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ESPN: SAS4 Shielding Processor for SCALE

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SUMMARY

Included in the SCALE (Standardized Computer Analyses for Licensing Evaluation) code system is the SAS4/MORSE three-dimensional (3-D) automated variance reduction radiation shielding analysis sequence. As part of Oak Ridge National Laboratory's continuing efforts to make SCALE easier to use, a Windows graphical user interface (GUI), ESPN (**E**asy **S**hielding **P**rocessor **In**put), has been developed for performing SAS4 radiation shielding analyses.

ESPN facilitates accurate and efficient evaluations of the radiation protection aspects of radioactive material transportation and storage package designs on a personal computer (PC). It is an easy-to-use GUI that reduces the training, expertise, and user time required for performing accurate three-dimensional shielding analyses. The program allows the user to generate input, execute SAS4, and view output and 2-D color geometry plots directly from the GUI. In addition, ESPN performs error checking prior to execution.

I. INTRODUCTION

SCALE (Standardized Computer Analyses for Licensing Evaluation)[1] is a widely used computational code system that has been developed and maintained by Oak Ridge National Laboratory. The purpose of SCALE has been to provide a comprehensive collection of easy-to-use calculational tools for performing accurate analyses of nuclear facilities and package designs. Included in SCALE is the SAS4 sequence that uses the 3-D Monte Carlo shielding code MORSE-SGC along with automated variance reduction techniques specifically designed for spent fuel cask analyses. The SAS4 sequence performs a 1-D adjoint calculation with XSDRNPM to generate the biasing parameters for MORSE-SGC. SAS4 automatically passes the biasing parameters to MORSE-SGC and executes the code. A generic cask model is included in SAS4 that enables several simplified cask geometry input options.

As part of ORNL's continuing efforts to make SCALE easier to use, a Windows PC graphical user interface (GUI) named ESPN (**E**asy **S**hielding **P**rocessor **In**put), has been developed for creating and executing SAS4 radiation shielding calculations. ESPN can read existing SAS4 input files, perform error checking, execute SCALE and display the output. Included in ESPN is the capability to check the geometry model by generating and viewing 2-D color plots of the geometry model using the SCALE module PICTURE. Input files generated with ESPN may also be transferred to Unix workstations to execute SCALE. Online help and documentation are provided with the program.

II. DESCRIPTION OF ESPN

Figure 1 shows one of the ESPN input screens. The toolbar buttons across the top of the screen provide the functions of opening and saving files, running SCALE, viewing output and 2-D plots, and accessing online help. The toolbar on the left side of the screen contains nine buttons:

- General
- Std Comp
- Unit Cell
- More Data
- Adjoint Data
- Monte Carlo
- 2-D Plots
- Cask Geom
- Fuel Geom

The forms activated by these buttons will be discussed in detail in the following sections.

Figure 1. ESPN Standard Composition window.

A. General Form

As its name implies, this form contains general information for the case, such as title, sequence, cross-section library, unit cell type, and fuel geometry type.

B. Standard Compositions Window

The **Std Comp** button opens the Standard Compositions window, which contains the input menus for the three types of composition data that are common to the SCALE control sequences: basic standard compositions, arbitrary materials, and fissile solutions. The SCALE Standard Composition Library contains over 600 basic standard compositions with alphanumeric names (e.g., “UO2” or “H2O”) and default densities and isotopic compositions that may be overridden by the user. The user may use arbitrary materials to construct other compositions by specifying the content in weight percent (wt %) or as a chemical formula of elements and/or isotopes. SCALE automatically calculates the number densities for each isotope and provides problem-dependent resonance self-shielded cross sections.

The Standard Compositions window (Figure 1) displays a list of the compositions and their properties created by the user in a spreadsheet format. Pressing the **Create** button and selecting “Basic Compositions” allows the user to define mixtures by selecting valid basic standard compositions from a multiple-choice menu. If the composition contains a multiple isotope nuclide, ESPN displays the isotopic distribution and allows the user to modify it (Figure 2).

