DEVELOPMENT OF A GRAPHICAL USER INTERFACE FOR THE COARSE MESH RADIATION TRANSPORT CODE COMET AND CROSS SECTION GENERATION WITH HELIOS

A Thesis
Presented to
The Academic Faculty

by

Andrew Michael Holcomb

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Nuclear Engineering in the
G.W. Woodruff School of Mechanical Engineering

Georgia Institute of Technology
December 2013

DEVELOPMENT OF A GRAPHICAL USER INTERFACE FOR THE COARSE MESH RADIATION TRANSPORT CODE COMET AND CROSS SECTION GENERATION WITH HELIOS

Approved by:

Dr. Farzad Rahnema, Advisor
G.W. Woodruff School
Georgia Institute of Technology

Dr. Bojan Petrovic
G.W. Woodruff School
Georgia Institute of Technology

Dr. Dingkang Zhang
G.W. Woodruff School
Georgia Institute of Technology

Date Approved: 11/4/2013

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. Farzad Rahnema for his guidance, Dr. Dingkang Zhang for his thoughtful feedback, and Dr. Bojan Petrovic for serving on my committee.

I would also like to thank my family for their continual support, encouragement, and love.

TABLE OF CONTENTS

		Page
ACKNOWLEDGEMENTS		iii
LIST OF TABLES		vi
LIST OF FIGURES		vii
LIST OF SYMBOLS AND ABBREVIATIONS		ix
SUMMARY		x
CHAPTER		
1	INTRODUCTION	1
2	GUI INPUT FILE CREATION	3
	COMET “DAT” File	3
	COMET “GENRF” and “CREATEDB” Files	5
	COMET “CMCALC” File	7
	Geometry Visualization	11
	Complete COMET Input Example	13
3	GUI OUTPUT FILE PROCESSING	14
	Rotated Assemblies	15
	Formatted TecPlot Output File	17
	Formatted COMET Output Visualization Example	17
4	MHTGR BENCHMARK DESCRIPTION	21
5	CROSS SECTION LIBRARY GENERATION	24
	One-Sixth Fuel Assembly Lattice	24
	Full Fuel Assembly with Partial Graphite Reflector Lattice	28
	One-Half Fuel Assembly with One-Sixth Graphite Reflector Lattice	30

Coupled Neutron Transport and Thermal Fluids Solution 34

6 CONCLUSION 37

APPENDIX A: EXAMPLE COMET "DAT" FILE 38

APPENDIX B: EXAMPLE COMET "GENRF" FILES 45

APPENDIX C: EXAMPLE COMET "CREATEDB" FILES 47

APPENDIX D: EXAMPLE COMET "CMCALC" FILE 49

APPENDIX E: MATERIAL SPECIFICATIONS 57

APPENDIX F: 385° C CROSS SECTION LIBRARY 58

APPENDIX G: 485° C CROSS SECTION LIBRARY 61

APPENDIX H: 585° C CROSS SECTION LIBRARY 63

APPENDIX I: 685° C CROSS SECTION LIBRARY 65

APPENDIX J: 785° C CROSS SECTION LIBRARY 67

APPENDIX K: 885° C CROSS SECTION LIBRARY 69

APPENDIX L: 985° C CROSS SECTION LIBRARY 71

APPENDIX M: 1085° C CROSS SECTION LIBRARY 73

REFERENCES 75

LIST OF TABLES

Page

Table 1: Condensed six-group energy bounds 24

Table 2: Eigenvalue estimate for the original 1/6th model, the no graphite model, and the increased graphite model at temperature points between 385° C and 1085° C 28

Table 3: Eigenvalue estimate for the full fuel assembly neighboring two 1/3rd reflector blocks model at the temperature points between 385° C and 1085° C 30

Table 4: Eigenvalue estimate for the 1/2 fuel assembly coupled with a 1/6th reflector block model at the temperature points between 385° C and 1085° C 32

Table 5: Eigenvalue estimate for the 1/2 fuel assembly coupled with a 1/6th control rod reflector block model at the temperature points between 385° C and 1085° C 33

LIST OF FIGURES

Page

Figure 1: GUI input file generation startup window 3

Figure 2: GUI window that handles COMET “DAT” file creation 5

Figure 3: GUI window that creates COMET “GENRF” and “CREATEDB” file 6

Figure 4: GUI window responsible for the first step in creating the “CMCALC” file 8

Figure 5: GUI window responsible for the second step in creating the “CMCALC” file 9

Figure 6: GUI window responsible for the third step in creating the “CMCALC” file 10

Figure 7: GUI window used to set boundary conditions in the “CMCALC” file 11

Figure 8: GUI illustration generated from a partially completed coarse mesh layout 12

Figure 9: GUI illustration showing one axial zone of a 21x21 core 12

Figure 10: GUI output processing tool 15

Figure 11: Simple grid illustrating COMET's interpretation of a 90 degree rotation 16

Figure 12: Simple grid illustrating COMET's interpretation of a flip 16

Figure 13: 3-D TecPlot graph of the normalized pin fission densities of the entire EPR core 18

Figure 14: Top-down TecPlot graph of the normalized pin fission densities of the EPR core 19

Figure 15: 2-D TecPlot graph of the normalized pin fission densities at the midpoint of the centermost assembly in the EPR core 20

Figure 16: MHTGR plane view of reactor layout 22

Figure 17: HELIOS model of a $1/6^{th}$ fuel assembly 25

Figure 18: HELIOS model of a $1/6^{th}$ fuel assembly with graphite removed 26

Figure 19: HELIOS model of a $1/6^{th}$ fuel assembly with additional graphite 27

Figure 20: HELIOS model of a full fuel assembly neighboring two $1/3^{rd}$ reflector blocks 29

Figure 21: HELIOS model of 1/2 fuel assembly coupled with a $1/6^{th}$ reflector block 31

Figure 22: HELIOS model used to generate control material cross sections 33

LIST OF SYMBOLS AND ABBREVIATIONS

COMET	Coarse-mesh transport code
EPR	European Pressurized Reactor
GUI	Graphical user interface
k_{eff}	Effective core eigenvalue
MHTGR	Modular high temperature gas reactor
TRISO	Tristructural-Isotropic

SUMMARY

In this thesis, the development of a graphical user interface (GUI) for use with the Cartesian heterogeneous coarse-mesh transport code (COMET) is discussed. The main purpose of the GUI is to help eliminate the steep learning curve associated with using COMET. To this end, the GUI reduces pre-computational complexity by generating all of COMET's necessary input files and providing a way for the user to check the model's geometry. Further, the GUI processes the COMET output to produce a TecPlot file, which may then be used to generate three-dimensional plots of the COMET results.

In addition to the GUI, several multi-group, temperature dependent cross section libraries were generated as part of a modular high temperature gas reactor (MHTGR) benchmark problem. These cross section libraries were generated using HELIOS, a lattice depletion code based on a direct collision probability method. Furthermore, the three different models explored in generating the final set of cross section libraries are discussed.

CHAPTER 1

INTRODUCTION

With the development of ever more powerful computational hardware, it is now feasible to quickly and accurately solve large-scale transport problems. The heterogeneous coarse-mesh radiation transport (COMET) code is one such tool capable of solving full-core transport problems[1, 2]. However, COMET, like many other code packages, requires the user to overcome a steep learning curve in order to perform meaningful calculations. To address this issue, a graphical user interface (GUI) was created to help the user generate COMET input files and process the COMET results.

The GUI presented in this thesis was created to make running COMET easier as well as provide the user with a visual representation of COMET's results. The GUI input file generator and output processor were both written in Python 2.7 using the Tkinter module[3, 4]. The GUI was written in Python 2.7 to provide maximum portability[5, 6]. This choice of language allows the GUI to be used on a variety of operating systems, including Windows, Mac OSX, and most other Unix or Unix-like systems. The GUI is also available as an executable for Windows. The GUI input file generator is discussed in Chapter 2, and the GUI output processor is discussed in Chapter 3.

In addition to the GUI, multi-group cross section libraries were generated as part of the MHTGR-350 (Modular High Temperature Gas Reactor) benchmark problem under development at Georgia Tech. This project aims to couple COMET with a thermal hydraulics code to best model the true physics of the reactor design. In order for this goal to be actualized, six-group cross sections were generated over the operational temperature range of the MHTGR using the lattice depletion code HELIOS. In this thesis, we explore three different HELIOS models in order to outline the difficulties that arise in selecting a representative lattice of the MHTGR core. This exploration is intended to emphasize the importance of reactor physics data in governing the achievable accuracy of the transport

solution. A brief description of the MHTGR benchmark problem is presented in Chapter 4 and the cross section generation is discussed in Chapter 5. The condensed cross section libraries were created at discrete temperature points over the operational range of the MHTGR core and are presented in the appendices.

