g18          cross section library
***
***          11          fcl1f001          short cross section library
***
***          90          fct90f001          input data direct access
***
*****
***
***          standard composition library data
***          -----
***
***          unit number : 09
***
***          dataset name : /vcc/scale4.4a/data/scale.rev16.sclib
***
***          library title: scale-4 standard composition library
***          648 standard compositions, 490 nuclides
***          90 elements with variable isotopic distributions.
***
***          creation date:  9/ 8/ 0
***

```

[illegible]


```

1
0      -1q array has      1 entries.
0      0q array has      4 entries.
0      1q array has      6 entries.
0      2q array has      2 entries.

11logical assignments
0master library 11
0working library 0
0scratch file 18
0new library 1

0p r o b l e m   d e s c r i p t i o n
0igr--geometry (0/1/2/3--inf end/slab/cyl/sphere) 3
0ism--number of zones or material regions 1
0ms--mixing table length 3
0ibl--shielded cross section edit option (0/1--no/yes) 0
0ibr--bondarenko factor edit option (0/1--no/yes) 0
0isopt--dancoff factor option 0
0convergence criterion 1.00000E-03
0geometry correction factor for wigner rational approximation 1.350E+00

0      3q array has      3 entries.
0      4q array has      3 entries.
0      5q array has      3 entries.
0      6q array has      1 entries.
0      7q array has      1 entries.
0      8q array has      1 entries.
0      9q array has      1 entries.
0     10q array has      3 entries.
0     11q array has      1 entries.

0m i x i n g   t a b l e
0entry mixture isotope number density new identifier explicit temperature
1      1      92235 4.49942E-02 1092235 293.0
2      1      92238 2.49839E-03 1092238 293.0
3      1      92234 4.91846E-04 1092234 293.0

0geometry and material description
0zone mixture outer dimension temperature extra xs type (0/1--fuel/mod)
1      1      8.74141E+00 2.93000E+02 0.00000E+00 0

1734 locations of 100000 available are required to make a new master containing the self-shielded values
0no nuclides in your problem have bondarenko factor data==boname will copy from logical 11 to logical 1
0copy 92234 uranium-234 from log 11 to log 1 bondarenko trigger 0
0copy 92235 uranium-235 from log 11 to log 1 bondarenko trigger 0
0copy 92238 uranium-238 from log 11 to log 1 bondarenko trigger 0

1 scale4 - 27 neutron 18 gamm group shielding library
base on endf-b version 4 data
compiled for nrc 1/27/89
last updated
l.m.petrie ornl
tape id 4027018 number of nuclides 3
08/12/94

```

number of neutron groups	27	number of gamma groups	10
first thermal group	15	logical unit	1

Table of contents

uranium-234	endf/b-iv mat 1043	updated 08/12/94	id	1092234
uranium-235	endf/b-iv mat :261	updated 08/12/94	id	1092235
uranium-238	endf/b-iv mat :262	updated 08/12/94	id	1092238

[illegible]

9

```

XX          XX  VV          VV  CCCCCCCCCCCC
XX          XX  VV          VV  CCCCCCCCCCCC
  XX      XX  VV          VV  CC
  XX  XX  XX  VV          VV  CC
    XX XX    VV          VV  CC
      XXX    VV          VV  CC
        XXXX      VV      VV  CC
          XX XX    VV      VV  CC
            XX  XX      VV  VV  CC
              XX      XX    VV  VV  CC
                XX      XX    VV  CC
                  XX      XX    VV  CC
                    XX      XX    V

```

9

00000000	11	//	2222222222	3333333333	//	00000000	22222222
0000000000	111	//	222222222222	333333333333	//	0000000000	2222222222
00 00	1111	//	22 22	33 33	//	00 00	22
00 00	11	//	22 22	33 33	//	00 00	00
00 00	11	//	22 22	33 33	//	00 00	00
00 00	11	//	22 33	33 33	//	00 00	1
00 00	11	//	22 33	33 33	//	00 00	22
00 00	11	//	22 33	33 33	//	00 00	22
00 00	11	//	22 33	33 33	//	00 00	22
00 00	11	//	22 33	33 33	//	00 00	22
0000000000	11111111	//	22222222222222	33333333333333	//	0000000000	2222222222
00000000	11111111	//	22222222222222	3333333333	//	00000000	2222222222

Q

0000000	9999999999		2222222222	44		11	8888888888	
000000000	99999999999		222222222222	444		111	88888888888	
00	00	99	99	22	22	4444	1111	88
00	00	99	99	22	22	44 44	11	88
00	00	99	99	22	22	44 44	11	88
00	00	999999999999	22	44	44	11	888888888888	
00	00	999999999999	22	44	44	11	888888888888	
00	00	99	22	444444444444	11	88		
00	00	99	22	444444444444	11	88		
00	00	99	22	44	11	88		
000000000	99999999999		222222222222	44		11111111	8888888888	

```

0000000 99999999999 222222222222 44 11111111
1
0
      cccccccccc  aaaaaaaaaa  11  cccccccccc
      cccccccccc  aaaaaaaaaa  11  cccccccccc
      aa  aa  cc  cc  aa  aa  11  aa
      aa  aa  cc  cc  aa  aa  11  aa
      aa  aa  cc  cc  aa  aa  11  aa
      cccccccccc  cccccccccc  11  cccccccc
      cccccccccc  cccccccccc  11  cccccccc
      aa  aa  cc  aa  aa  11  aa
      aa  aa  cc  aa  aa  11  aa
      aa  aa  cc  aa  aa  11  aa
      cccccccccc  cccccccccc  aa  aa  111111111111  cccccccccc
      cccccccccc  cccccccccc  aa  aa  111111111111  cccccccccc

```

```

.....
.....
.....
****
****               program verification information
****
****               code system:  scale version:  4.4a
****
.....
.....
****
****               program:  o0o002
****
****               creation date:  08_sep_2000
****
****               library:  /vcc/scale4.4a/bin
****
****               production code:  nitawl
****
****               version:  4.40
****
****               jobname:  xvt
****
****               machine name:  cm0db
****
****               date of execution:  23_jan_2002
****
****               time of execution:  09:24:15.66
****
.....
.....
.....

```

```

1
0  -1q array has 1 entries.
0  0q array has 9 entries.
0  1q array has 12 entries.
0select 3 nuclides from the master library on logical 1
0        0 nuclides from the working library on logical 2

```

```

0 nuclides from the working library on logical 3
  to create the new working library on logical 4

3 resonance calculations have been requested
-1 output option for aspx formatted cross section data
2001 maximum number of resonance mesh intervals
2 order of resonance level processing
0the storage allocated for this case is 100000 words
0 2q array has 3 entries.
0 3q array has 45 entries.
0 4q array has 3 entries.
0 general information concerning cross section library
  tape identification number 4027018
  number of nuclides on tape 3
  number of neutron energy groups 27
  first thermal neutron energy group 15
  number of gamma energy groups 18
0 direct access unit number 9 requires 138 blocks of length 1160 words
- xsdn tape=4027018

scale4 - 27 neutron 18 gamma group shielding library
based on endf-b version 4 data
compiled for nrc 1/27/89
last updated 08/12/94
l.m.petrie oral

0 nuclides from xsdn tape
1 uranium-234 endf/b-iv mat 1043 updated 08/12/94 1092234
2 uranium-235 endf/b-iv mat 1261 updated 08/12/94 1092235
3 uranium-238 endf/b-iv mat 1262 updated 08/12/94 1092238
0 uranium-234 endf/b-iv mat 1043 updated 08/12/94 1092234 temperature= 293.00

0resonance data for this nuclide
0mass number (a) = 232.029 temperature(kelvin) = 293.000
0potential scatter sigma = 10.021 lumped nuclear density = 4.9184624E-04
0spin factor (g) = 6948.450 lump dimension (a-bar) = 8.7414103E-00
0inner radius = 0.0000000E+00 dencorr correction (c) = 0.0000000E+00
0the absorber will be treated by the nordheim integral method.
0mass of moderator-1 = 235.044 sigma(per absorber atom)= 1.0888430E+03
0moderator-1 will be treated by the nordheim integral method.
0mass of moderator-2 = 238.051 sigma(per absorber atom)= 6.2613255E+01
0moderator-2 will be treated by the nordheim integral method.
0this resonance material will be treated as a 0-dimensional object.
0volume fraction of lump in cell used to account for spatial self-shielding=1.00000

0group res abs res fss res scat
11 -4.570348E+00 0.000000E+00 -1.059324E+01
12 -2.433301E+01 0.000000E+00 -9.654057E+00
13 3.526091E-04 0.000000E+00 -1.132335E-03
14 -4.360511E-02 0.000000E+00 -6.426848E+01
15 1.888241E-02 0.000000E+00 -1.450920E-02
16 8.419596E-04 0.000000E+00 -1.309890E-03
17 4.381796E-05 0.000000E+00 -1.725384E-04
18 -2.432051E-06 0.000000E+00 -1.055472E-04
19 2.170118E-03 0.000000E+00 -2.928320E-03

0excess resonance integrals
0 resolved
0absorption 3.69075E+01
0fission 0.00000E+00
0 elapsed time 0.00 min.

process number 1007 is at temperature= 293.00
0 uranium-235 endf/b-iv mat 1261 updated 08/12/94 1092235 temperature= 293.00
0resonance data for this nuclide
0mass number (a) = 233.025 temperature(kelvin) = 293.000

```

```

Opotential scatter sigma = 11.500          lumped nuclear density = 4.4994228E-02
Ospin factor (g) = 15171.100             lump dimmeison (a-bar) = 8.7414103E+00
Oinner radius = 0.0000000E+00             dancoff correction (c) = 0.0000000E+00
Othe absorber will be treated by the nordheim integral method.
Or of moderator-1 = 238.051               sigma(per absorber atom)= 6.8444544E-01
Om. ator-1 will be treated by the nordheim integral method.
Omass of moderator-2 = 234.040             sigma(per absorber atom)= 1.3322173E-01
Omoderator-2 will be treated by the nordheim integral method.
Othis resonance material will be treated as a 0-dimensional object.
Ovolume fraction of lump in cell used to account for spatial self-shielding=1.00000
Ogroup      res abs      res fiss      res scat
12 -4.361296E+01 -2.818056E+01 4.715909E-01
13 -6.937902E+01 -3.728180E+01 6.341171E-01
14 -5.468336E+01 -3.054570E+01 1.339782E+00
15 -1.372778E+00 -1.028349E+00 3.058823E-02
16 -1.026263E-03 -7.820863E-04 1.137792E-04
Oexcess resonance integrals
0 resolved
Oabsorption 1.59760E+01
Ofission 1.13303E+01
O elapsed time 0.01 min.

process number 1007 is at temperature= 293.00
updated 08/12/94 1092238 temperature= 293.00