The Arbitrary Materials form allows the user to define arbitrary material mixtures by selecting valid nuclides from a multiple-choice menu. The nuclide distribution can be specified by atoms per molecule or by wt %.

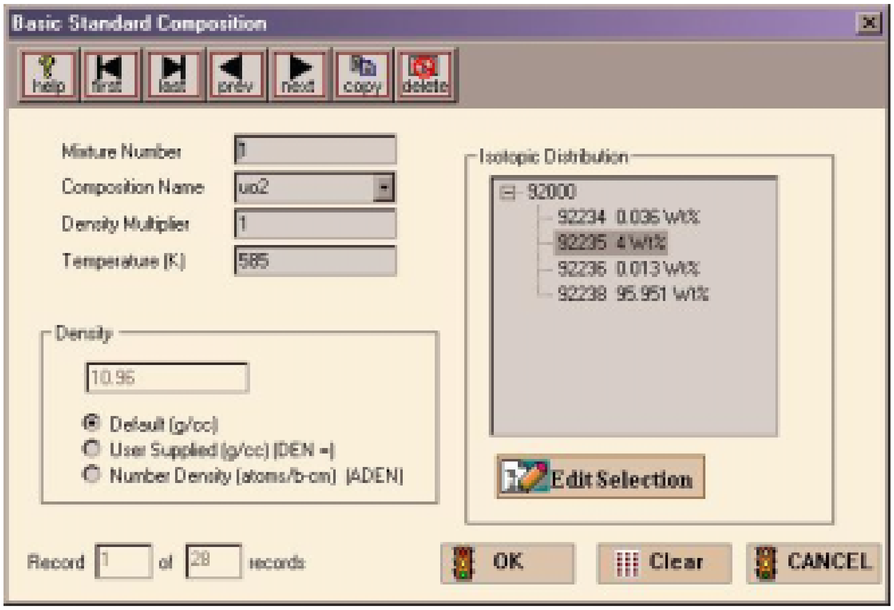

Figure 2. Standard Composition isotopic distribution edit.

The Solutions form contains three fissile solutions available in SCALE. The window is very similar to the Standard Compositions window.

C. Unit Cell and MORE DATA

The **Unit Cell** and **MORE DATA** forms are only available if the lattice cell is selected as the unit cell type on the **General** form. The data on the **Unit Cell** form define the dimensions and compositions of the fuel, clad, and moderator in the fuel assembly lattice.

The **MORE DATA** button displays a window of optional parameters for the XSDRNPM 1-D lattice cell calculation.

D. Adjoint Data

The **Adjoint Data** form includes all input data required for the XSDRNPM 1-D adjoint case. The form contains four tabs: Parameters, Fuel Assembly, Zone Boundaries and Mixtures, and Response Function Array. Figure 3 illustrates the Parameters data tab, which contains all input parameters for the adjoint calculation. The Fuel Assembly tab describes the fuel assembly data for the 1-D adjoint model. The size and contents of each zone in the 1-D model are specified under Zone Boundaries and Mixtures. The Response Function Array tab allows the user to define a group-by-group response function for the adjoint calculation if none of the SCALE built-in response functions are suitable.

E. Monte Carlo

The Monte Carlo form includes input data required for the MORSE 3-D Monte Carlo calculation (except geometry and arrays). This form includes five tabs: Parameters, Source Spectrum, Point Detectors, Surface Detectors, and Axial Profile. The Parameters tab includes all MORSE problem parameters such as number of batches, source particles per batch, and maximum run time. The Source Spectrum tab (Figure 4) specifies the neutron/gamma radiation source on a groupwise basis. The positions of any point detectors or surface detectors are input on the Point Detectors or Surface Detectors tabs, respectively. The user can specify an axial profile for the source on the Axial Profile tab.