CHAPTER 2

GUI INPUT FILE CREATION

The GUI input file generator helps the user create all of the necessary input files to run COMET. The four input files required to run COMET are the “DAT” file, the “GENRF” file, the “CREATEDB” file, and the “CMCALC” file. While the files can be generated manually by the user, the GUI provides the user a way to generate the files with real time input error checking. Further, the GUI is flexible; the user may choose which files to create using the GUI. The GUI’s input file generation startup window can be seen in Figure 1.

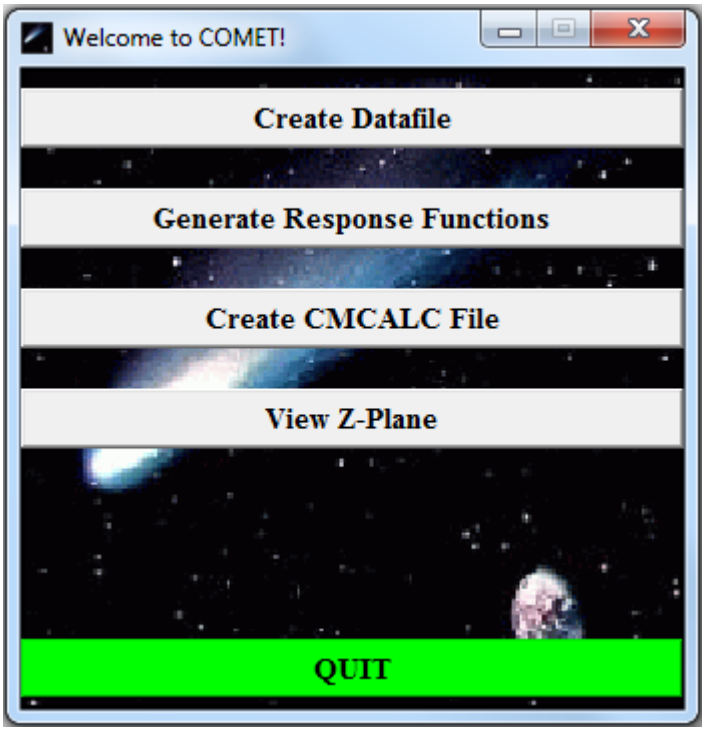

Figure 1. GUI input file generation startup window

COMET “DAT” File

After creating the necessary MCNP template files, the user needs to create the first COMET input file, known as the “DAT” file. The “DAT” file contains a definition

for each unique coarse mesh used in the computation. For each unique assembly, a three-character identifier is assigned by the user. Each three-character identifier is then coupled with all of the pertinent information about that coarse mesh. This information includes the mesh's length in the x, y, and z directions, the mesh type, the choice of pin mapping, and the mesh symmetry value.

For an experienced COMET user, creating this file manually is a relatively simple task. For novice users, however, the numerous required input fields for each unique coarse mesh introduce a new source of confusion, as well as a new source of input error for COMET. The GUI helps avoid these errors by forcing the user to select a value for each input field as well as restricting allowable input. This is accomplished by selective use of entry forms and radio buttons displayed to the user by the GUI.

The GUI starts the COMET "DAT" file creation by asking the user to name the file. This is the only field that will remain constant after the user completes the definition of the first coarse mesh; as each new coarse mesh is written to the COMET "DAT" file, the other fields will automatically reset. The part of the GUI dealing with creation of the COMET "DAT" file is shown in Figure 2.

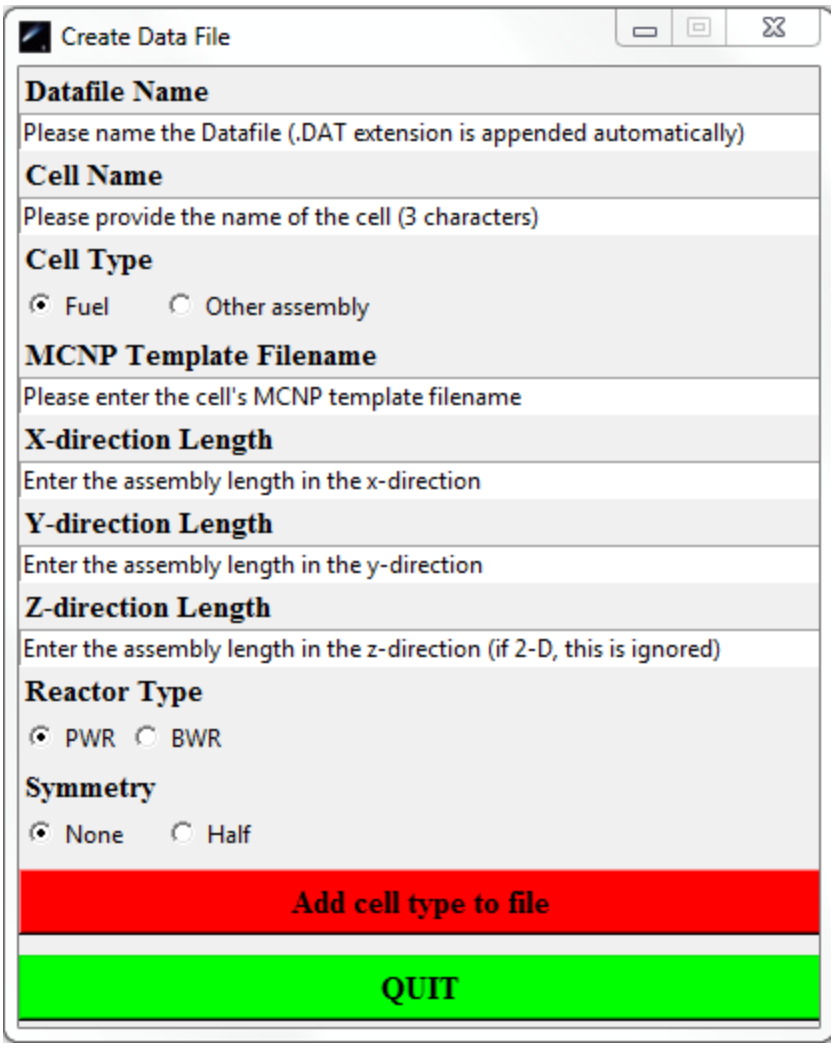

Figure 2. GUI window that handles COMET "DAT" file creation

COMET "GENRF" and "CREATEDB" Files

Before the COMET calculation can take place, a database of response expansion coefficients must be generated. The input file used to generate the response expansion coefficients is called the "GENRF" file. After the response expansion coefficients have been calculated, they are then compiled into a database and provided to COMET. The input file used to create this response coefficient database is known as the "CREATEDB" file. The "GENRF" and "CREATEDB" files are very similar; once the "GENRF" file is

created, the “CREATEDB” file is generated by the GUI for the user automatically. The part of the GUI that creates the COMET “GENRF” and “CREATEDB” files is shown in Figure 3.

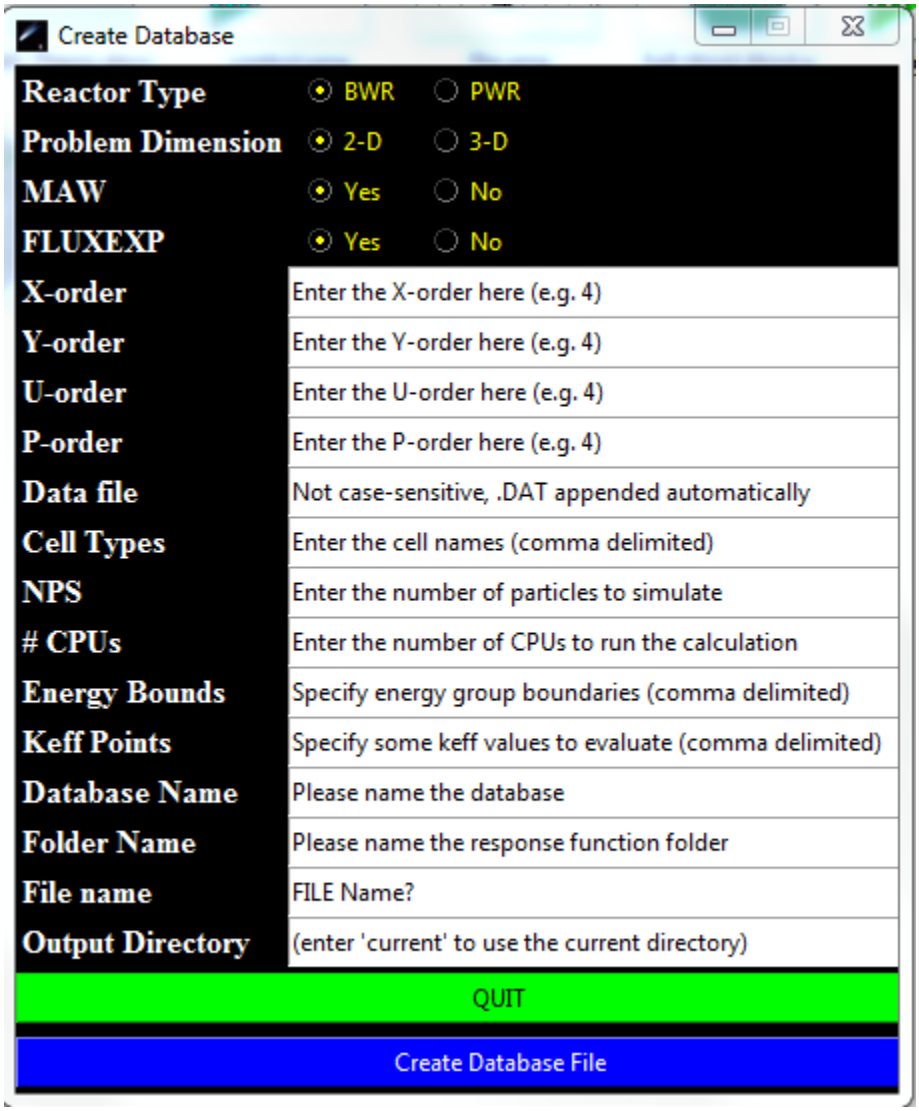

Figure 3. GUI window that creates COMET “GENRF” and “CREATEDB” file

As shown in Figure 3, the “GENRF” input file requires a large number of user inputs. As with the “DAT” file, the widgets were purposefully chosen to help the user select valid, meaningful input. For example, since COMET will perform either a two-