O uranium-238 endf/b-iv mat 1262
Oresonance data for this nuclide
Omass number (a) = 236.006 temperature(kelvin) = 293.000
Opotential scatter sigma = 10.599 lumped nuclear density = 2.4983932E-03
Ospin factor (g) = 686.527 lump dimmeison (a-bar) = 8.7414103E+00
Oinner radius = 0.0000000E+00 dancoff correction (c) = 0.0000000E+00
Othe absorber will be treated by the nordheim integral method.
Omass of moderator-1 = 235.044 sigma(per absorber atom)= 2.1435510E+02
Omoderator-1 will be treated by the nordheim integral method.
Omass of moderator-2 = 234.040 sigma(per absorber atom)= 2.3992255E+00
Omoderator-2 will be treated by the nordheim integral method.
Othis resonance material will be treated as a 0-dimensional object.
Ow fraction of lump in cell used to account for spatial self-shielding=1.00000
Ogroup      res abs      res fiss      res scat
9 -2.358645E-02 0.000000E+00 -2.429588E-01
10 -7.342265E-01 -8.848661E-06 -4.755040E+00
11 -9.059561E+00 0.000000E+00 -2.303091E+01
12 -4.241810E+01 0.000000E+00 -4.742245E+01
13 -5.136169E+01 0.000000E+00 -1.295629E+01
14 -1.046324E+02 0.000000E+00 -3.035308E+00
15 3.015853E-03 0.000000E+00 -5.925817E-03
Oexcess resonance integrals
0 resolved
Oabsorption 1.39489E+01
Ofission 5.17922E-04
O elapsed time 0.02 min.

process number 1007 is at temperature= 293.00

O elapsed time 0.02 min.
1 this xadn working tape was created 01/23/02 at 09:24:15
the title of the parent case is as follows
scale4 - 27 neutron 18 gamma group shielding library
based on endf-b version 4 data
compiled for nrc 1/27/89
tape id 4027018 number of nuclides 3
number of neutron groups 27 number of gamma groups 18
first thermal group 15 logical unit 4
table of contents
uranium-234 endf/b-iv mat 1043 updated 08/12/94 id 1092234

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1

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source term search for dantys calc's extracted based on ocd benchmark input
0      -1q array has      1 entries.
0      0q array has      17 entries.
0      1q array has      15 entries.
0      2q array has      10 entries.
0      3q array has      12 entries.
0      4q array has       9 entries.
0      5q array has      10 entries.
0direct access unit 9 requires 4 blocks of length 1520 for cross section fixing.

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1          source term search for dantsys calcs errterm4 based on oecd benchmark input
0general problem description data block
0          general problem data

ige 1/2/3 = plane/cylinder/sphere      3      ism quadrature order                8
izm number of zones                     1      isct order of scattering              3
im  number of special intervals         4      isvt 0/1/2/3/4/5/6-g/k/alpha/c/z/x/h    1
ibl 0/1/2/3 = vacuum/refl/per/white    1      iim inner iteration maximum            20
ibr right boundary condition            0      icm outer iteration maximum            25
mxx number of mixtures                  1      iclc -1/0/n--flat res/en/opt           0
ms  mixing table length                  3      ith 0/1 = forward/adjoint              0
igm number of energy groups              45     iflu not used(always wycd)              0
nng number of neutron groups             27     iprt -2/-1/0/n-mixture xsec print      -2
nng number of gamma groups              18     idl 0/1/2/3=no/prt nd/pch n/both      -1
ifcg number of first thermal group       15     ipbt -1/0/1-norm/fine/all bal. prt     0
0          special options

ifg 0/1 = none/weighting calculation    1      ipn 0/1/2 diff. coef. param            0
igm volumetric sources (0/n-no/yes)     0      idfm 0/1 = none/density factors 30°    1
ipm boundary sources (0/n-no/yes)       0      iax 0/n = none/n activities by zone    0
ifn 0/1/2 = input 33°/34°/use last     0      ial 0/1=none/activities by interval    0
itmx maximum time (minutes)             0      ifct 0/1=no/yes upscatter scaling      0
idtl 0/1/2/3=no/xsect/erce/flux--out   0      ipvt 0/1/2=none/k/alpha parametric arch 0
iax broad group fluxes                  0      isen outer iteration acceleration      0
ibln                                     0      nbnd band rebal parameter              -1
nbl                                     0      jhkl 0/1/2 buckling geometry          0
0          weighting data (ifg=1)

icon -1/0/1-cell/zone/region weight    -1     ibtf total xsect pan in brd gp tables  0
igmf number of broad groups              45     ndsf pan g-g or file number            0
itp 0/10/20/30/40 0/c/e/ac/a           0      msf table length or max order          44
ipp -2/-1/0/n-wyctd xsect print        -2     wcm extra 1-d x-sect positions         0
iap -1/n anis xsect print               0
0          floating point parameters

eps overall convergence                  1.00000E-04  dy cyl/pla ht for buckling             0.00000E+00
ptc point convergence                    1.00000E-05  dz plane depth for buckling             0.00000E+00
xnf normalization factor                 1.00000E+00  vec void streaming correction           0.00000E+00
ev  eigenvalue guess                     0.00000E+00  pv  ipvt=1/2--k/alpha                   0.00000E+00
eva eigenvalue modifier                  0.00000E+00  eql ev change eps for search            1.00000E-03
bf  buckling factor=1.420892 1.42089E+00  xpm new param mnd for search            7.50000E-01
      this case will require      2824 locations for mixing
      this case has been allocated 100000 locations
1          source term search for dantsys calcs errterm4 based on oecd benchmark input
0          13q array has      3 entries.
0          14q array has      3 entries.
0          15q array has      3 entries.
0
0          data block 2 (mixing table, etc.)
0          nuclides      cccc      mixing table      extra
      on tape      identification      mixture      component      atom density      xsect id's
1 1092234              1              1092235      4.99942E-02
2 1092235              1              1092236      2.49839E-03
3 1092236              1              1092234      4.91846E-04
0 elapsed time 0.00 min.
0          7381 locations will be used
0          33q array has      360 entries.
0          35q array has      5 entries.
0          36q array has      4 entries.
0          38q array has      4 entries.
0          39q array has      1 entries.

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0      41q array has      1 entries.
0      51q array has     45 entries.
1      source term search for dantsys calcs srcterm4 based on oecd benchmark input
      neutron group parameters
0      energy      lethargy      weighted      broad gp      calc      group      right      left
      boundaries boundaries velocities numbers type band albedo albedo
1      2.00000E+07 -6.93147E-01 4.60581E+09      1      0      1
2      6.43400E+06 4.40989E-01 2.88737E+09      2      0      2
3      3.00000E+06 1.20397E+00 2.12201E+09      3      0      3
4      1.85000E+06 1.68740E+00 1.75673E+09      4      0      4
5      1.40000E+06 1.96611E+00 1.46535E+09      5      0      5
6      9.00000E+05 2.40795E+00 1.06620E+09      6      0      6
7      4.00000E+05 3.21888E+00 6.07557E+08      7      0      7
8      1.00000E+05 4.60517E+00 2.72415E+08      8      0      8
9      1.70000E+04 6.37713E+00 1.13526E+08      9      0      9
10     1.00000E+03 8.11173E+00 4.82126E+07     10      0     10
11     5.50000E+02 9.80818E+00 2.05946E+07     11      0     11
12     1.00000E+02 1.15129E+01 1.01036E+07     12      0     12
13     3.00000E+01 1.27169E+01 5.69595E+06     13      0     13
14     1.00000E+01 1.38155E+01 3.20957E+06     14      0     14
15     3.04999E+00 1.50030E+01 2.10601E+06     15      0     15
16     1.77000E+00 1.58471E+01 1.70522E+06     16      0     15
17     1.29999E+00 1.58557E+01 1.52545E+06     17      0     15
18     1.12999E+00 1.59959E+01 1.42867E+06     18      0     15
19     1.00000E+00 1.61181E+01 1.31002E+06     19      0     15
20     8.00000E-01 1.63412E+01 9.29104E+05     20      0     15
21     4.00000E-01 1.70344E+01 8.15206E+05     21      0     15
22     3.25000E-01 1.72420E+01 6.90059E+05     22      0     15
23     2.25000E-01 1.76098E+01 4.86933E+05     23      0     15
24     9.99999E-02 1.84207E+01 3.57766E+05     24      0     15
25     5.00000E-02 1.91138E+01 2.71895E+05     25      0     15
26     3.00000E-02 1.96247E+01 1.87283E+05     26      0     15
27     1.00000E-02 2.07233E+01 8.88202E+04     27      0     15
28     1.00000E-05 2.76310E+01
1      source term search for dantsys calcs srcterm4 based on oecd benchmark input
      gamma group parameters
0      gp      energy      lethargy      weighted      broad gp      calc      group      right      left
      boundaries boundaries velocities numbers type band albedo albedo
1      1.00000E+07 0.00000E+00 3.00000E+10     28      0     16
2      8.00000E+06 2.23144E-01 3.00000E+10     29      0     17
3      6.50000E+06 4.30783E-01 3.00000E+10     30      0     18
4      5.00000E+06 6.93147E-01 3.00000E+10     31      0     19
5      4.00000E+06 9.16291E-01 3.00000E+10     32      0     20
6      3.00000E+06 1.20397E+00 3.00000E+10     33      0     21
7      2.50000E+06 1.38629E+00 3.00000E+10     34      0     22
8      2.00000E+06 1.60944E+00 3.00000E+10     35      0     23
9      1.66000E+06 1.79577E+00 3.00000E+10     36      0     24
10     1.33000E+06 2.01741E+00 3.00000E+10     37      0     25
11     1.00000E+06 2.30259E+00 3.00000E+10     38      0     26
12     8.00000E+05 2.52573E+00 3.00000E+10     39      0     27
13     6.00000E+05 2.81341E+00 3.00000E+10     40      0     28
14     4.00000E+05 3.21888E+00 3.00000E+10     41      0     29
15     3.00000E+05 3.50656E+00 3.00000E+10     42      0     30
16     2.00000E+05 3.91202E+00 3.00000E+10     43      0     31
17     1.00000E+05 4.60517E+00 3.00000E+10     44      0     32
18     5.00000E+04 5.29832E+00 3.00000E+10     45      0     33
19     1.00000E+04 6.90776E+00
1      source term search for dantsys calcs srcterm4 based on oecd benchmark input
0      mixture      order p(1)      activity table      quadrature constants
      by zone      by zone      matl no.      reaction      weights      directions      refl direc      wt x cos

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1      1      3      0.00000E+00 -1.00000E+00      9      0.00000E+00
2      5.06143E-02 -9.60290E-01      9      -4.86044E-02
3      1.11191E-01 -7.96667E-01      8      -0.85818E-02
4      1.56853E-01 -5.25532E-01      7      -0.24315E-02
5      1.81342E-01 -1.83435E-01      6      -3.32644E-02
6      1.81342E-01 1.83435E-01      5      3.32644E-02
7      1.56853E-01 5.25532E-01      4      0.24315E-02
8      1.11191E-01 7.96667E-01      3      0.85818E-02
9      5.06143E-02 9.60290E-01      2      4.86044E-02

0constants for p ( 3 ) scattering
0angl set 1 set 2 set 3
1 -1.00000E+00 1.00000E+00 -1.00000E+00
2 -9.60290E-01 8.83235E-01 -7.73409E-01
3 -7.96667E-01 4.52016E-01 -6.90660E-02
4 -5.25532E-01 8.57235E-02 4.25439E-01
5 -1.83435E-01 -4.49528E-01 2.59721E-01
6 1.83435E-01 -4.49528E-01 -2.59721E-01
7 5.25532E-01 -8.57235E-02 -4.25439E-01
8 7.96667E-01 4.52016E-01 6.90660E-02
9 9.60290E-01 8.83235E-01 7.73409E-01