F. Geometry

In SAS4, the user can choose from five different geometry options, IGO = 0 to 4:

- Simplified geometry with cylindrical homogeneous fuel
- Simplified geometry with fuel in concentric cylindrical rings

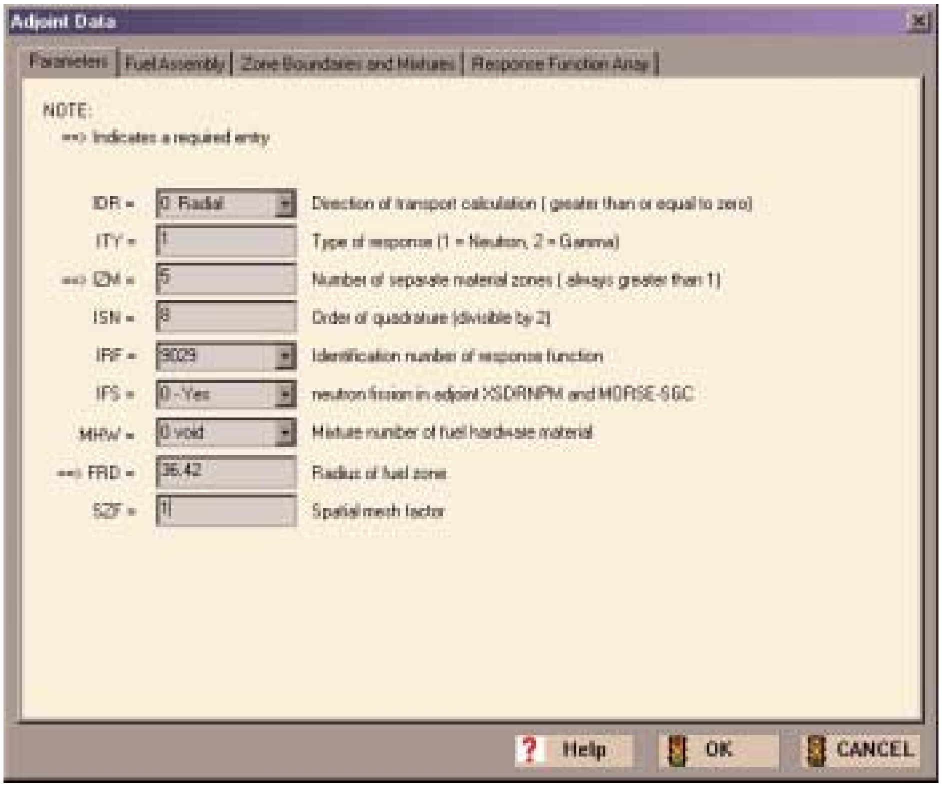

Figure 3. Adjoint Data form.