dimensional or three-dimensional calculation, the user has been presented with a radio button that provides only those two choices. Similarly, while the user is free to choose the spatial expansion orders, the provided entry fields give an appropriate suggestion for the values.

COMET "CMCALC" File

After the response expansion coefficients have been generated and compiled into a single database, the COMET calculation can take place. In order to perform the full core computation, COMET requires one last input file, known as the "CMCALC" file. The "CMCALC" file is created in a four step process to avoid overwhelming the user with too many input choices all at once. The first step requires the user to specify the corresponding "GENRF" file, the name of the response expansion coefficient database, the initial eigenvalue guess, the desired acceleration technique, and the number of coarse meshes and axial zones. The GUI window that is used to complete the first step is shown in Figure 4.

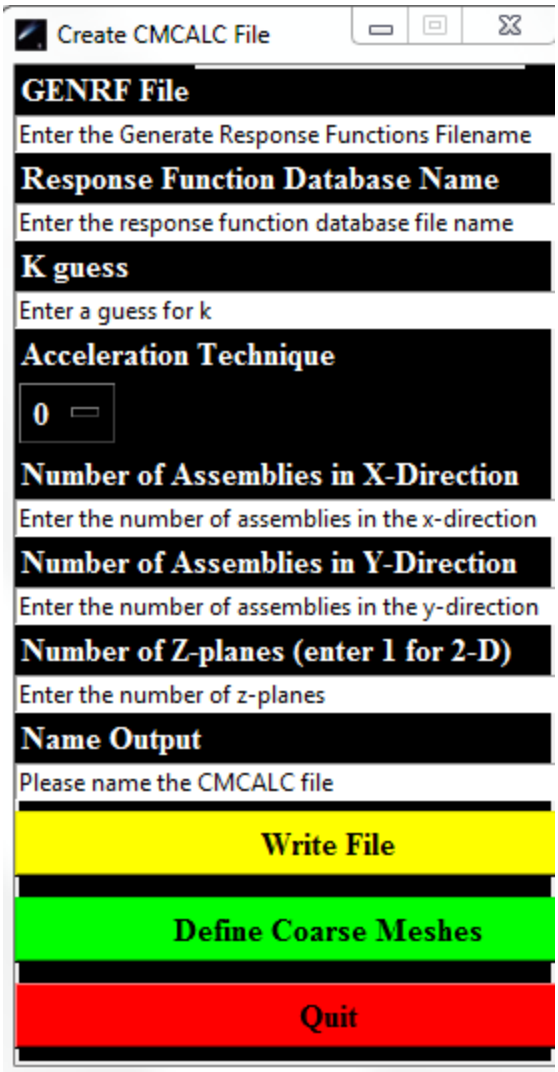

Figure 4. GUI window responsible for the first step in creating the "CMCALC" file

The second step in creating the "CMCALC" file is to define, if necessary, any rotated and/or flipped coarse meshes. After the user has defined all coarse meshes, they are added to the "CMCALC" file. The GUI window guiding the user through this process is shown in Figure 5.

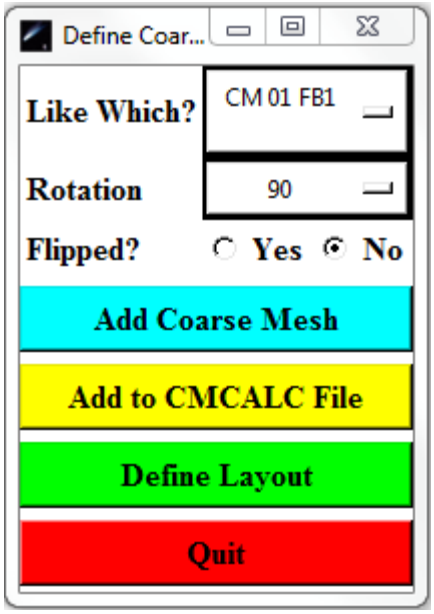

Figure 5. GUI window responsible for the second step in creating the "CMCALC" file

The third step in creating the "CMCALC" file is to define the geometry of the full core problem. Each axial zone is defined by an $M \cdot N$ grid of coarse meshes in the x and y directions. The GUI provides the user with a corresponding $M \cdot N$ grid of entry fields to define each axial zone's x-y coarse mesh layout. Before each axial zone is added to the "CMCALC" file, the GUI performs a check on the user's definition to make sure that all grid positions have been assigned a valid coarse mesh. Further, the GUI provides the user with a visual representation of the current axial zone's coarse mesh mapping at any point before it is added to the "CMCALC" file. The GUI window that facilitates the geometry definition is shown in Figure 6. Figure 6 also shows an example of the GUI's visual representation of a particular axial zone before it is added to the "CMCALC" file. This geometry visualization is discussed in more detail in the next section.

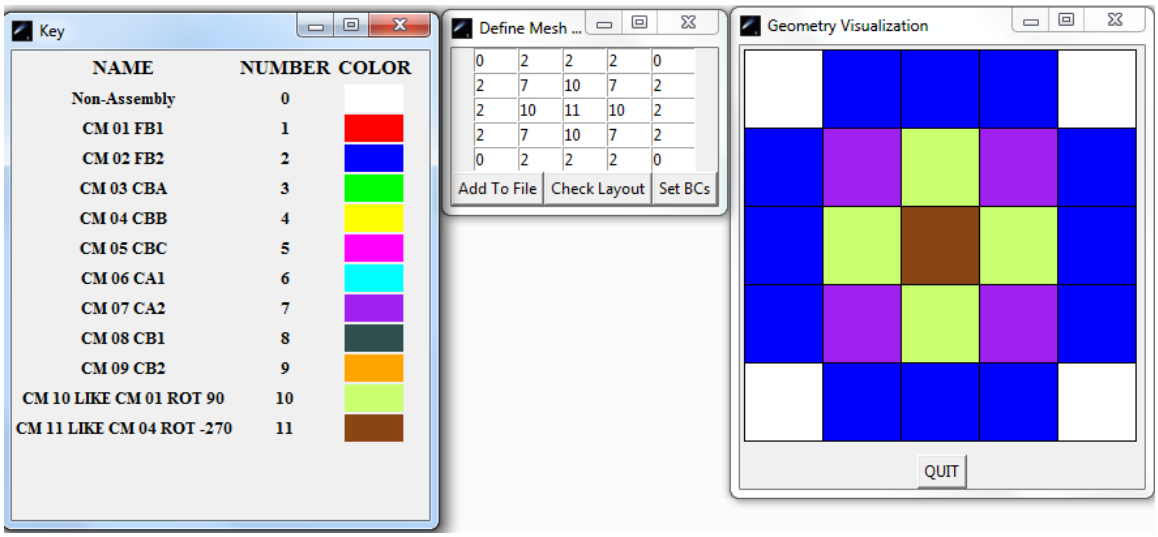

Figure 6. GUI window responsible for the third step in creating the "CMCALC" file

After the problem geometry has been defined, the last step in creating the "CMCALC" file is to set the perimeter boundary conditions. Currently, COMET allows two different boundary conditions: vacuum and specular reflective. To ensure that the user sets only valid boundary conditions, each of the six perimeter boundaries are set using a drop down menu. A drop down menu was chosen over a radio button to better facilitate the addition of new boundary conditions that may be added to future incarnations of COMET. The GUI window responsible for helping the user set the boundary conditions is shown in Figure 7.