1 int radii mid pts zone no. areas volumes dens fact radius mod spec(int)
1 0.00000E+00 5.67399E-01 1 0.00000E+00 6.12131E+00 1.00000E+00 0.00000E+00
2 1.13480E+00 2.75275E+00 1 1.61826E+01 3.43617E+02 1.00000E+00
3 4.37071E+00 5.98866E+00 1 2.40056E+02 1.49384E+03 1.00000E+00
4 7.60661E+00 8.17401E+00 1 7.27097E+02 9.54324E+02 1.00000E+00
5 8.74141E+00 9.60225E+02

0 elapsed time 0.00 min.
1 outer inner 1 - balance eigenvalue 1 - source 1 - scatter 1 - upecat search time
iter iters ratio ratio ratio parameter (min)
1 273 -3.92682E-08 9.13163E-01 8.68370E-02 1.00000E+00 9.77531E-07 0.00000E+00 0.0015
2 499 -4.03986E-08 9.73183E-01 -6.57276E-02 -6.10271E-02 -9.90048E-08 0.00000E+00 0.0017
3 701 -4.07824E-08 9.93572E-01 -2.09503E-02 -1.94238E-02 2.58241E-08 0.00000E+00 0.0020
4 881 -4.09185E-08 1.00077E+00 -7.24867E-03 -6.71402E-03 1.67190E-07 0.00000E+00 0.0020
5 1038 -4.09678E-08 1.00337E+00 -2.59525E-03 -2.40305E-03 3.65056E-07 0.00000E+00 0.0022
6 1190 -4.09857E-08 1.00432E+00 -9.42075E-04 -8.72006E-04 1.32166E-07 0.00000E+00 0.0023
7 1317 -4.09922E-08 1.00466E+00 -3.44674E-04 -3.18850E-04 2.36998E-07 0.00000E+00 0.0025
8 1422 -4.09946E-08 1.00479E+00 -1.25456E-04 -1.16427E-04 3.70057E-07 0.00000E+00 0.0025
9 1500 -4.09955E-08 1.00484E+00 -4.81582E-05 -4.54546E-05 4.09803E-07 0.00000E+00 0.0027

grp to grp inner mfd max. flux waf max. scale
iters int. difference int. factor
1 1 2 2 2.68776E-06 2 9.99999E-01
2 2 2 4 2.61068E-06 4 9.99999E-01
3 3 2 4 2.58869E-06 4 9.99999E-01
4 4 2 4 2.00048E-06 4 1.00000E+00
5 5 2 4 2.15828E-06 4 1.00000E+00
6 6 2 1 4.35514E-06 2 1.00000E+00
7 7 2 1 5.71869E-06 2 1.00000E+00
8 8 2 1 8.46680E-06 2 1.00001E+00
9 9 3 1 3.87370E-06 2 1.00000E+00
10 10 3 1 3.30215E-06 1 1.00000E+00
11 11 3 1 1.57924E-06 1 1.00000E+00
12 12 3 1 3.13486E-06 1 1.00000E+00
13 13 3 1 3.71222E-06 1 1.00000E+00
14 14 3 1 3.84729E-06 1 1.00000E+00
15 15 3 1 2.03146E-06 1 1.00000E+00
16 16 3 1 2.08861E-06 1 1.00000E+00
17 17 2 1 3.25980E-06 1 1.00000E+00
18 18 2 1 1.83655E-06 1 1.00000E+00
19 19 2 1 4.08954E-06 1 1.00000E+00
20 20 2 1 3.36830E-06 1 1.00000E+00

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21 21 2 1 1.19202E-06 1 1.00000E+00
22 22 2 1 7.86600E-07 1 1.00000E+00
23 23 2 1 7.82789E-07 1 1.00000E+00
24 24 2 1 3.62913E-07 1 1.00000E+00
25 25 2 1 2.15951E-07 1 1.00000E+00
26 26 2 1 1.15405E-07 1 1.00000E+00
27 27 2 1 3.78915E-08 1 1.00000E+00
28 28 4 1 6.68701E-06 1 1.00000E+00
29 29 4 1 2.47880E-07 1 1.00000E+00
30 30 4 1 1.00418E-06 2 1.00000E+00
31 31 4 1 1.40616E-06 2 1.00000E+00
32 32 4 1 6.12088E-06 2 1.00000E+00
33 33 4 1 3.37295E-06 2 1.00000E+00
34 34 4 1 8.82566E-06 1 1.00000E+00
35 35 4 1 7.11296E-06 1 1.00000E+00
36 36 5 1 8.73712E-07 1 1.00000E+00
37 37 5 1 2.09719E-06 1 1.00000E+00
38 38 4 4 6.91001E-06 2 1.00000E+00
39 39 4 4 6.92980E-06 4 1.00000E+00
40 40 4 4 3.53889E-06 3 1.00000E+00
41 41 3 4 6.66180E-06 4 1.00000E+00
42 42 3 4 1.96571E-06 4 1.00000E+00
43 43 3 1 6.65637E-07 1 1.00000E+00
44 44 3 1 8.68399E-07 1 1.00000E+00
45 45 3 1 4.12514E-09 1 1.00000E+00

10 1631 -2.04094E-08 1.00485E+00 -1.52581E-05 -1.36369E-05 -2.37727E-06 0.00000E+00 0.0028
    final monitor
        lambda 1.00485E+00 production/absorption 2.36293E+00 angular flux on 16
0 elapsed time 0.00 min.
1 source term search for dantysv calcs structure based on ocd benchmark input
0 int. zone number radius int. midpoint area volume prod density
1 1 0.00000E+00 5.67399E-01 0.00000E+00 6.12131E+00 6.31424E-04
2 1 1.13480E+00 2.75275E+00 1.61826E+01 3.43617E+02 5.87994E-04
3 1 4.37071E+00 5.98866E+00 2.40084E+02 1.49384E+03 4.83011E-04
4 1 7.60661E+00 8.17401E+00 7.27897E+02 9.54324E+02 2.06331E-04
5 8.74141E+00 9.60225E+02
0 elapsed time 0.00 min.
1 fine group summary for system
0 energy corresponding to the average lethargy causing fission 8.9625E+05
0 grp. fix source fiss source in scatter elf scatter out scatter absorption leakage balance
1 0.00000E+00 2.10763E-02 0.00000E+00 1.74540E-02 5.76923E-03 7.24544E-03 9.62853E-03 1.00000E+00
2 0.00000E+00 1.88300E-01 6.01352E-04 1.94292E-01 6.58837E-02 4.52727E-02 7.81826E-02 9.99740E-01
3 0.00000E+00 2.14891E-01 1.37892E-02 2.42713E-01 6.77832E-02 6.43861E-02 9.64883E-02 1.00011E+00
4 0.00000E+00 1.24530E-01 3.08334E-02 1.33858E-01 5.08016E-02 4.22166E-02 6.23853E-02 9.99936E-01
5 0.00000E+00 1.66151E-01 5.80268E-02 2.21887E-01 6.22814E-02 6.59373E-02 9.59678E-02 9.99960E-01
6 0.00000E+00 1.80463E-01 1.02500E-01 4.71692E-01 4.43846E-02 9.91373E-02 1.39531E-01 1.00000E+00
7 0.00000E+00 8.96470E-02 8.43331E-02 4.50560E-01 7.45775E-03 8.30065E-02 8.34723E-02 1.00002E+00
8 0.00000E+00 1.38461E-02 1.39151E-02 7.99942E-02 4.91063E-04 1.84002E-02 8.87025E-03 9.99991E-01
9 0.00000E+00 1.00554E-03 8.02295E-04 3.75448E-03 1.92200E-05 1.45705E-03 3.31569E-04 9.99996E-01
10 0.00000E+00 7.46949E-05 3.01827E-05 1.08534E-04 5.42315E-07 9.60776E-05 8.28682E-06 1.00001E+00
11 0.00000E+00 5.87660E-06 8.32575E-07 3.16208E-06 1.51586E-08 6.48289E-06 2.11104E-07 1.00000E+00
12 0.00000E+00 4.12822E-07 2.33400E-08 3.24650E-07 1.69970E-09 4.12078E-07 2.23866E-08 9.99994E-01
13 0.00000E+00 6.55524E-08 2.64510E-09 6.19721E-08 4.21617E-10 6.31017E-08 4.67375E-09 1.00001E+00
14 0.00000E+00 1.29908E-08 6.23982E-10 1.37974E-08 9.78415E-11 1.24367E-08 1.08011E-09 1.00001E+00
15 0.00000E+00 1.46810E-09 1.33411E-10 8.99787E-10 1.18356E-11 1.51927E-09 7.04004E-11 1.00000E+00
16 0.00000E+00 4.31884E-10 2.17422E-11 2.52855E-10 8.92122E-12 4.24690E-10 1.92135E-11 1.00000E+00
17 0.00000E+00 1.38830E-10 1.16626E-11 2.33619E-11 2.55205E-12 1.46430E-10 1.51018E-12 1.00000E+00
18 0.00000E+00 9.93983E-11 5.91937E-12 1.10362E-11 1.71099E-12 1.02894E-10 7.12326E-13 1.00001E+00
19 0.00000E+00 1.40528E-10 9.56899E-12 2.84878E-11 1.76940E-12 1.46528E-10 1.80021E-12 1.00000E+00
20 0.00000E+00 2.28513E-10 8.72524E-12 3.88718E-11 5.36140E-13 2.34554E-10 2.14812E-12 1.00000E+00