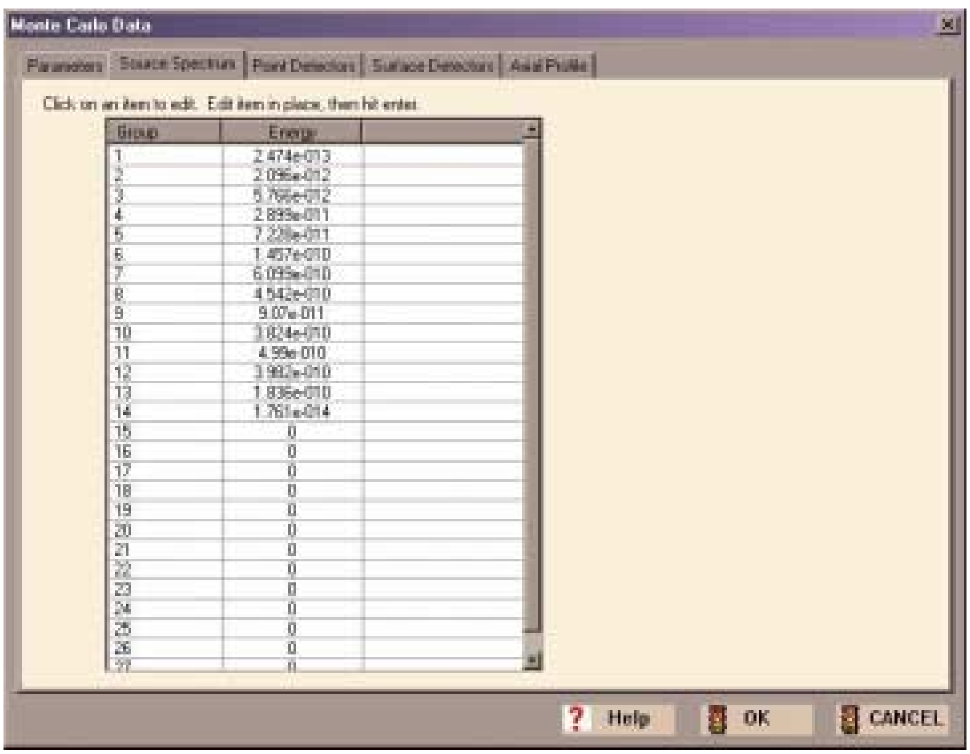

Figure 4. Monte Carlo Data form.

- Simplified geometry with each fuel assembly modeled as separate homogeneous box
- Simplified geometry with each fuel assembly modeled separately in detail
- Detailed geometry input using MARS geometry.

For the four simplified geometry options, a **Cask Geometry** and a **Fuel Geometry** form are provided. The **Cask Geometry** form is shown in Figure 5. Five sections of the cask model are required by SAS4. In addition, there are nine optional sections that may be selected by the user. Using the convenient Fill Wizard, the user is able to input the dimensions for only the sections of the cask that they want to model. The Fill Wizard will automatically calculate the dimensions for the remaining sections of the cask model that are required.

The **Fuel Geometry** form varies depending upon the IGO geometry option chosen. The **Fuel Geometry** form for IGO=2 or 3 is shown in Figure 6. The form always depicts a 3-D image of the appropriate fuel geometry model with dimension variables labeled. The illustration makes it easy for the user to visualize the input data required on the form.

For the detailed geometry option (IGO=4), two different forms, the **Geometry** and the **Array** forms, are presented. The Geometry window facilitates the input of the MARS geometry for the IGO=4 (detailed geometry input) option. It contains toolbar buttons for all geometric body types available: arbitrary polyhedron (ARB), box (BOX), ellipsoid (ELL), right circular cylinder (RCC), right elliptical cylinder (REC), right parallelepiped (RPP), sphere (SPH), truncated cone (TRC), and wedge (WED). Pressing one of these buttons displays an input form for that body type. The geometry bodies are combined in zones by Boolean logic parameters (i.e., combinatorial geometry).

The **Array** form (Figure 7) provides a simple interactive method to construct and fill arrays in the MARS geometry model. The user can point and click to fill individual locations in the array or use the more advanced tools to quickly fill patterns. The Line, Rectangle, and Circle tools allow the user to draw one of these shapes and fill all locations within it. The Inverse tool can be used to fill all the locations outside one of these shapes, and the All tool fills all array locations. The visual feedback provided by this form ensures the user correctly specifies the array input for the model.

G. 2-D Plots

The **2-D Plots** form (Figure 8) assists the user in quickly creating customized X-Y, X-Z, and Y-Z plots of any portion of the geometry model. The user can select from a palette of 256 colors or create custom colors to display mixtures, zones, or regions. Figure 9 shows the X-Y plot of a cask containing seven fuel assemblies generated with the input from Figure 8.

III. CONCLUSIONS

ESPN adds another powerful GUI tool to the growing SCALE graphical visualization toolkit for assisting users in rapidly preparing and performing accurate analyses of nuclear packages and facilities.