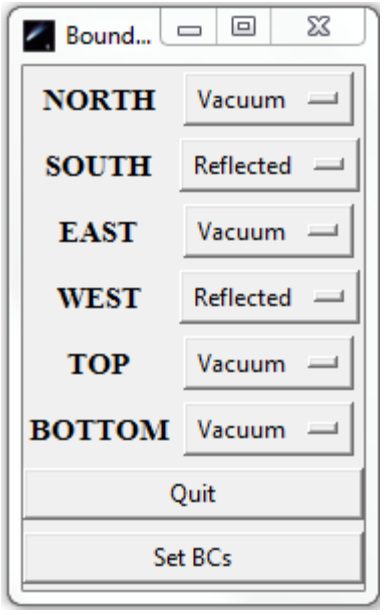

Figure 7. GUI window used to set boundary conditions in the “CMCALC” file

Geometry Visualization

In addition to the ability to create all of the necessary input files to run COMET, the GUI also allows the user to generate simple visual representations of any axial zone's coarse mesh layout. In order to help the user avoid errant coarse mesh placement, the GUI gives the user the ability to check the COMET coarse mesh layout while generating the "CMCALC" file. Further, the GUI allows the user to check a mesh that isn't completely defined; an example of the GUI creating an image from a partially defined coarse mesh layout is given in Figure 8. In addition, the GUI also provides a tool to check the coarse mesh layout of any axial zone in a completed "CMCALC" file. Figure 9 shows the image generated by the GUI for one coarse mesh grid of a 21x21 assembly layout.

Lastly, the edge length of each square coarse mesh in the geometry visualization is chosen according to the limiting dimensions of the user's screen. In the geometry visualization, the default edge length is 60 pixels. However, if the default dimension would result in the image being larger than the user's screen can display, the edge length

is reduced until the resulting image will fit entirely within the user's display. This resizing effect accounts for the different square sizes seen between Figure 8 and Figure 9.

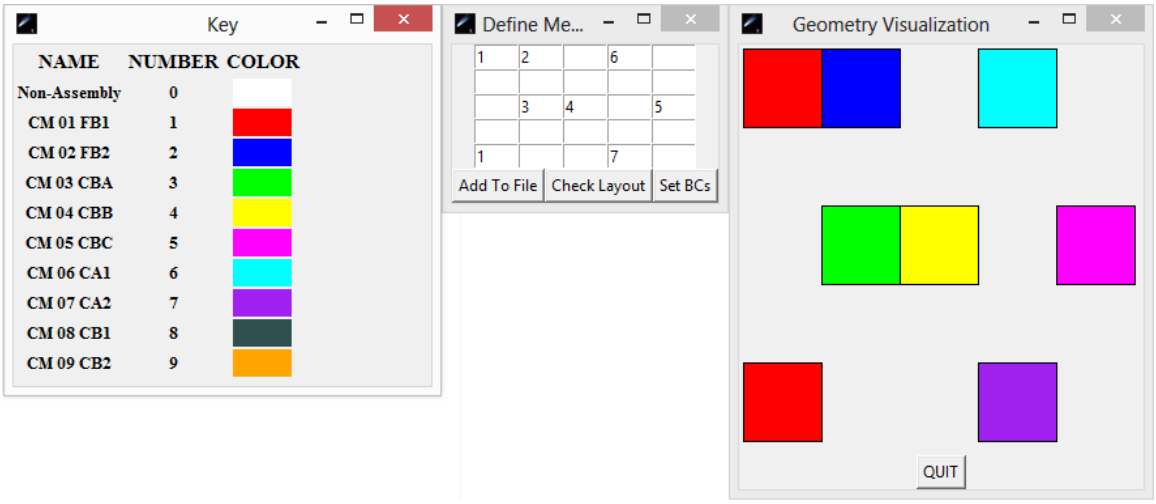

Figure 8. GUI illustration generated from a partially completed coarse mesh layout

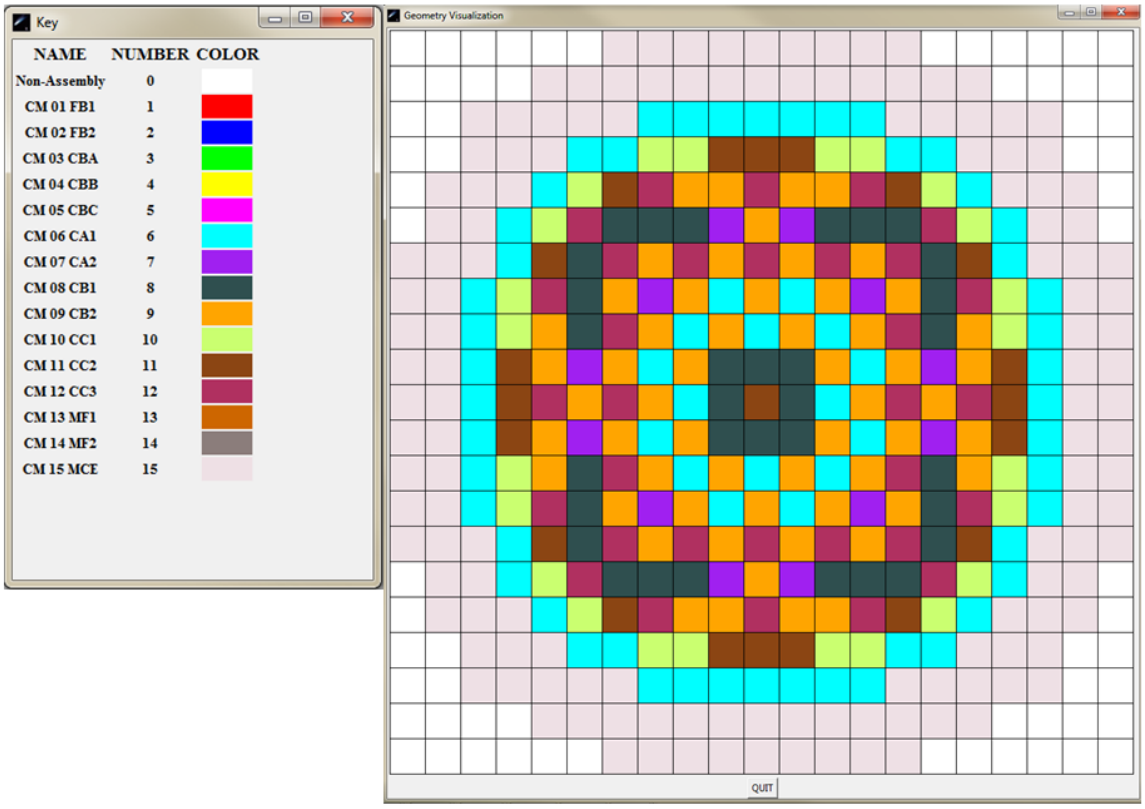

Figure 9. GUI illustration showing one axial zone of a 21x21 core

Complete COMET Input Example

In order to show that the GUI generates all input files correctly, the GUI was used to create the COMET files used by Daniel Lago[*] to solve the European Pressurized Reactor (EPR) benchmark problem[9]. As expected, the COMET solution to the EPR benchmark problem produced results that were in excellent agreement with the MCNP solution; the higher order COMET solution produced an eigenvalue that differed from the MCNP solution by less than 44 pcm. The COMET "DAT" file used in his calculation is presented in Appendix A. The accompanying COMET "GENRF" and "CREATEDB" files can be found Appendix B and Appendix C, respectively. The COMET "CMCALC" file is presented in Appendix D. The GUI geometry visualization of one axial zone of the EPR core was presented in Figure 9.

[*] Daniel Lago is a PhD student in the Computational Reactor and Medical Physics (CRMP) Laboratory at the Georgia Institute of Technology.

CHAPTER 3

GUI OUTPUT FILE PROCESSING

After the COMET calculation is performed, the results and relevant input parameters are written to the output file specified by the user. The output file begins by listing the maximum expansion orders used in creating the response function database; this information is then followed by the expansion orders used in carrying out the COMET calculation. The output file also contains the core eigenvalue and its associated standard deviation. Unfortunately, the rest of the information in the file is presented in a way that is not easily accessible to the user or most plotting software.

The rest of the output file contains the normalized bundle averaged fission densities and the normalized pin fission densities. The bundle averaged fission densities are normalized to the total number of fissile assemblies in the core. For example, if there are twenty assemblies with a non-zero fission density, then the sum of the reported bundle averages is twenty. Similarly, the pin fission densities are normalized to the total number of fissile pins in the core.

The bundle averaged pin fission densities are reported in a manageable manner that can be plotted relatively directly (assuming each axial zone is of equal length). However, the pin fission densities are presented in a way that takes a great deal of post-processing before they can be used meaningfully by any plotting software.

The location of each pin fission density is reported as the index of the assembly that it's found in. For example, if a standard 17x17 fuel assembly is located in the third row, fourth column, and second axial zone, the index (4,3,2) would be reported for each of the 264 pins in that assembly. Since the pins are in different locations and there are locations where no fission is occurring, some post-processing must take place in order to convert the given indices into a Cartesian coordinate system.