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21	0.00000E+00	3.34470E-11	1.93116E-12	2.80004E-12	2.98151E-13	3.49448E-11	1.35322E-13	9.99997E-01
22	0.00000E+00	3.88061E-11	3.11173E-12	2.55970E-12	1.50151E-13	4.16677E-11	1.00018E-13	1.00000E+00
23	0.00000E+00	3.71029E-11	3.15390E-12	2.45734E-12	6.30307E-14	4.01844E-11	8.72560E-14	1.00000E+00
24	0.00000E+00	1.00989E-11	2.01357E-12	4.74115E-13	3.25238E-14	1.20407E-11	1.12033E-14	1.00000E+00
25	0.00000E+00	2.95431E-12	1.47876E-13	8.40358E-14	9.16523E-15	3.09289E-12	2.12698E-15	1.00000E+00
26	0.00000E+00	2.07298E-12	1.20541E-13	4.16985E-14	2.71011E-15	2.19009E-12	7.21487E-16	9.99999E-01
27	0.00000E+00	4.94002E-13	3.14045E-14	5.44440E-15	5.02202E-24	5.25418E-13	6.87457E-17	9.99999E-01
28	0.00000E+00	0.00000E+00	1.86720E-06	2.09833E-08	2.53414E-06	2.62038E-08	8.81877E-08	9.99998E-01
29	0.00000E+00	0.00000E+00	5.89421E-03	9.66785E-05	9.08295E-03	1.37499E-04	3.83917E-04	9.99999E-01
30	0.00000E+00	0.00000E+00	1.70346E-02	4.57461E-04	2.40043E-02	5.61115E-04	1.07131E-03	9.99998E-01
31	0.00000E+00	0.00000E+00	2.91018E-02	8.77347E-04	3.92160E-02	1.37162E-03	1.91204E-03	1.00000E+00
32	0.00000E+00	0.00000E+00	8.09190E-02	4.08249E-03	9.84640E-02	5.72542E-03	5.56546E-03	1.00000E+00
33	0.00000E+00	0.00000E+00	9.31301E-02	3.82973E-03	1.00105E-01	9.36289E-03	6.33558E-03	1.00000E+00
34	0.00000E+00	0.00000E+00	1.67990E-01	9.98222E-03	1.60972E-01	2.25894E-02	1.12494E-02	1.00000E+00
35	0.00000E+00	0.00000E+00	1.90525E-01	1.09346E-02	1.60983E-01	3.39949E-02	1.17900E-02	1.00000E+00
36	0.00000E+00	0.00000E+00	3.02009E-01	2.28639E-02	2.20479E-01	7.25843E-02	1.68185E-02	1.00000E+00
37	0.00000E+00	0.00000E+00	4.98650E-01	5.12824E-02	3.12618E-01	1.63815E-01	2.25406E-02	1.00000E+00
38	0.00000E+00	0.00000E+00	4.86127E-01	3.96003E-02	2.70243E-01	1.99992E-01	1.58908E-02	1.00000E+00
39	0.00000E+00	0.00000E+00	7.38994E-01	7.24946E-02	3.28328E-01	3.90014E-01	1.68540E-02	1.00000E+00
40	0.00000E+00	0.00000E+00	1.27925E+00	1.40643E-01	3.58973E-01	9.00110E-01	1.81642E-02	1.00000E+00
41	0.00000E+00	0.00000E+00	7.27046E-01	4.21221E-02	1.23137E-01	6.00070E-01	3.63708E-03	1.00000E+00
42	0.00000E+00	0.00000E+00	8.27699E-01	3.88273E-02	6.07378E-02	7.66023E-01	9.36171E-04	1.00000E+00
43	0.00000E+00	0.00000E+00	5.42911E-01	1.89786E-02	6.14001E-03	5.36652E-01	1.12908E-04	1.00000E+00
44	0.00000E+00	0.00000E+00	2.29715E-01	5.88692E-03	7.34240E-04	2.28953E-01	2.74342E-05	1.00000E+00
45	0.00000E+00	0.00000E+00	1.73622E-01	5.13094E-04	0.00000E+00	1.73816E-01	1.77972E-06	1.00002E+00
46	0.00000E+00	1.00000E+00	6.69245E+00	2.28020E+00	2.57706E+00	4.84111E+00	7.04999E-01	9.99997E-01
0 grp.	rt bdy flux	rt leakago	lft bdy flux	lft leakago	adm rate	flaw rate	flaw cap v2	total flux
1	1.48857E-05	9.62813E-03	5.50093E-05	0.00000E+00	1.86732E-03	7.19980E-03	0.00000E+00	9.40722E-02
2	1.22848E-04	7.81026E-02	4.87925E-04	0.00000E+00	3.00369E-04	4.42857E-02	0.00000E+00	8.17473E-01
3	1.53058E-04	9.64853E-02	6.32620E-04	0.00000E+00	0.00000E+00	6.20743E-02	0.00000E+00	1.04803E+00
4	9.91242E-05	6.23553E-02	4.15221E-04	0.00000E+00	0.00000E+00	3.99364E-02	0.00000E+00	6.86301E-01
5	1.83084E-04	9.59678E-02	6.59837E-04	0.00000E+00	0.00000E+00	6.04000E-02	0.00000E+00	1.07193E+00
6	2.25426E-04	1.39521E-01	1.02616E-03	0.00000E+00	0.00000E+00	8.70172E-02	0.00000E+00	1.65964E+00
7	1.37526E-04	8.34723E-02	7.41826E-04	0.00000E+00	0.00000E+00	6.82895E-02	0.00000E+00	1.14707E+00
8	1.49761E-05	8.07025E-03	1.05624E-04	0.00000E+00	0.00000E+00	1.36041E-02	0.00000E+00	1.84651E-01
9	5.69469E-07	3.31569E-04	4.88364E-06	0.00000E+00	0.00000E+00	1.05184E-03	0.00000E+00	6.60453E-03
10	1.48941E-08	8.28482E-04	1.22404E-07	0.00000E+00	0.00000E+00	6.23982E-05	0.00000E+00	1.83611E-04
11	3.82180E-10	2.11104E-07	3.28640E-09	0.00000E+00	0.00000E+00	4.36585E-06	0.00000E+00	5.18751E-06
12	4.01821E-11	2.23866E-08	3.28729E-10	0.00000E+00	0.00000E+00	2.77263E-07	0.00000E+00	5.12128E-07
13	8.32690E-12	4.67375E-09	6.64936E-11	0.00000E+00	0.00000E+00	4.19614E-08	0.00000E+00	1.02323E-07
14	1.91642E-12	1.00011E-09	1.81844E-11	0.00000E+00	0.00000E+00	8.29774E-09	0.00000E+00	2.31999E-08
15	1.26833E-13	7.04004E-11	1.84350E-12	0.00000E+00	0.00000E+00	9.57162E-10	0.00000E+00	1.63125E-09
16	3.46478E-14	1.92135E-11	2.83210E-13	0.00000E+00	0.00000E+00	3.33605E-10	0.00000E+00	4.44837E-10
17	2.70824E-15	1.81018E-12	2.51803E-14	0.00000E+00	0.00000E+00	1.09482E-10	0.00000E+00	4.21366E-11
18	1.26196E-15	7.12328E-13	1.23067E-14	0.00000E+00	0.00000E+00	8.57481E-11	0.00000E+00	2.10254E-11
19	3.25054E-15	1.80021E-12	2.99248E-14	0.00000E+00	0.00000E+00	1.31287E-10	0.00000E+00	4.96730E-11
20	3.84000E-15	2.14812E-12	3.60792E-14	0.00000E+00	0.00000E+00	2.10000E-10	0.00000E+00	6.09875E-11
21	2.34180E-16	1.35792E-13	2.55488E-15	0.00000E+00	0.00000E+00	2.92757E-11	0.00000E+00	4.58040E-12
22	1.72409E-16	1.00018E-13	2.14982E-15	0.00000E+00	0.00000E+00	3.38395E-11	0.00000E+00	3.97194E-12
23	1.50742E-16	8.72560E-14	1.93910E-15	0.00000E+00	0.00000E+00	3.38112E-11	0.00000E+00	3.59772E-12
24	2.03128E-17	1.12033E-14	3.64861E-16	0.00000E+00	0.00000E+00	1.03070E-11	0.00000E+00	7.06815E-13
25	3.81390E-18	2.12698E-15	6.61713E-17	0.00000E+00	0.00000E+00	2.64742E-12	0.00000E+00	1.28815E-13
26	1.37839E-18	7.21487E-16	3.07098E-17	0.00000E+00	0.00000E+00	1.87115E-12	0.00000E+00	6.09501E-14
27	1.41990E-19	6.87457E-17	3.67034E-18	0.00000E+00	0.00000E+00	4.47422E-13	0.00000E+00	7.44093E-15
28	1.57555E-10	8.81877E-08	1.01974E-09	0.00000E+00	1.08133E-06	0.00000E+00	0.00000E+00	1.61195E-06
29	6.28279E-07	3.83917E-04	4.08975E-06	0.00000E+00	3.68013E-03	0.00000E+00	0.00000E+00	6.40044E-03
30	1.88646E-06	1.07131E-03	1.23268E-05	0.00000E+00	9.40404E-03	0.00000E+00	0.00000E+00	1.93441E-02
31	3.35933E-06	1.91204E-03	2.18522E-05	0.00000E+00	1.33979E-02	0.00000E+00	0.00000E+00	3.28365E-02
32	9.75094E-06	5.56546E-03	6.25873E-05	0.00000E+00	2.88361E-02	0.00000E+00	0.00000E+00	9.69481E-02
33	1.10923E-05	6.33558E-03	7.06491E-05	0.00000E+00	2.25741E-02	0.00000E+00	0.00000E+00	1.09622E-01

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34 1.96995E-05 1.12494E-02 1.24784E-04 0.00000E+00 2.68209E-02 0.00000E+00 0.00000E+00 1.94060E-01
35 2.06800E-05 1.17900E-02 1.31745E-04 0.00000E+00 1.62053E-02 0.00000E+00 0.00000E+00 2.05210E-01
36 2.95931E-05 1.68185E-02 1.92178E-04 0.00000E+00 7.87324E-03 0.00000E+00 0.00000E+00 2.99616E-01
37 3.99011E-05 2.25406E-02 2.65321E-04 0.00000E+00 2.45327E-05 0.00000E+00 0.00000E+00 4.20420E-01
8 2.82913E-05 1.58908E-02 1.99649E-04 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 3.15514E-01
9 3.01230E-05 1.68540E-02 2.26944E-04 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 3.62983E-01
40 2.69619E-05 1.51642E-02 2.39492E-04 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 3.87864E-01
41 6.32515E-06 3.62786E-03 6.64931E-05 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.23234E-01
42 1.71690E-06 9.36171E-04 3.31091E-05 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 5.96677E-02
43 2.36323E-07 1.12908E-04 6.47718E-06 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.27776E-02
44 5.61725E-08 2.74342E-05 1.40413E-06 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 2.85762E-03
45 3.66282E-09 1.77972E-06 9.43913E-08 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.95893E-04
46 1.15182E-03 7.04995E-01 5.78230E-03 0.00000E+00 1.30685E-01 3.84830E-01 0.00000E+00 9.32643E+00