ACKNOWLEDGMENTS

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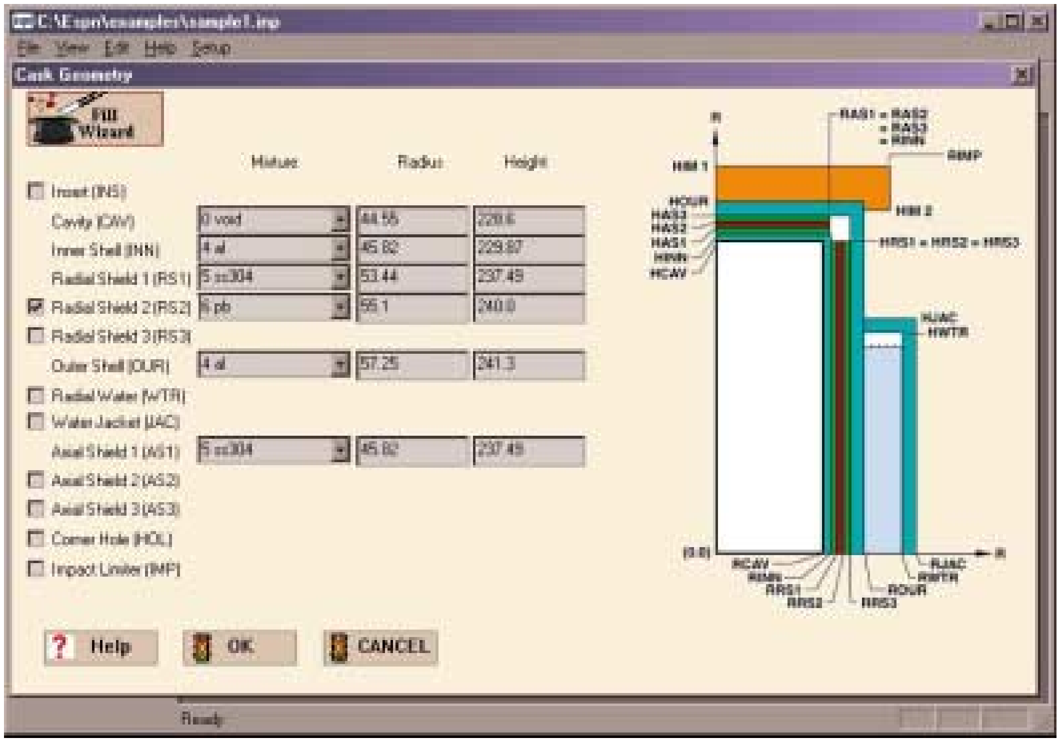

Figure 5. Cask Geometry form.

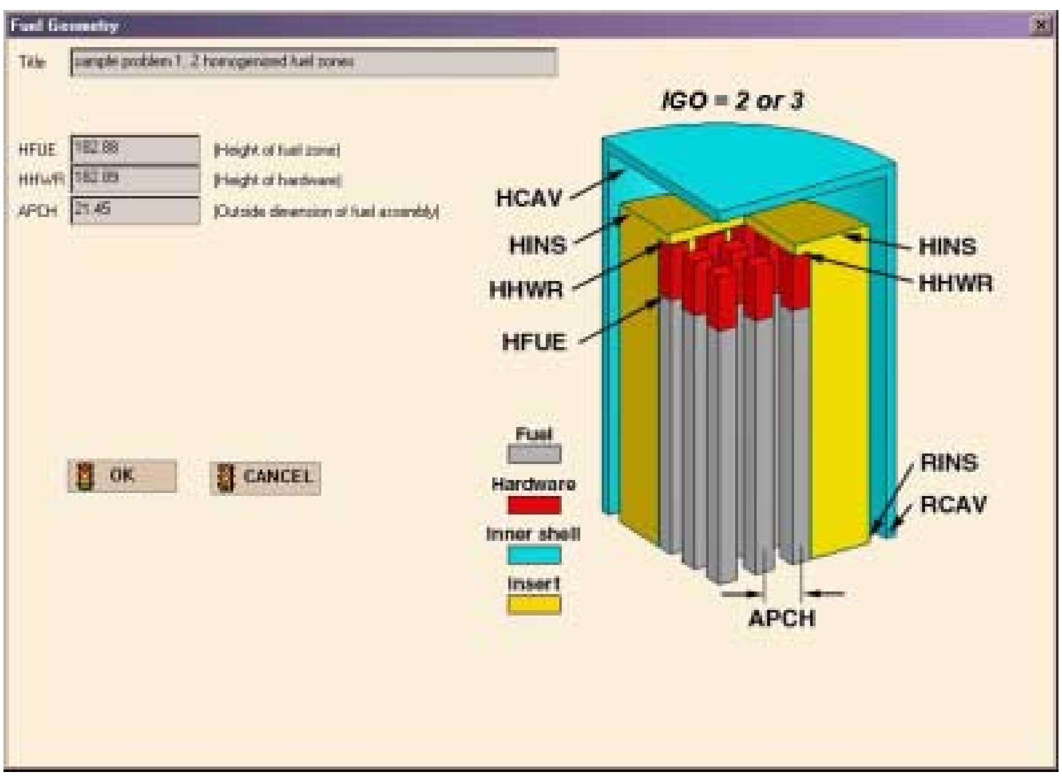

Figure 6. Fuel Geometry form.