This Cartesian mapping requires the dimensions of each assembly, the relative location of each assembly in the core, and the relative location of the fuel pins in each assembly. Fortunately, all of this information can be found in either the COMET "DAT" file or the COMET "CMCALC" file. The "DAT" file contains the relative location of the fuel pins and dimensions of each unique assembly. The "CMCALC" file contains the relative x-y location of each assembly for each axial zone. Therefore, in order to perform the post-processing of the pin power information, the user only needs to provide the GUI with the name and location of these two files. The GUI used to post-process the data is shown in Figure 10.

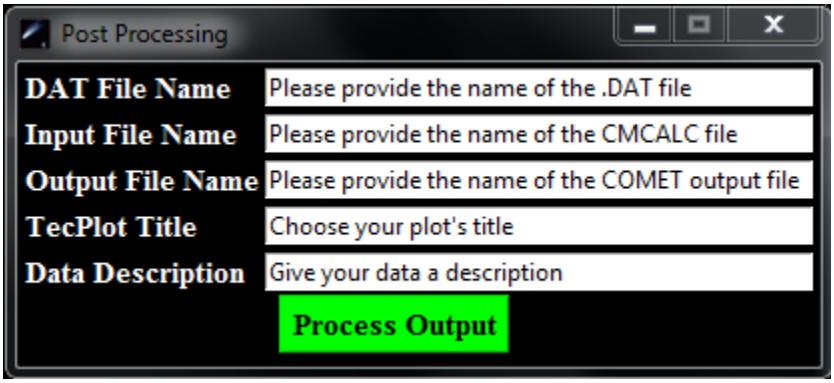

Figure 10. GUI output processing tool

Rotated Assemblies

In order to perform the COMET calculation, a database containing the response expansion coefficients must be generated. However, these coefficients only need to be generated for each unique assembly, regardless of the assembly's orientation inside of the core. This allows the user to introduce rotated and flipped meshes into the COMET calculation without any additional computational cost. COMET allows the user to rotate any coarse mesh in 90 degree increments. COMET also allows the user to flip a coarse mesh over its anti-diagonal. An example showing how COMET performs the rotation is

shown in Figure 11. Similarly, an example illustrating the way COMET flips an assembly is shown in Figure 12.

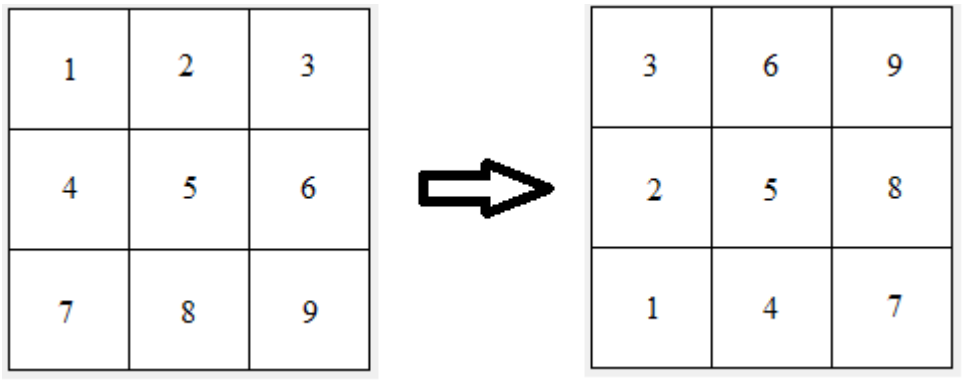

Figure 11. Simple grid illustrating COMET's interpretation of a 90 degree rotation

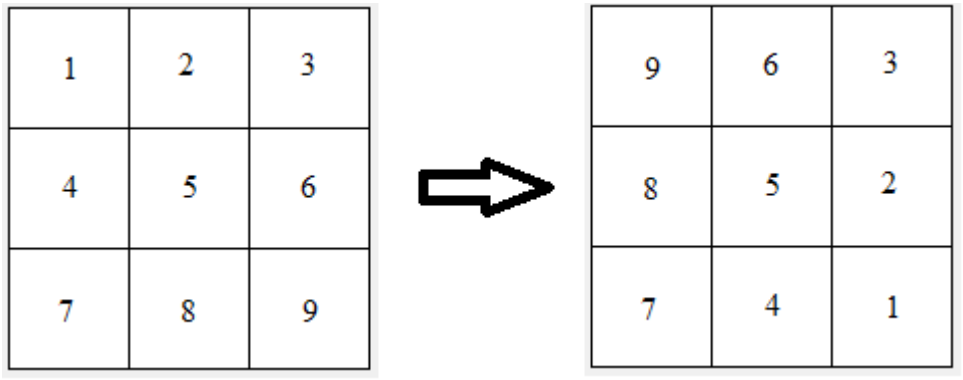

Figure 12. Simple grid illustrating COMET's interpretation of a flip

If the user chooses to use rotated or flipped assemblies, COMET will perform the calculation correctly, but will misleadingly print the results as if no rotation or flip had occurred. Clearly, this is not an ideal situation, even for a veteran COMET user. To combat this issue, the GUI uses the COMET "DAT" file as well as the COMET "CMCALC" file to locate any rotated or flipped assemblies and performs the necessary rearrangements to the raw COMET output.

Formatted TecPlot Output File

After the GUI's post-processing, any necessary flips or rotations have been performed and the pin fission densities are expressed with a Cartesian coordinate system. At this point, the only thing left to do with the processed COMET output is to write it to a file. Currently, the GUI will write the reformatted COMET output to a TecPlot ".dat" file, complete with a title and description of the user's choosing. This choice of output formatting is not a restrictive one; in the future, it would be a relatively straight forward process to write the processed COMET output to any format the user desires. TecPlot was chosen for its robust functionality and extremely intuitive data format. Further, the TecPlot format isn't very restrictive; should the user desire to use a different plotting software, the output file could be adapted to many new formats with relative ease.

The GUI is capable of generating both full-core TecPlot ".dat" files as well as single coarse mesh level files. This allows the user direct access to the pin fission densities in any assembly within any axial zone. Each of these assembly level files is written to its own unique Cartesian grid, so that the output doesn't require any of the flips or rotations performed on individual meshes in the full-core file.

Formatted COMET Output Visualization Example

In order to show that the GUI correctly processes the COMET output file, the GUI was used to process the output file generated by Daniel Lago[†] for the EPR benchmark[9]. Due to the extreme size of the COMET output file, it is not recreated here. Instead, a few images produced using the TecPlot files generated by the GUI are shown in Figure 13, Figure 14, and Figure 15. The images presented here have been generated using preliminary results of the EPR analysis. As such, the images are only intended to

---

[†] Daniel Lago is a PhD student in the Computational Reactor and Medical Physics (CRMP) Laboratory at the Georgia Institute of Technology.

demonstrate that the COMET output is being formatted correctly. Figure 13 shows the normalized fission density at each pin in the entire core. Figure 14 shows the relative pin fission densities from a top-down view of the core. Since Figure 13 shows the fission density at every pin at nineteen different axial locations, the individual data points smear together, losing the appearance of individual points. Figure 15 is presented to confirm the individual representation of each pin fission density inside any assembly. By displaying the pin fission densities at the midpoint of the core's centermost assembly, Figure 15 also demonstrates the correct symmetry expected of the centermost point of the core.

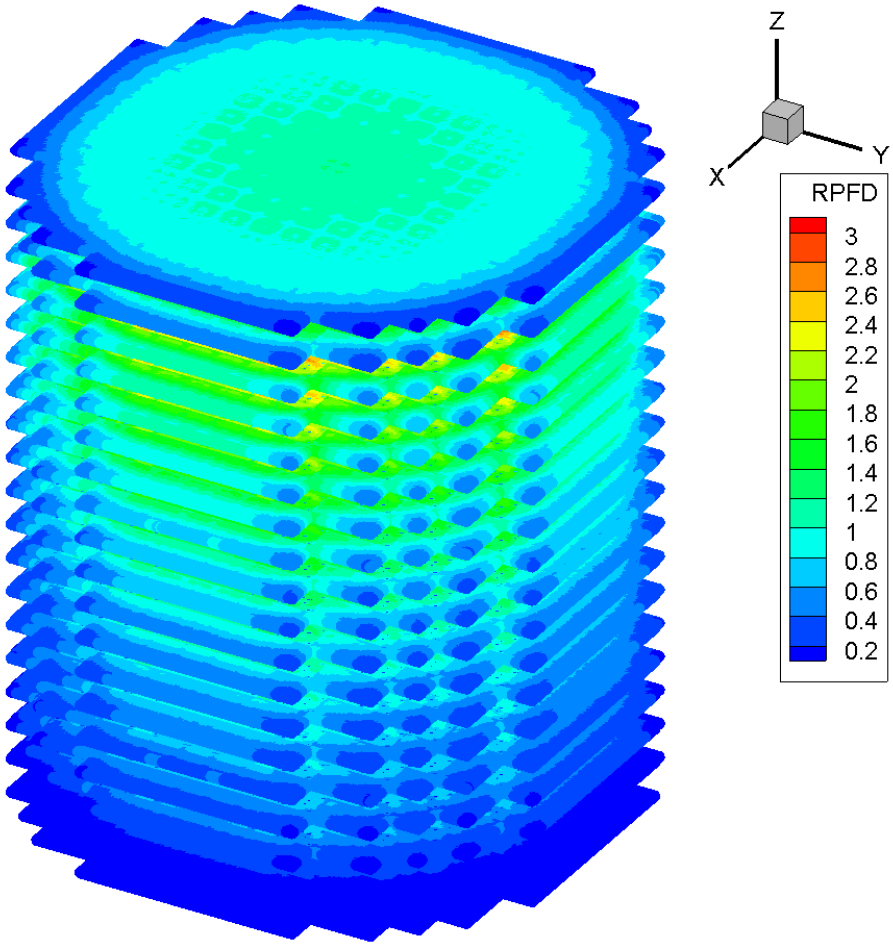

Figure 13. 3-D TecPlot graph of the normalized pin fission densities of the entire EPR core