0 elapsed time 0.00 min.
Odirect across unit 9 requires 45 blocks of length 1160 for cross section weighting.
1 transport cross section weighting function
Ozone grp. 1 grp. 2 grp. 3 grp. 4 grp. 5 grp. 6 grp. 7 grp. 8
1 9.40517E-06 7.58539E-05 9.30759E-05 5.99562E-05 9.19785E-05 1.32605E-04 7.80862E-05 7.87455E-06
2 9.40517E-06 7.58539E-05 9.30759E-05 5.99562E-05 9.19785E-05 1.32605E-04 7.80862E-05 7.87455E-06
Ozone grp. 9 grp. 10 grp. 11 grp. 12 grp. 13 grp. 14 grp. 15 grp. 16
1 2.73468E-07 5.54821E-09 9.71584E-11 1.24803E-11 2.89520E-12 7.82328E-13 3.73151E-14 9.97658E-15
2 2.73468E-07 5.54821E-09 9.71584E-11 1.24803E-11 2.89520E-12 7.82328E-13 3.73151E-14 9.97658E-15
Ozone grp. 17 grp. 18 grp. 19 grp. 20 grp. 21 grp. 22 grp. 23 grp. 24
1 3.55979E-16 1.22506E-16 4.01048E-16 4.38312E-16 1.28313E-17 1.04880E-17 9.39638E-18 4.12693E-18
2 3.55979E-16 1.22506E-16 4.01048E-16 4.38312E-16 1.28313E-17 1.04880E-17 9.39638E-18 4.12693E-18
Ozone grp. 25 grp. 26 grp. 27 grp. 28 grp. 29 grp. 30 grp. 31 grp. 32
1 1.90477E-19 7.30979E-20 1.09401E-20 5.67524E-11 2.38365E-07 7.62282E-07 1.37683E-06 4.06702E-06
2 1.90477E-19 7.30979E-20 1.09401E-20 5.67524E-11 2.38365E-07 7.62282E-07 1.37683E-06 4.06702E-06
Ozone grp. 33 grp. 34 grp. 35 grp. 36 grp. 37 grp. 38 grp. 39 grp. 40
1 4.64264E-06 8.21787E-06 8.51049E-06 1.18571E-05 1.49891E-05 9.63891E-06 8.87249E-06 5.93795E-06
2 4.64264E-06 8.21787E-06 8.51049E-06 1.18571E-05 1.49891E-05 9.63891E-06 8.87249E-06 5.93795E-06
Ozone grp. 41 grp. 42 grp. 43 grp. 44 grp. 45 grp. 46
1 8.43036E-07 2.19772E-07 2.30309E-08 1.58334E-09 9.92884E-12 6.29312E-04
2 8.43036E-07 2.19772E-07 2.30309E-08 1.58334E-09 9.92884E-12 6.29312E-04
1 source term search for dantys calcs error term based on ocd benchmark in
Ocd... averaged fluxes
Ozone grp. 1 grp. 2 grp. 3 grp. 4 grp. 5 grp. 6 grp. 7 grp. 8
1 3.36224E-05 2.92173E-04 3.74933E-04 2.45291E-04 3.83113E-04 5.93172E-04 4.09975E-04 5.52740E-05
2 3.36224E-05 2.92173E-04 3.74933E-04 2.45291E-04 3.83113E-04 5.93172E-04 4.09975E-04 5.52740E-05
Ozone grp. 9 grp. 10 grp. 11 grp. 12 grp. 13 grp. 14 grp. 15 grp. 16
1 2.36125E-06 6.56246E-08 1.85407E-09 1.83040E-10 3.85714E-11 8.29188E-12 5.83837E-13 1.58878E-13
2 2.36125E-06 6.56246E-08 1.85407E-09 1.83040E-10 3.85714E-11 8.29188E-12 5.83837E-13 1.58878E-13
Ozone grp. 17 grp. 18 grp. 19 grp. 20 grp. 21 grp. 22 grp. 23 grp. 24
1 1.50601E-14 7.51583E-15 1.77538E-14 2.17975E-14 1.63715E-15 1.41961E-15 1.28657E-15 2.52337E-16
2 1.50601E-14 7.51583E-15 1.77538E-14 2.17975E-14 1.63715E-15 1.41961E-15 1.28657E-15 2.52337E-16
Ozone grp. 25 grp. 26 grp. 27 grp. 28 grp. 29 grp. 30 grp. 31 grp. 32
1 4.60399E-17 2.17870E-17 2.68946E-18 5.76126E-10 2.29044E-06 6.91378E-06 1.20938E-05 3.46874E-05
2 4.60399E-17 2.17870E-17 2.68946E-18 5.76126E-10 2.29044E-06 6.91378E-06 1.20938E-05 3.46874E-05
Ozone grp. 33 grp. 34 grp. 35 grp. 36 grp. 37 grp. 38 grp. 39 grp. 40
1 3.91801E-05 6.93590E-05 7.33440E-05 1.07086E-04 1.50262E-04 1.12768E-04 1.29708E-04 1.38626E-04
2 3.91801E-05 6.93590E-05 7.33440E-05 1.07086E-04 1.50262E-04 1.12768E-04 1.29708E-04 1.38626E-04
Ozone grp. 41 grp. 42 grp. 43 grp. 44 grp. 45
1 4.01107E-05 2.13241E-05 4.56685E-06 1.02134E-06 7.00143E-08
2 4.01107E-05 2.13241E-05 4.56685E-06 1.02134E-06 7.00143E-08
Oflux disadvantage factors (zone average/cell average-flux)
Ozone grp. 1 grp. 2 grp. 3 grp. 4 grp. 5 grp. 6 grp. 7 grp. 8
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00

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Ozone grp 9 grp. 10 grp. 11 grp. 12 grp. 13 grp. 14 grp. 15 grp. 16
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
Ozone grp. 17 grp. 18 grp. 19 grp. 20 grp. 21 grp. 22 grp. 23 grp. 24
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
Ozone grp. 25 grp. 26 grp. 27 grp. 28 grp. 29 grp. 30 grp. 31 grp. 32
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
Ozone grp. 33 grp. 34 grp. 35 grp. 36 grp. 37 grp. 38 grp. 39 grp. 40
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
Ozone grp. 41 grp. 42 grp. 43 grp. 44 grp. 45
1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
Ocell averaged currents