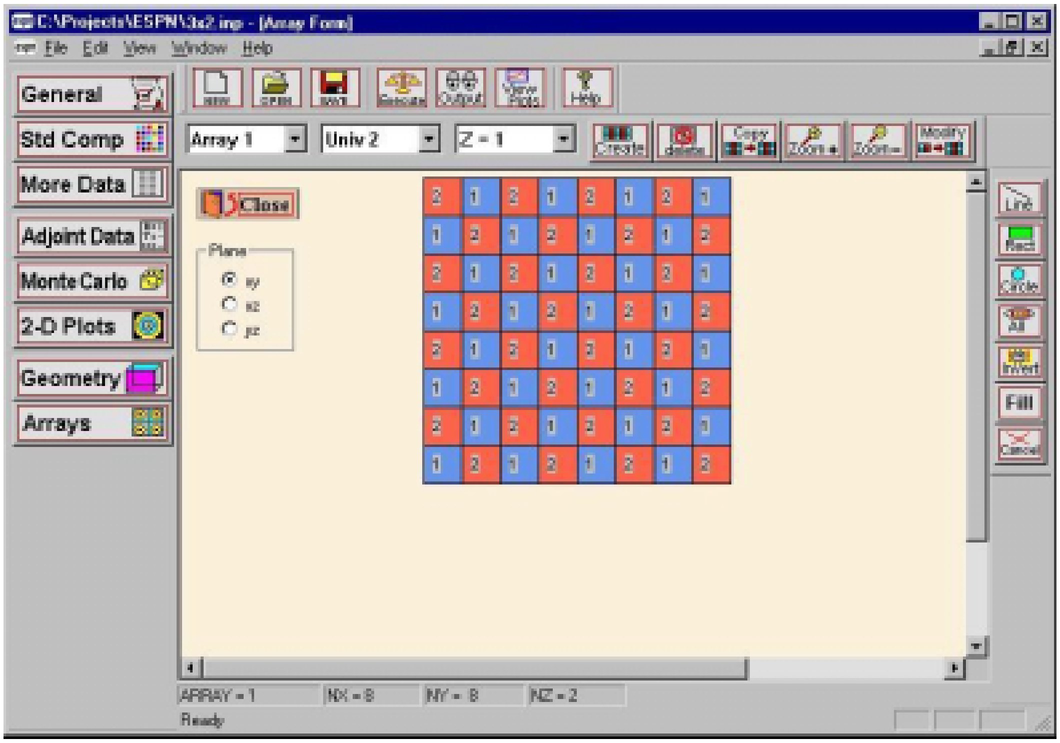

Figure 7. Array form.