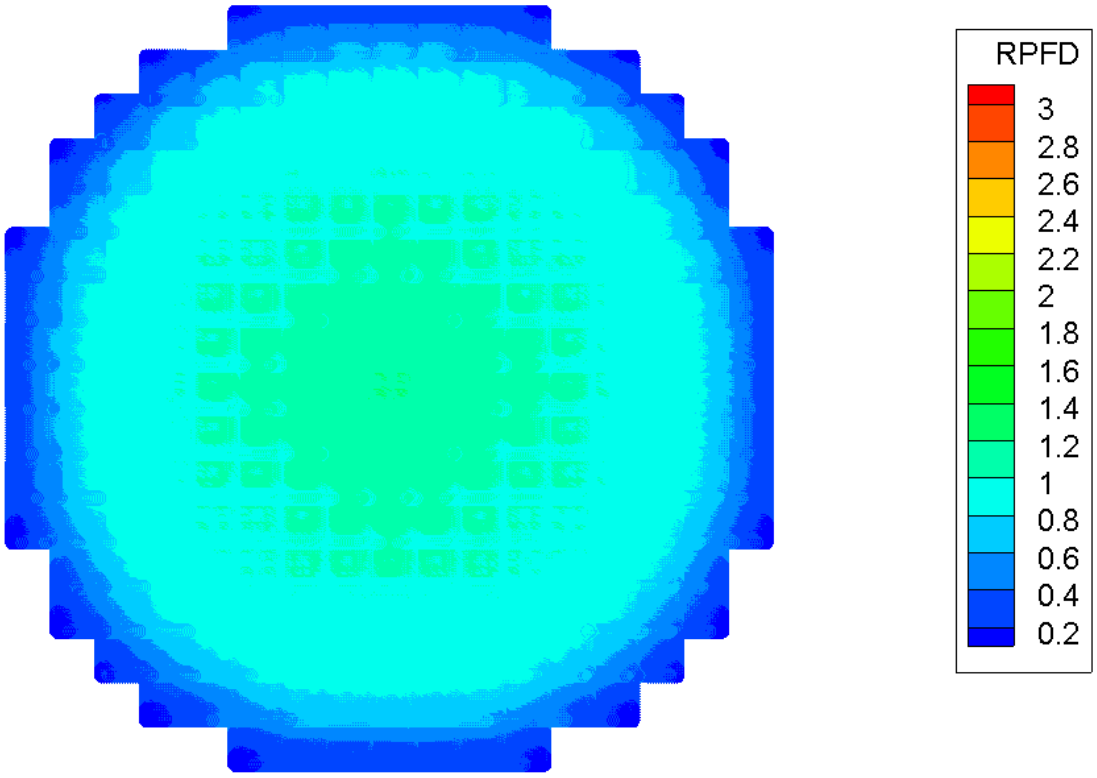

Figure 14. Top-down TecPlot graph of the normalized pin fission densities of the EPR core

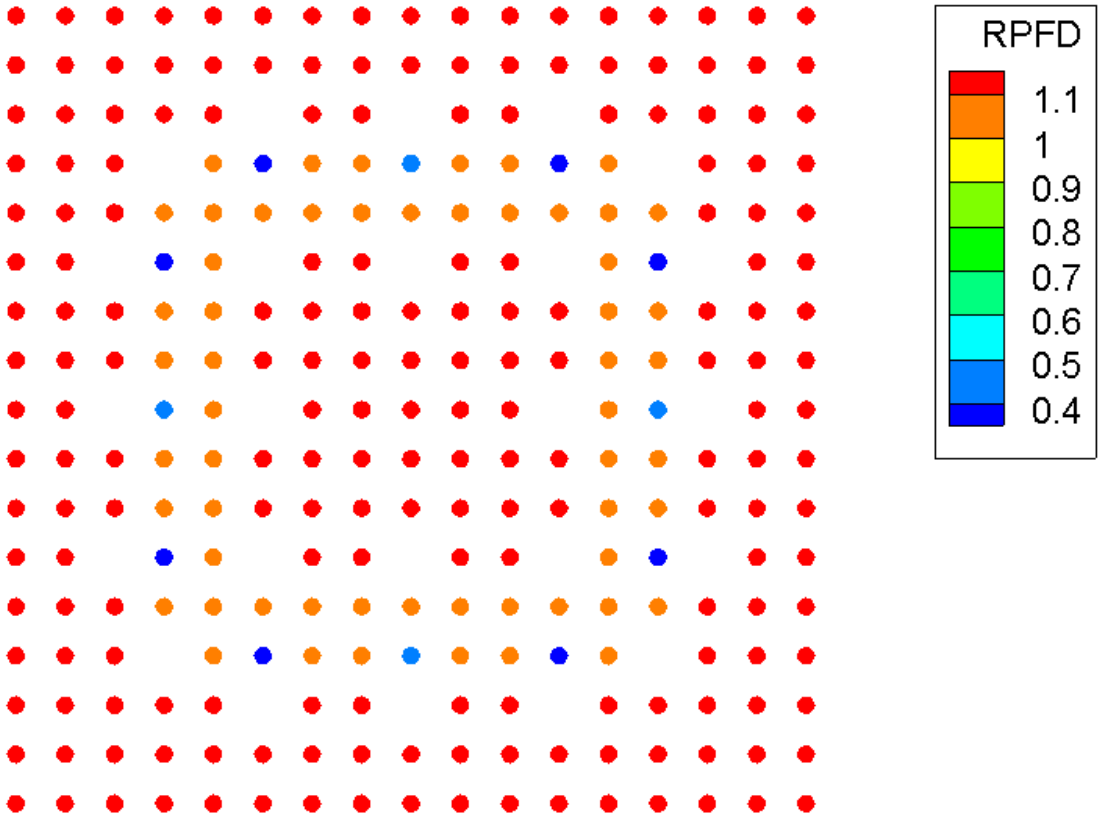

Figure 15. 2-D TecPlot graph of the normalized pin fission densities at the midpoint of the centermost assembly in the EPR core

CHAPTER 4

MHTGR BENCHMARK DESCRIPTION

The MHTGR benchmark is based on a 350 MW(t) design that utilizes prismatic hexagonal-block fuel assemblies. The fuel assemblies are arranged in an annular fashion inside the reactor core. This fuel ring is surrounded inside and out by hexagonal graphite reflector blocks. The MHTGR reactor core configuration is shown in Figure 16 (taken from reference 7).