Ozone grp. 1 grp. 2 grp. 3 grp. 4 grp. 5 grp. 6 grp. 7 grp. 8
1 9.40517E-06 7.58539E-05 9.30759E-05 5.99552E-05 9.19798E-05 1.32608E-04 7.00642E-05 7.87455E-06
2 9.40517E-06 7.58539E-05 9.30759E-05 5.99552E-05 9.19798E-05 1.32608E-04 7.00642E-05 7.87455E-06
Ozone grp. 9 grp. 10 grp. 11 grp. 12 grp. 13 grp. 14 grp. 15 grp. 16
1 2.73468E-07 5.54021E-09 9.71584E-11 1.24803E-11 2.89520E-12 7.02328E-13 3.73151E-14 9.97658E-15
2 2.73468E-07 5.54021E-09 9.71584E-11 1.24803E-11 2.89520E-12 7.02328E-13 3.73151E-14 9.97658E-15
Ozone grp. 17 grp. 18 grp. 19 grp. 20 grp. 21 grp. 22 grp. 23 grp. 24
1 3.55979E-16 1.22506E-16 4.01048E-16 4.30312E-16 1.28313E-17 1.04850E-17 9.39638E-18 4.12693E-18
2 3.55979E-16 1.22506E-16 4.01048E-16 4.30312E-16 1.28313E-17 1.04850E-17 9.39638E-18 4.12693E-18
Ozone grp. 25 grp. 26 grp. 27 grp. 28 grp. 29 grp. 30 grp. 31 grp. 32
1 1.90477E-19 7.30979E-20 1.09401E-20 5.67524E-11 2.38365E-07 7.62282E-07 1.37683E-06 4.06702E-06
2 1.90477E-19 7.30979E-20 1.09401E-20 5.67524E-11 2.38365E-07 7.62282E-07 1.37683E-06 4.06702E-06
Ozone grp. 33 grp. 34 grp. 35 grp. 36 grp. 37 grp. 38 grp. 39 grp. 40
1 4.64264E-06 8.21787E-06 8.51049E-06 1.18571E-05 1.49891E-05 9.63891E-06 8.87249E-06 5.93795E-06
2 4.64264E-06 8.21787E-06 8.51049E-06 1.18571E-05 1.49891E-05 9.63891E-06 8.87249E-06 5.93795E-06
Ozone grp. 41 grp. 42 grp. 43 grp. 44 grp. 45
1 8.43036E-07 2.19772E-07 2.30309E-08 1.58334E-09 9.92086E-12
2 8.43036E-07 2.19772E-07 2.30309E-08 1.58334E-09 9.92086E-12
Ozone volume vol. fraction
1 2.79791E+03 1.00000E+00
2 2.79791E+03 1.00000E+00
0 elapsed time 0.00 min.

```

Histogram values -

Bar #	Value	(As a density)
1	7.5690420E-02	(8.4100460E-01)
2	5.4942510E-01	(1.3735630E+00)
3	1.7300000E+00	(3.4600000E+00)
4	6.0750000E+00	(6.0750000E+00)
5	8.7550000E+00	(8.7550000E+00)
6	1.1030000E+01	(1.1030000E+01)
7	1.3100000E+01	(1.3100000E+01)
8	1.5100000E+01	(1.5100000E+01)
9	1.7100000E+01	(1.7100000E+01)
10	1.9100000E+01	(1.9100000E+01)
11	2.1075000E+01	(2.1075000E+01)
12	2.3025000E+01	(2.3025000E+01)
13	2.4000000E+02	(2.4000000E+01)
	3.7671510E+02	

INTEGRATE used 42 out of 1000000 real/integer variables (.004%)
 and 0 out of 10000 characters (.000%)

Stop - Program terminated.

1129102

K_a/φ

2/3/02

COLLAPSING RT BOUNDARY LEAKAGE FROM GODIVA:

18 Gamma Groups from 27 m-18 g coupled cross section

GODIVA RESULTS

# particles/cm ² s	ENERGY GROUP (mev)
1 $8.51977E-8$	10 $\frac{1}{2}$
2 $3.53917E-4$	8 $\frac{1}{2}$ 9 $\frac{1}{2}$ 213
3 $1.07131E-3$	6.5 $\frac{1}{2}$ = $1.1797233E-4$
4 $1.91204E-3$	5 $\frac{1}{2}$ = $3.571033E-4$
5 $5.56546E-3$	4 $\frac{1}{2}$ = $7.142066E-4$
6 $6.33558E-3$	3
7 $1.12494E-2$	2.5
8 $1.17900E-2$	2
9 $1.68185E-2$	1.66
10 $2.25406E-2$	1.33
11 $1.58908E-2$	1
12 $1.68540E-2$	.8
13 $1.51642E-2$	.6 $\frac{1}{2}$ = $7.5821E-3$
14 $3.62788E-3$	.4 $\frac{1}{2}$ = $7.5821E-3$
15 $9.36171E-4$	.3
16 $1.12908E-4$	.2
17 $2.74342E-5$	.1
18 $1.77972E-6$	.01

12 ENERGY GROUPS FOR SOURCE INPUT:

ENERGY GROUP	# particles/cm ² s	GROUP
20		
10	$4.401385E-8$	1
9	$4.401385E-8$	2
8	$2.35945E-4$	3
7	$4.75056E-4$	4
6	$7.142066E-4$	5
5	$1.91204E-3$	6
4	$5.56546E-3$	7
3		
2	$1.758448E-2$	8
1		
	$5.11491E-2$	9
	$4.03269E-2$	10
.5		
	$1.2259059E-2$	11
.1		
	$2.921392E-5$	12
.01		

APPENDIX C: Kansas State University Skyshine Benchmark Experiments Data Development

C.1 Kansas State University Skyshine Experiments

The Kansas State University Skyshine Experiments were conducted to provide experimental data against which a calculational model and method could be compared and benchmarked. These experiments use a simple geometry of a known source inside a thick-walled concrete silo with detectors at increasing distances from the outside of the silo walls. The experiments were performed by KSU and Radiation Research Associates personnel at the KSU Nuclear Engineering Shielding Facility from May to November, 1977.

Three different ^{60}Co photon sources were used in the experiments: 10.3 Ci, 229 Ci, and 3804 Ci sources. They were placed at the same location inside the concrete silo 2.54 cm above a steel cask, 1.98 m above grade on the axis of the annular concrete silo. The walls were sufficiently thick (3 ft or 91.44 cm) to prevent radiation from penetrating horizontally outward. The photon emission from the source was collimated into a 150 degree upward conical distribution. The experiments were conducted with each of the sources, without a roof. Other experiments were planned with a 21 cm roof, and with a 42 cm roof, but were not conducted.

Both energy spectra and exposure rate were measured by detectors placed in various increments from 50 feet to 700 m from the outside silo wall, at an elevation 100 cm above grade. These detectors have isotropic response so that the measurements can be considered to integrate the incident skyshine and groundshine photon fluence over a 4π steradian solid angle (background measurements were subtracted). Air density, air temperature, relative humidity, and pressure were recorded for each measurement.

A material composition is not given in the benchmark reference for the steel cask, but calculational model evaluated in MCNP accounted for Compton scatter off the casks, cart, silo walls, and floor by modeling a scattering medium. A 0.635 cm thick steel plate was used for the top of the casks and a 0.318 cm thick steel layer was used for the sides

of the casks and the cart. Results of the MCNP models are reported at 50, 100, and 200 meters for three different scattering treatments inside the silo: no scatter, partial scatter, and full scatter. In the MCNP model, the best agreement with the experimental results occur with the full scattering treatment. The evaluation performed in the PARTISN 2.64/DANTSYS 3.1 model did not include the stainless steel, but only includes the concrete portion of the shielding. See Figure C-1 for the TWODANT model of the KSU silo.

The concrete composition used in the MCNP model is the same as is recommended in the ANSI/ANS 6.6.1-1987 standard, and is found in Table 6-1, *Concrete Composition from ANSI/ANS-6.6.1* of this work. The ground composition is also the same as that recommended in the standard and is found in Table 6-2, *Ground Composition from ANSI/ANS-6.6.1* of this work. The air composition is more detailed as shown in Table C-1 below:

Table C-1. Air Composition from KSU Experiments from Tables II of *Nuclear Science and Engineering* MCNP Benchmark.

Element	Atom Density	Weight Fraction
H	1.1080 E-6	0.001692
N	4.0000 E-5	0.7435
O	1.0000 E-5	0.242
Ar	2.1149 E-7	0.0128

Deposited energy in the MCNP model was measured in MeV/cm³ and converted to deposited dose in air in units of rads as follows:

$$\text{Dose (rad)} = [(1.602 \text{ e-6 erg/MeV}) (1 \text{ rad/100 erg/g}) / \rho_{\text{air}} (\text{g/cm}^3)] \times \text{Dose (MeV / cm}^3) .$$

Absorbed dose in rads was then converted to exposure in roentgens for the KSU Skyshine report by

$$\text{Exposure (R)} = \text{Dose (rad)} / 0.87$$

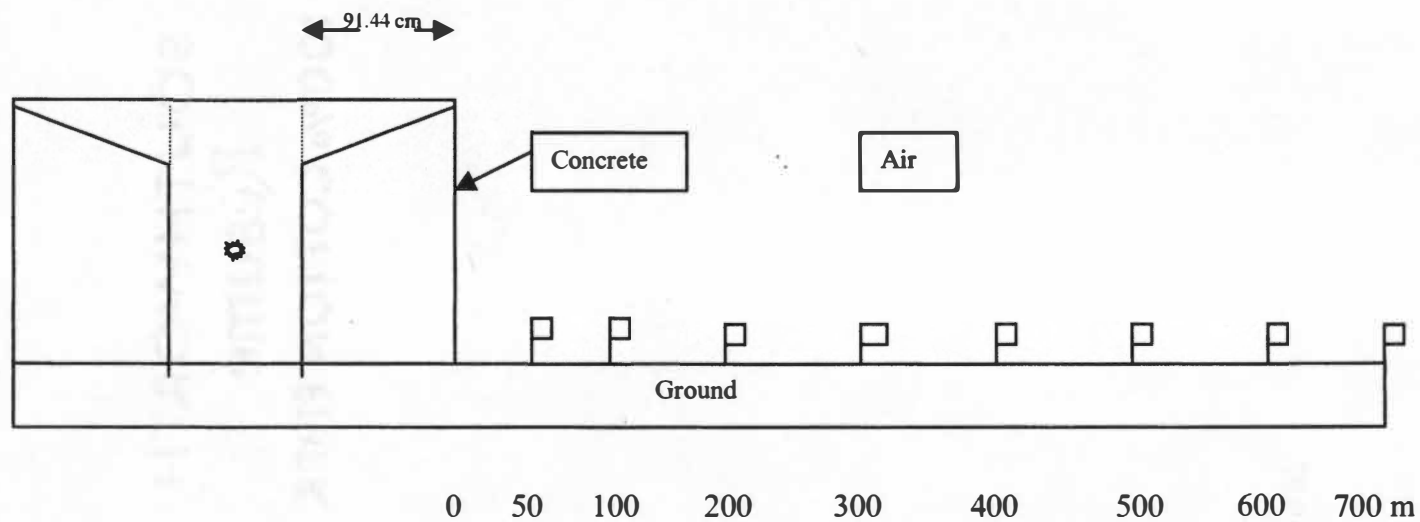


Figure C-1. Kansas State University Skyshine Experiment Model.

(small burst indicates source, small blocks indicate detector)

C.2 Photon Source Spectra for KSU Experiments

Calculations were performed to determine the actual photon spectra emitted from the various ^{60}Co sources used in the KSU experiments since over time, photon collisions inside the source capsule cause the source to degrade. The results of these calculations are given in Table C-2 below:

Table C-2. Original Source Spectrum for KSU Experiments from Tables VI, VII, and VIII of *Nuclear Science and Engineering* MCNP Benchmark.

10.33 Ci Photon Source		229.1 Ci Photon Source		3804 Ci Photon Source	
Energy (keV)	Photon Fluence per Source Photon at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence per Source Photon at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence per Source Photon at 1 m (photon/cm ²)
10 to 200	8.93 E-8	10 to 200	6.80 E-8	10 to 200	2.18 E-7
200 to 400	3.21 E-7	200 to 400	2.54 E-7	200 to 400	5.66 E-7
400 to 600	2.27 E-7	400 to 600	1.80 E-7	400 to 600	4.09 E-7
600 to 800	2.41 E-7	600 to 800	2.06 E-7	600 to 800	3.84 E-7
800 to 1000	2.39 E-7	800 to 1000	2.42 E-7	800 to 1000	3.67 E-7
1000 to 1123	1.48 E-7	1000 to 1123	1.86 E-7	1000 to 1123	2.35 E-7
1123 to 1173	3.27 E-6	1123 to 1173	2.86 E-6	1123 to 1173	2.69 E-6
1173 to 1272	5.19 E-8	1173 to 1272	7.79 E-8	1173 to 1272	8.93 E-8
1272 to 1322	3.28 E-6	1272 to 1322	2.87 E-6	1272 to 1322	2.69 E-6

These source spectra were regrouped in order to eventually match the photon energy groups of the MENDFG 12-group photon energy cross section library used for validation of PARTISN 2.64/DANTSYS 3.1. The regrouping was accomplished by assuming a histogram energy distribution of the source spectra and integrating over the new group structure. The results of the regrouping are given in Table C-3. These results were then used to collapse into 12 energy groups as shown in Tables C-4, C-5 and C-6 for each of the three sources.

**Table C-3. Modified Source Spectrum for KSU Experiments used in PARTISN
2.64/DANTSYS 3.1 Model.**

10.33 Ci Photon Source		229.1 Ci Photon Source		3804 Ci Photon Source	
Energy (keV)	Photon Fluence at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)
10 to 100	4.23 E-8	10 to 100	3.22105 E-8	10 to 100	1.03263 E-7
100 to 200	4.70 E-8	100 to 200	3.5789 E-8	100 to 200	1.14737 E-7
200 to 400	3.21 E-7	200 to 400	2.54 E-7	200 to 400	5.66 E-7
400 to 500	1.135 E-7	400 to 500	9.00 E-8	400 to 500	2.045 E-7
500 to 600	1.135 E-7	500 to 600	9.00 E-8	500 to 600	2.045 E-7
600 to 800	2.41 E-7	600 to 800	2.06 E-7	600 to 800	3.84 E-7
800 to 1000	2.39 E-7	800 to 1000	2.42 E-7	800 to 1000	3.67 E-7
1000 to 1123	1.48 E-7	1000 to 1123	1.86 E-7	1000 to 1123	2.35 E-7