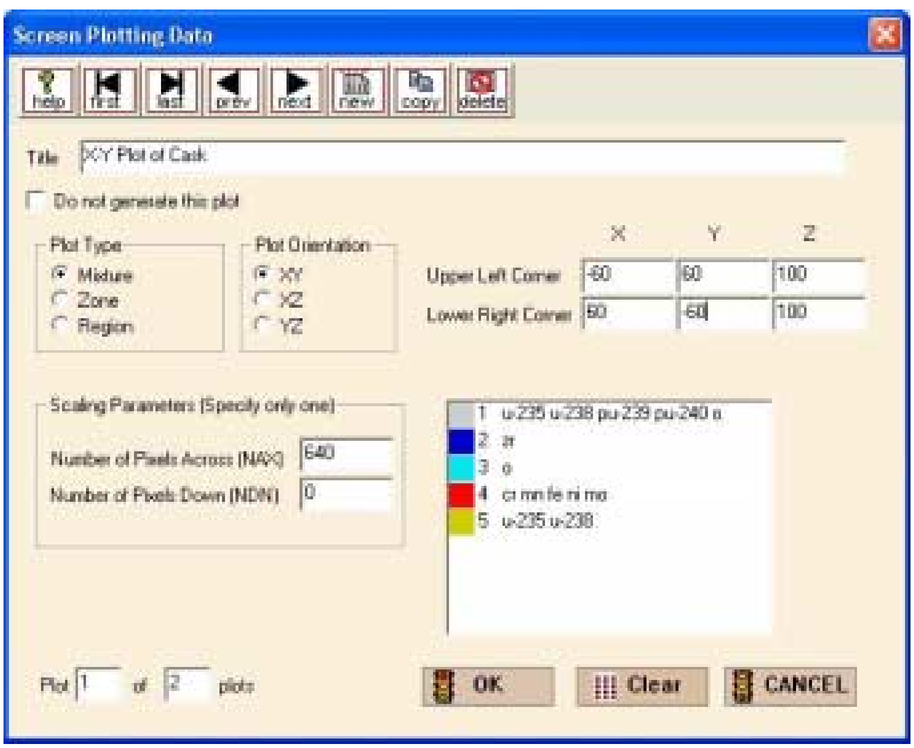

Figure 8. 2-D Plots form.

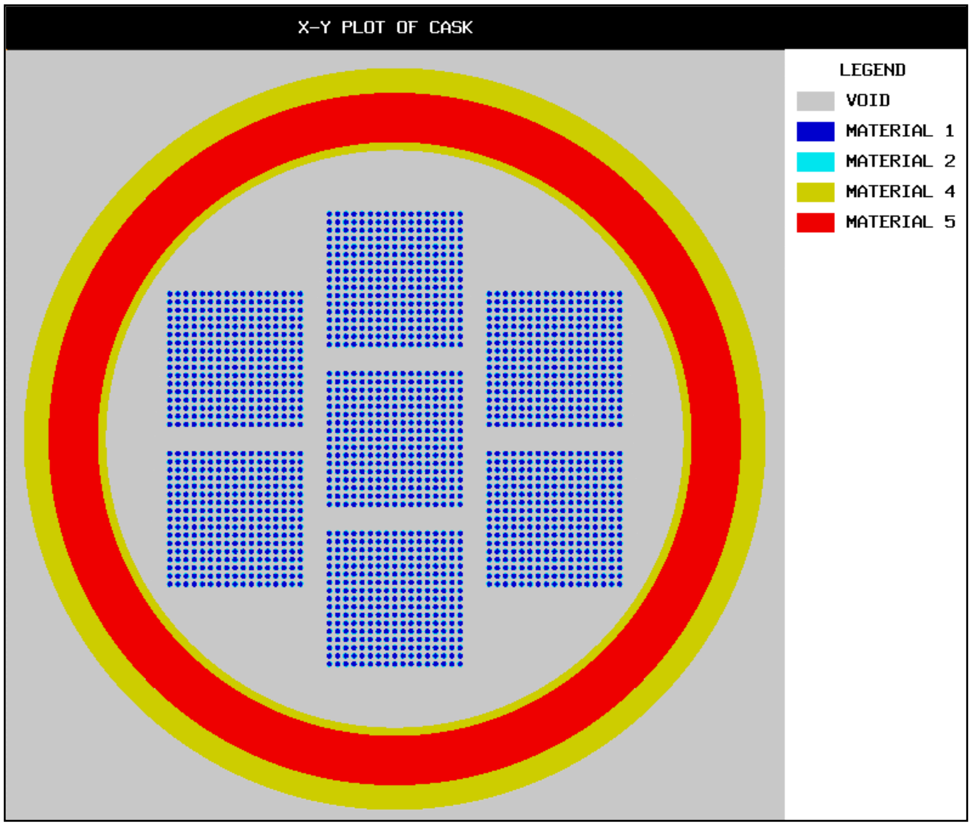

Figure 9. 2-D Plot of cask model.