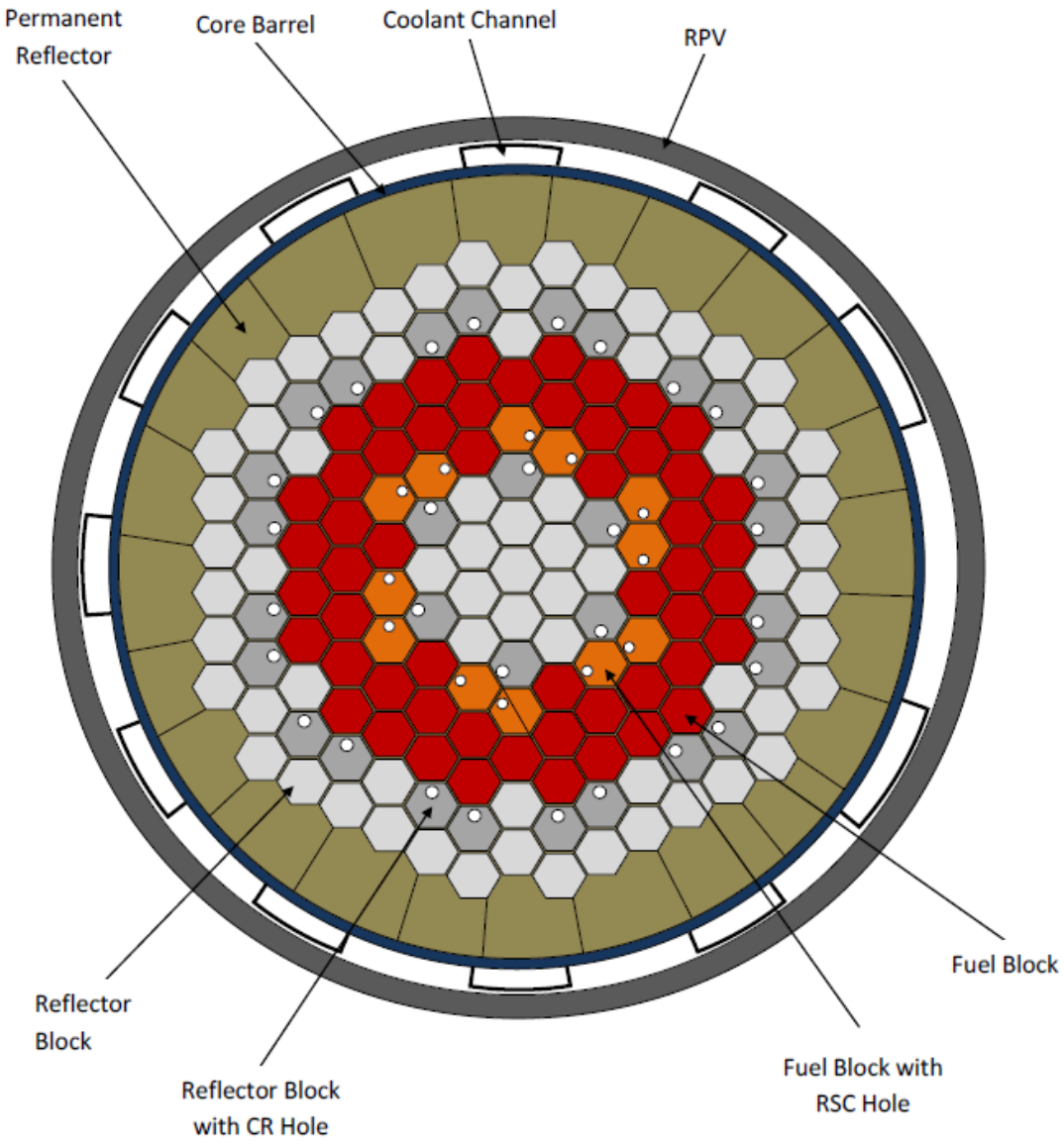

Figure 16. MHTGR plane view of reactor layout

Each fuel assembly consists of a hexagonal graphite matrix with holes for the helium coolant, fuel compacts, and burnable poison. The fuel compacts are composed of Tristructural-Isotropic (TRISO) fuel particles bonded in a cylindrical graphite matrix with an average packing fraction of 0.350. The TRISO fuel is composed of a fuel kernel, porous carbon layer, inner pyrolitic carbon layer, silicon carbide layer, and an outer

pyrolitic carbon layer. The fuel particles are enriched to an average of 15.5% U-235. Every fuel assembly contains burnable poison compacts placed at the six vertices of the block. The burnable poison compacts are composed of boron carbide (B4C) granules dispersed in graphite. The volume homogenized material compositions are given in Appendix E. A full description of the MHTGR benchmark problem is given in reference 7.

CHAPTER 5

CROSS SECTION LIBRARY GENERATION

The multi-group cross section libraries were generated using the lattice depletion code HELIOS. The condensed six-group libraries were generated in 100° C increments between 385° C and 1085° C (the libraries are identified by the temperature of the fuel). The six-group energy bounds are given in Table 1. In all of the models investigated, for every temperature point, all materials are assumed to be at the same temperature except for the fuel; the fuel is always taken to be 85° C hotter than all other materials. Further, the flat flux regions for each model were chosen such that further mesh refinement effected no change in the eigenvalue.

TABLE 1. Condensed six-group energy bounds

Group	Upper Energy Bound (eV)
1	2.0×10^{7}
2	1.8316×10^{5}
3	961.12
4	2.3824
5	0.62506
6	0.11157

One-Sixth Fuel Assembly Lattice

In some reactor applications, cross section libraries may be generated by modeling a single fuel assembly, or some fraction thereof, with appropriately chosen boundary conditions. For the MHTGR in question, the hexagonal fuel blocks are symmetric; as such, modeling an entire assembly with specular boundary conditions is equivalent to modeling only one-sixth of the assembly with the same specular boundary conditions. The HELIOS model of a one-sixth fuel assembly is shown in Figure 17.

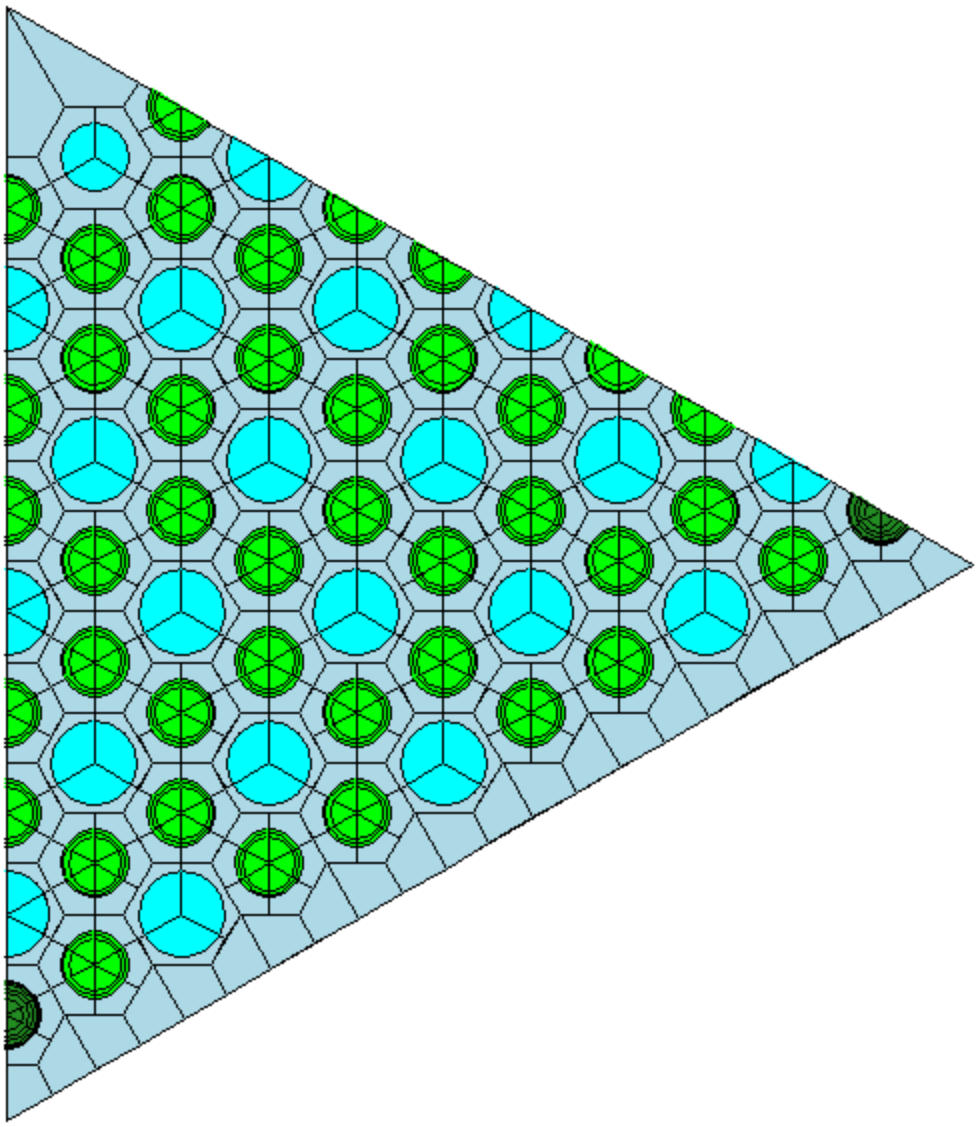

Figure 17. HELIOS model of a 1/6th fuel assembly

This one-sixth assembly model is attractive because of its simplicity; only modeling a fraction of a fuel block is relatively straightforward and requires minimal memory and runtime. Unfortunately, this simplistic model fails to capture the true physics of the situation in the MHTGR core. Without the addition of more reflector material to the model, the one-sixth assembly model is highly under-moderated. The lack of additional graphite moderator leads to an inaccurate estimate of the eigenvalue and

energy spectrum; the inaccurate estimation of these quantities leads to a very poor set of collapsed cross section libraries.

In order to demonstrate that the one-sixth fuel block is under-moderated, two additional models were investigated. Each of the models has the same geometry as the original one-sixth fuel block, but has a material arrangement that is different from the original model. In the first model, shown in Figure 18, the graphite moderator was replaced with the nearly neutron-transparent helium. In the second model, shown in Figure 19, the helium was replaced with additional graphite moderator.