1123 to 1173	3.27 E-6	1123 to 1173	2.86 E-6	1123 to 1173	2.69 E-6
1173 to 1272	5.19 E-8	1173 to 1272	7.79 E-8	1173 to 1272	8.93 E-8
1272 to 1322	3.28 E-6	1272 to 1322	2.87 E-6	1272 to 1322	2.69 E-6

**Table C-4. 10.33 Photon Source Spectra for 12-Group Photon Energy
Cross Section Library.**

12-Group Photon Energy Spectrum			Modified Photon Spectrum	
Group	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)
Group 12 Total	10 to 100	4.23 E-8	10 to 100	4.23 E-8
11	100 to 200	4.70 E-8	100 to 200	4.70 E-8
11	200 to 400	3.21 E-7	200 to 400	3.21 E-7
11	400 to 500	1.135 E-7	400 to 500	1.135 E-7
Group 11 Total	100 to 500	4.82 E-7		
10	500 to 600	1.135 E-7	500 to 600	1.135 E-7
10	600 to 800	2.41 E-7	600 to 800	2.41 E-7
10	800 to 1000	2.39 E-7	800 to 1000	2.39 E-7
Group 10 Total	500 to 1000	5.93 E-7		
9	1000 to 1123	1.48 E-7	1000 to 1123	1.48 E-7
9	1123 to 1173	3.27 E-6	1123 to 1173	3.27 E-6
9	1173 to 1272	5.19 E-8	1173 to 1272	5.19 E-8
9	1272 to 1322	3.28 E-6	1272 to 1322	3.28 E-6
Group 9 Total	1000 to 2000	6.75 E-6		
Group 8 Total	2000 to 3000	0		
Group 7 Total	3000 to 4000	0		
Group 6 Total	4000 to 5000	0		
Group 5 Total	5000 to 6000	0		
Group 4 Total	6000 to 7000	0		
Group 3 Total	7000 to 8000	0		
Group 2 Total	8000 to 9000	0		
Group 1 Total	9000 to 20000	0		

**Table C-5. 229.1 Ci Photon Source Spectra for 12-Group Photon Energy
Cross Section Library.**

12-Group Photon Energy Spectrum			Modified Photon Spectrum	
Group	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)
Group 12 Total	10 to 100	3.22105 E-8	10 to 100	3.22105 E-8
11	100 to 200	3.5789 E-8	100 to 200	3.5789 E-8
11	200 to 400	2.54 E-7	200 to 400	2.54 E-7
11	400 to 500	9.00 E-8	400 to 500	9.00 E-8
Group 11 Total	100 to 500	3.79789 E-7		
10	500 to 600	9.00 E-8	500 to 600	9.00 E-8
10	600 to 800	2.06 E-7	600 to 800	2.06 E-7
10	800 to 1000	2.42 E-7	800 to 1000	2.42 E-7
Group 10 Total	500 to 1000	5.38 E-7		
9	1000 to 1123	1.86 E-7	1000 to 1123	1.86 E-7
9	1123 to 1173	2.86 E-6	1123 to 1173	2.86 E-6
9	1173 to 1272	7.79 E-8	1173 to 1272	7.79 E-8
9	1272 to 1322	2.87 E-6	1272 to 1322	2.87 E-6
Group 9 Total	1000 to 2000	5.9939 E-6		
Group 8 Total	2000 to 3000	0		
Group 7 Total	3000 to 4000	0		
Group 6 Total	4000 to 5000	0		
Group 5 Total	5000 to 6000	0		
Group 4 Total	6000 to 7000	0		
Group 3 Total	7000 to 8000	0		
Group 2 Total	8000 to 9000	0		
Group 1 Total	9000 to 20000	0		

**Table C-6. 3804 Ci Photon Source Spectra for 12-Group Photon Energy
Cross Section Library.**

12-Group Photon Energy Spectrum			Modified Photon Spectrum	
Group	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)	Energy (keV)	Photon Fluence at 1 m (photon/cm ²)
Group 12 Total	10 to 100	1.03263 E-7	10 to 100	1.03263 E-7
11	100 to 200	1.14737 E-7	100 to 200	1.14737 E-7
11	200 to 400	5.66 E-7	200 to 400	5.66 E-7
11	400 to 500	2.045 E-7	400 to 500	2.045 E-7
Group 11 Total	100 to 500	8.85237 E-7		
10	500 to 600	2.045 E-7	500 to 600	2.045 E-7
10	600 to 800	3.84 E-7	600 to 800	3.84 E-7
10	800 to 1000	3.67 E-7	800 to 1000	3.67 E-7
Group 10 Total	500 to 1000	9.555 E-7		
9	1000 to 1123	2.35 E-7	1000 to 1123	2.35 E-7
9	1123 to 1173	2.69 E-6	1123 to 1173	2.69 E-6
9	1173 to 1272	8.93 E-8	1173 to 1272	8.93 E-8
9	1272 to 1322	2.69 E-6	1272 to 1322	2.69 E-6
Group 9 Total	1000 to 2000	5.7043 E-6		
Group 8 Total	2000 to 3000	0		
Group 7 Total	3000 to 4000	0		
Group 6 Total	4000 to 5000	0		
Group 5 Total	5000 to 6000	0		
Group 4 Total	6000 to 7000	0		
Group 3 Total	7000 to 8000	0		
Group 2 Total	8000 to 9000	0		
Group 1 Total	9000 to 20000	0		

Table C-7. KSU Experiment Results Comparison Between Experiment, MCNP Model, and TWODANT--PARTISN 2.64/DANTSYS 3.1 Model Future Work.

Distance (m)	Gamma Source (Ci)	Experimental Results ($\mu\text{R/h} \cdot \text{Ci}^{-1}$)	MCNP Calculational Results ($\pm \%$) ($\mu\text{R/h} \cdot \text{Ci}^{-1}$)	PARTISN 2.64 /DANTSYS 3.1 ($\mu\text{R/h} \cdot \text{Ci}^{-1}$)
10	10.33	-	108.1 ± 0.85	Future work
20	10.33	-	63.8 ± 0.71	Future work
30	10.33	-	42.3 ± 0.60	Future work
40	10.33	-	31.0 ± 0.61	Future work
50	10.33	24.24	$23.95 \pm 0.61^*$	Future work
100	10.33	9.66	$9.17 \pm 0.84^*$	Future work
200	10.33	2.425	$2.415 \pm 0.73^*$	Future work
300	229.1	0.76	0.851 ± 0.44	Future work
400	229.1	0.31	0.327 ± 0.37	Future work
500	229.1	0.117	0.135 ± 0.40	Future work
600	3804	0.0542	0.0541 ± 1.18	Future work
700	3804	0.0244	0.0235 ± 1.15	Future work

* It should be noted that the results for MCNP in Table C-7 include full scatter for the different in-silo scatter conditions. If scattering due to the steel cask and silo walls is ignored, the results for these three distances are reduced to 20.05 ± 0.67 , 7.77 ± 0.60 , and 2.17 ± 0.59 , respectively.

APPENDIX D: Additional Three-Dimensional Storage Vault Models

Additional Three-Dimensional Storage Vault Models

The fission source (nuclear criticality accident) is modeled in one corner of a vault that is a total of 140 feet wide by 190.3 feet long. The floor to ceiling height is 20 feet (240 inches), but the storage area stops at 200 inches, leaving a 40-inch air gap at the top of the vault. The fission source is placed at 10 cm above the floor and approximately 1 m from the front face of the first storage area in the vault. The first detector is placed approximately 1293 cm on the x-axis and 564 cm on the z-axis from the fission source. The second detector is placed 2735 cm on the x-axis and 1711 cm on the y-axis and 564 cm on the z-axis from the fission source. Other dose points are placed in various positions to analyze the flux stream. See Figure E-1, *Proposed Vault-Type Storage Area with Fission Source, Detectors, and Dose Points*, and Figure E-2 for details. Note that Figure E-1 shows just one-half of the proposed vault.

The thickness of the concrete walls around the vaults is 32 inches. It is assumed that the vaults are filled with large concrete pallets that are modeled as slabs of concrete 200 inches high and 48 inches deep, extending the length of the vault, but not containing any fissile material. In Figure D-2, the vault walls are shown surrounding the large concrete pallets modeled as slabs of concrete. The single slabs (48 inches deep) are the thinner of the two interior lines. Double slabs (96 inches deep) are pictured as the thicker of the two interior lines.

Other areas of the proposed storage building include receiving and dispatching areas and handling operations areas. Detectors are placed in these areas, but are not shielded by significant amounts of concrete.

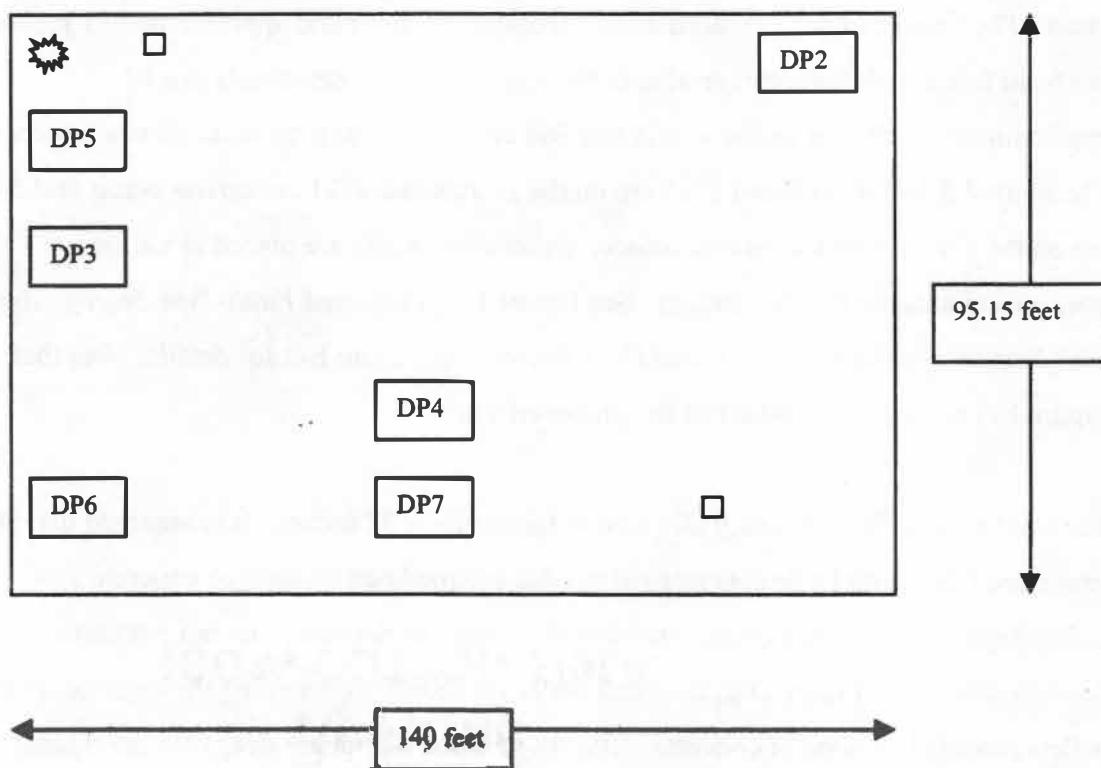


Figure D-1. Proposed Vault-Type Storage Area with Fission Source, Detectors, and Dose Points.

(small burst indicates source, small blocks indicate detectors)

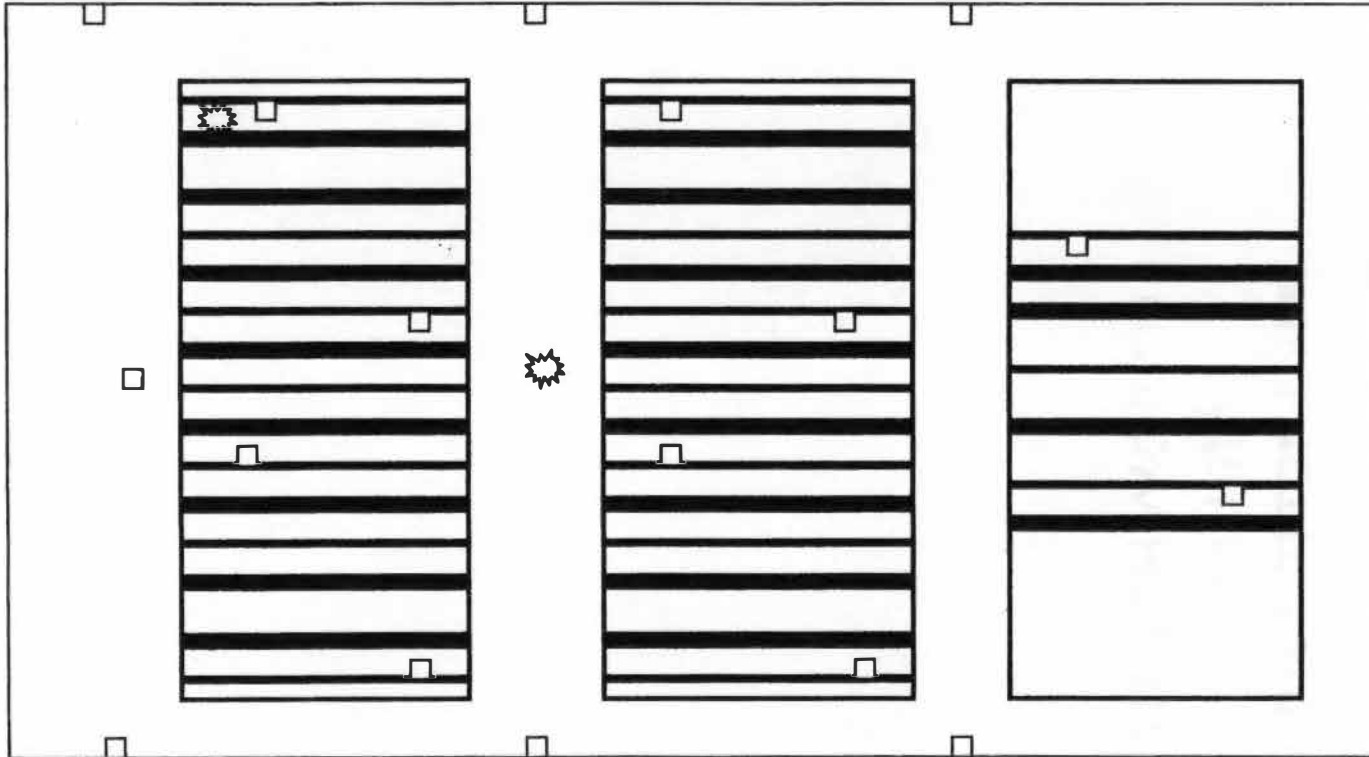


**Figure D-2. Proposed Vault-Type Storage Building Floor Plan for CAAS
Detector Placement.**

(small burst indicates source, small blocks indicate detectors)

APPENDIX E: Current Published Articles of Interest

New storage vaults at Y-12 now urgent

In the weeks following the Sept. 11 terrorist attacks, security at the Y-12 nuclear weapons plant in Oak Ridge has attracted public attention and rightly so.

People are asking all sorts of questions. Is Y-12 a potential target? What are the hazards in the event of attack? Is the plant prepared for terrorism?

Here's a fact that may come as a surprise to many:

There are no airspace restrictions enforced at the Oak Ridge warhead factory.

The U.S. Department of Energy and the Federal Aviation Administration confirmed the situation, although officials at each agency weren't very talkative on the topic.

A local supervisor with the FAA referred me to her agency's Web site for more information and offered the telephone number of the public affairs office in Atlanta, where staffers apparently are too busy to return telephone calls.

Although Y-12's airspace is not off limits in the strictest sense, the Oak Ridge facility would seem to be covered by a broad-based advisory issued Sept. 28 by the FAA.

The so-called NOTAM (Notice to Airmen) includes this language:

"In the interest of national security, and to the extent practicable, pilots are advised to avoid the airspace above, or in proximity to, sites such as nuclear power plants, power plants, dams, refineries, industrial complexes, and other similar facilities. Pilots should not circle as to loiter in the vicinity of such facilities."

"This is only an advisory, of course, not a prohibition or even a stern warning to pilots. It's sort of a please-uh-pretty-please approach."

But, then, if you have suicide-bound terrorists

piloting an airplane, it probably doesn't matter much if you have airspace restrictions. It's for sure nobody was asking permission Sept. 11.

Oak Ridge airspace has been an issue before. As I recall, DOE argued mightily for restrictions in the 1980s, expressing concern that aerial reconnaissance could reveal secrets about nuclear weapons production or plant security.

When asked the matter this week, DOE spokesman Steven Wyatt responded, "A restricted air space above and around Y-12 does have some merit from a security standpoint; however, we consider this to be a low priority. We have not taken any steps to pursue this with the FAA."

Y-12, of course, is not your average, run-of-the-mill industrial site. The plant houses most of the nation's stockpile of bomb-grade uranium.

Is the plant vulnerable?

Absolutely, and that's not just hype. It should be frightfully obvious to everybody now that even institutions once thought to be impenetrable are at risk.

Office towers rising halfway to the heavens always seemed a little precarious. But the Pentagon? It was designed and built as a virtual symbol of U.S. invincibility.

Y-12, too, has the look of a fearsome fortress, surrounded by rows of wire-topped fences and lines of guard towers. But its facilities are antiquated.

A 1996 DOE report addressed significant vulnerabilities to the precious stockpile of highly enriched uranium, and many of those reflected the deteriorated condition of Y-12's physical plant.

There's a good reason the first project in a \$4 billion modernization plan is construction of a new uranium storage vault. Some of the nuclear material currently is housed in wood-frame structures as old as I am.

In a Sept. 19 interview, the top federal official at Y-12 emphasized that, if an airplane struck the Oak Ridge plant, it would not cause a nuclear-

type explosion or produce a mushroom cloud - a concern voiced by many area residents.

"We do not make nuclear bombs," said Bill Brumley of the National Nuclear Security Administration. "There has never been a nuclear weapon at this site. We do not have plutonium. We do not have high explosives ... We make uranium components (for nuclear warheads)."

The uranium parts by themselves will not detonate like a nuclear bomb, he said.

But Brumley acknowledged a large airplane crash - officials have studied a scenario based on a military cargo plane loaded with 28,000 gallons of fuel - would result in human casualties at Y-12 and an off-site release of radioactive materials.

He declined to say how many lives might be lost or how much radioactivity might be carried away in the smoky plume.

"We looked at that as just the absolute worst case that could happen," he said.

"I'm not sure we would want to tell the bad guys exactly what would happen."

While details of the plant's various accident analyses were not made public, it's likely that much of the hazard would result from the combination of fire and enriched uranium.

About a year ago, Y-12 officials were displaying some preliminary designs for the new uranium storage complex. It showed a facility covered by an earthen berm.

Asked if the proposed facility would be hardened, Brumley and others declined comment, citing security concerns. If not included in the design at that time, it would seem imperative that such protection be added now.

It also seems likely that new storage vaults, already the top priority in Y-12's modernization plan, just grew in importance. The sooner they're built, the better we'll feel.

Senior Writer Frank Munger covers the Department of Energy for the News-Sentinel. He can be reached at 865-482-3213 or at fm1@hca.com. This column is also available on the Web at www.hca.com/stories/munger/

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**FRANK
MUNGER**

BWX TYMES

An employee newsletter from the Y-12 National Security Complex

Y-12

Volume 2, Number 8

Super computer critical to Y-12's model-based manufacturing

The Manhattan computer—named in recognition of the project that started Y-12—is playing a key role in helping achieve the science- and model-based manufacturing vision of Y-12's future.

Manhattan's power represents a marked advance in Y-12's capability to enhance design and manufacturing efficiency and reliability. This tool for stockpile stewardship and other national security missions is a joint effort between Y-12 and the National Nuclear Security Administration's Advanced Simulation and Computing Campaign.

"This is a key element in the modernization of Y-12 technology," said Jim Seyler, Advanced Simulation and Computing campaign manager. "At this point, people are connecting with the idea of new buildings. A less visible but equally important element of modernization is the infusion of new technologies and skills to develop and support the improved processes. This is a clear example of science and technology being brought to the table to support the Y-12 National Security mission. It's not a pipe dream—it's being delivered now."

The 50 billion operations per second computer—online at Y-12 since September 1998—has 96 processors, 13 gigabytes of memory, 700 gigabytes of disk storage and approximately 30 terabytes of tape-storage capacity.

These high-speed capabilities are applied in a variety of settings at Y-12. From virtual prototyping and process simulation to advanced material modeling and digital data storage, the Manhattan computer puts a power formerly reserved for research environments in the hands of production and engineering specialists who apply that power to solve real-world problems.

Susan Turner, an engineer with Criticality Safety, uses the computer to perform shielding calculations, which determine the number and location of Criticality Accident Alarm System (CAAS) detectors in buildings that house special nuclear material (SNM).

"Typically, a building storing SNM is made of concrete and/or steel," Turner said. "If I place a CAAS detector on the opposite side of a concrete wall from where SNM is stored, and there is a criticality accident involving the SNM, I must be able to prove the CAAS detects the accident, even though the concrete may be shielding most of the neutron and gamma particles (produced in the accident). The workers need to hear the CAAS alarm to promptly evacuate the area. This proof is very difficult without sophisticated computer simulation and calculations."

Turner factors in certain variables—thickness of the wall, size of the criticality accident and the potential location and number of the CAAS detectors—to arrive at a result. Using the Manhattan computer and transport codes developed by Oak Ridge and Los Alamos national laboratories, Turner creates a model of the building, which includes the neutron/gamma source and the proposed CAAS detector locations. In a matter of seconds, minutes or a few hours—depending on the size of the problem—the Manhattan computer can tell Turner the number of particles per unit area of the building and at the detector site, as well as the

continued on page 22



Vince Lambert, left, of Y-12 Development and Susan Turner of Criticality Safety discuss the use of the Manhattan computer.

Manhattan

continued from page 4

abstract radiation dose at the detector site. Previously, calculations using existing computers took weeks or months.

"Manhattan can track more particles at a time, using multiple parallel processors, saving us time and money," Turner said. "More importantly, the new building design and storage process is almost instant."

Vince Lambert, a senior member of the Technology Development staff, applies the Manhattan computer to heavy metals casting.

"We work with a variety of materials," Lambert said. "Y-12 has a good track record for casting objects for our customers. But procedures for this work are complex—so people leave and equipment changes, knowledge is lost."

"We want to be able to use simulations to lead guidance to the Y-12 facility," he said. "Our ultimate goal is to place a gateway to the Manhattan computer on the facility floor, where a worker would enter a shape and a material into the computer and receive a set of instructions, such as 'heat at this rate, pour at that rate.' These calculations are very expensive. To accomplish them, we need the power of the Manhattan."

Lambert hopes the Manhattan computer's capabilities will lead to fewer part failures and less material waste. "You can avoid a lot of costly trial and error," he said. "And there's less exposure of workers to possibly dangerous materials and methods."

BWX Times

VITA

Susan Barnard Turner (born Susan Mae Barnard) was born in Knoxville, Tennessee, to parents who both worked and met at the Y-12 Plant before the end of World War II. Both her parents performed work that contributed to the making of the first atomic bomb for the Manhattan Project. Her father (now deceased) retired from the K-25 Gaseous Diffusion Plant as a computer programmer/analyst in 1980. Her mother still resides near Oak Ridge.

Susan graduated high school from Bob Jones Academy in Greenville, South Carolina and attended Bob Jones University for one year. She returned home and entered the University of Tennessee as a part-time student and began working full-time for Union Carbide Nuclear Division's K-25 Gaseous Diffusion Plant in 1975. In 1978 she transferred from the Computing Division to the Gas Centrifuge Enrichment Project as an Engineering Technician and soon decided to change her major from Business to Engineering. Marriage and family responsibilities delayed her completion of a degree until she entered Roane State Community College in 1981. She received an Associate of Science degree in Business in 1982 and an Associate of Science degree in Chemical Engineering Technology in 1984, graduating Magna Cum Laude, with a 3.94 GPA at the top of her engineering class, the Chemical Engineering Technology Award, and the College Physics Award. She began work at Lockheed Martin Energy Systems as a radiochemical analyst at the Y-12 Plant Laboratory in 1990, but returned to the University of Tennessee in 1995 to complete a bachelor's degree in Nuclear Engineering, the fulfillment of a lifelong dream.

She began working as a student intern at the Y-12 Nuclear Criticality Safety Division in July of 1995. Susan graduated in May of 1997, and was offered a graduate assistantship at UT which she declined in order to work full time with Navarro Research and Engineering at the Y-12 Nuclear Criticality Safety Division. She is now a permanent employee of the Y-12 National Security Complex. She attended the University of Tennessee as a part-time graduate student to complete course work for a Master of Science in Nuclear Engineering. Susan's work and research are in the fields of nuclear criticality safety and radiation shielding. She expects to receive the Master of Science in Nuclear Engineering in May, 2002.