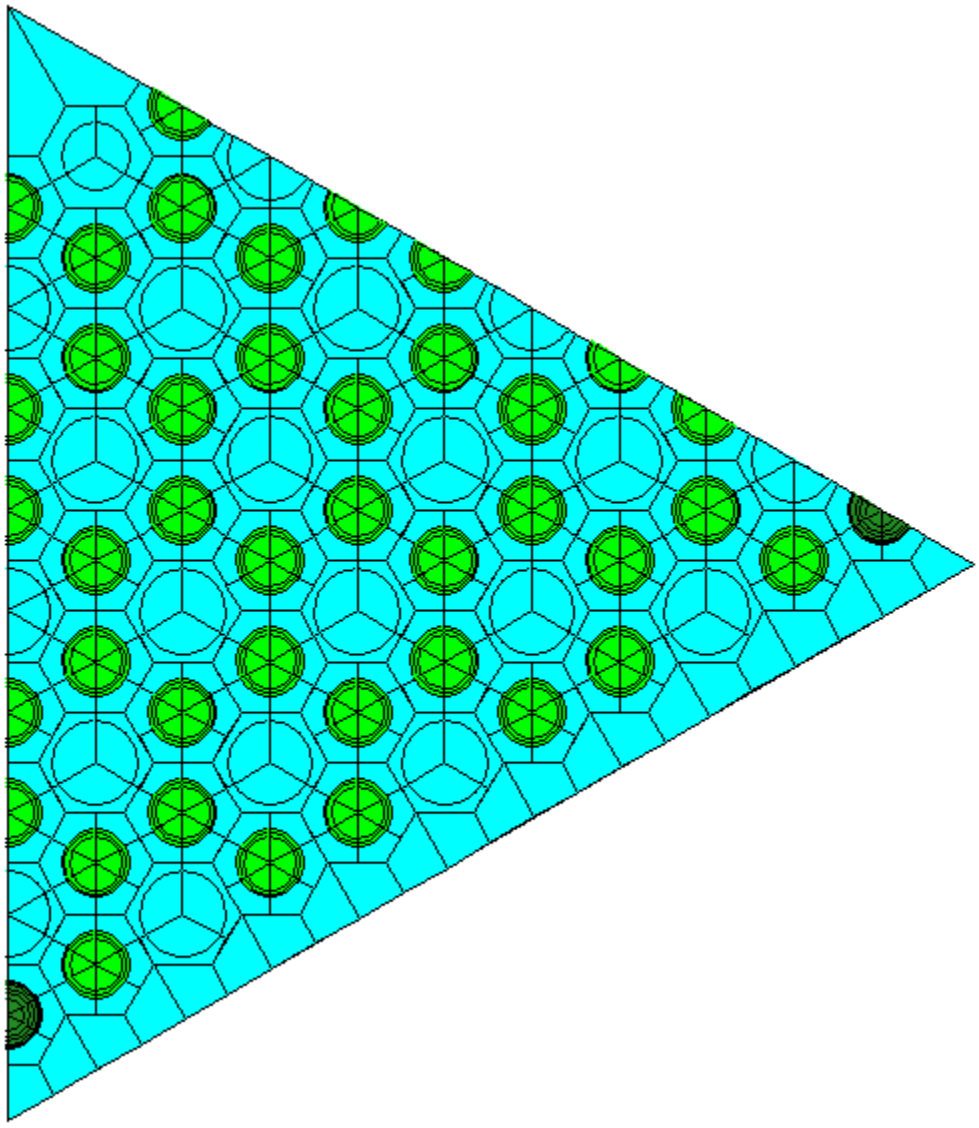

Figure 18. HELIOS model of a 1/6th fuel assembly with graphite removed

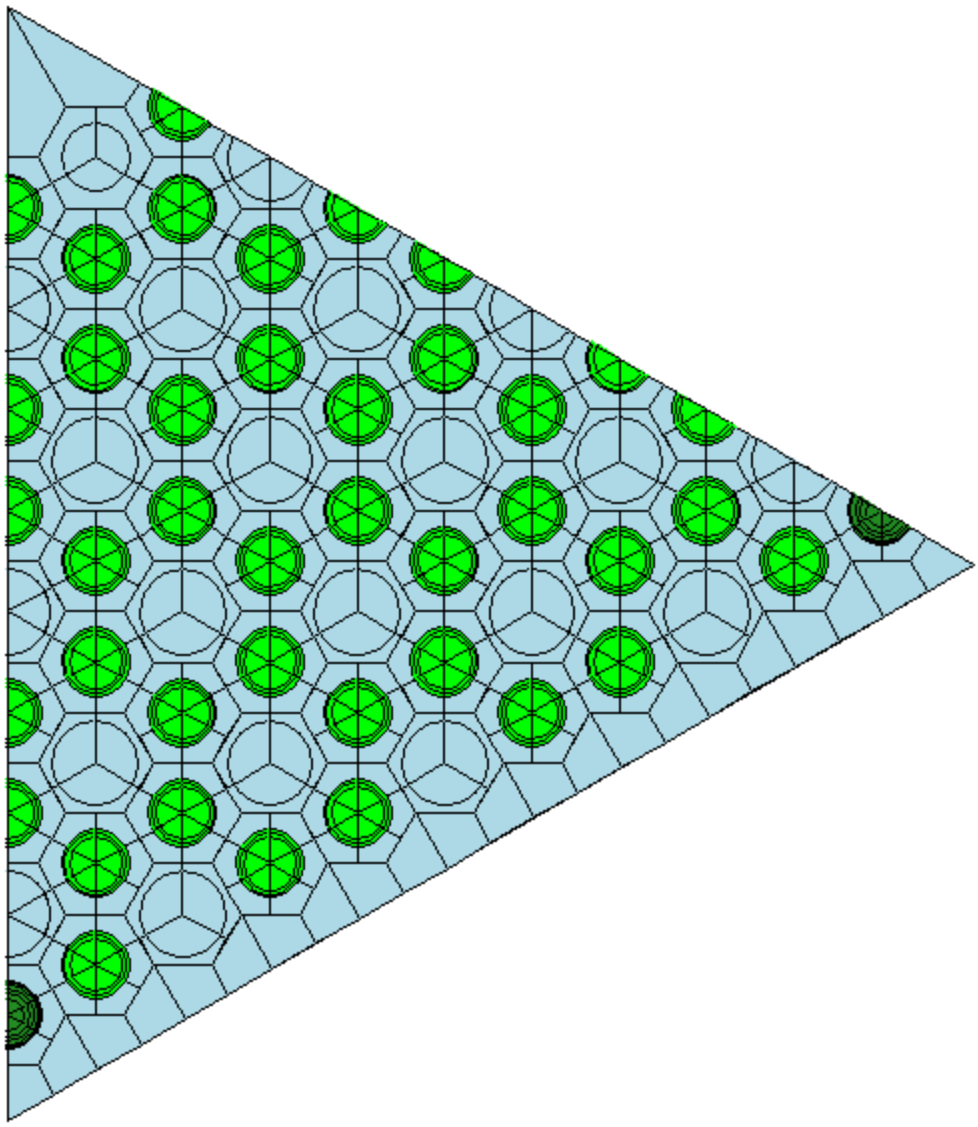

Figure 19. HELIOS model of a 1/6th fuel assembly with additional graphite

As expected, with the moderator removed, the effect of the under-moderation is even more pronounced, leading to a stark decrease in the eigenvalue. In the second model, the increase in graphite, and thus neutron moderation, causes an increase in the eigenvalue. The eigenvalues of the three different models at the temperature points between 385° C and 1085° C are presented in Table 2. The drastic effect of the graphite on the system's eigenvalue reveals that the spectrum is driven by the neighboring graphite moderator. With this realization, the one-sixth fuel block model was abandoned in search

of a more suitable model.

TABLE 2. Eigenvalue estimate for the original 1/6th model, the no graphite model, and the increased graphite model at temperature points between 385° C and 1085° C

Fuel Temperature	Non-fuel Temperature	Original	No graphite	Increased Graphite
385° C	300° C	1.03113	0.84331	1.10188
485° C	400° C	1.01887	0.83661	1.08921
585° C	500° C	1.00819	0.83062	1.07808
685° C	600° C	0.99854	0.82505	1.06804
785° C	700° C	0.98951	0.81983	1.05873
885° C	800° C	0.98142	0.81506	1.05040
985° C	900° C	0.97386	0.81054	1.04264
1085° C	1000° C	0.96616	0.80619	1.03470

Full Fuel Assembly with Partial Graphite Reflector Lattice

Since the one-sixth fuel assembly model was severely under-moderated, it proved to be a poor choice for cross section generation. To better account for the effect of the graphite moderator on the flux distribution, a larger HELIOS model was created to incorporate partial graphite moderator blocks. This model consists of a full fuel block neighboring two one-third graphite blocks. The HELIOS model depicting this configuration is shown in Figure 20.

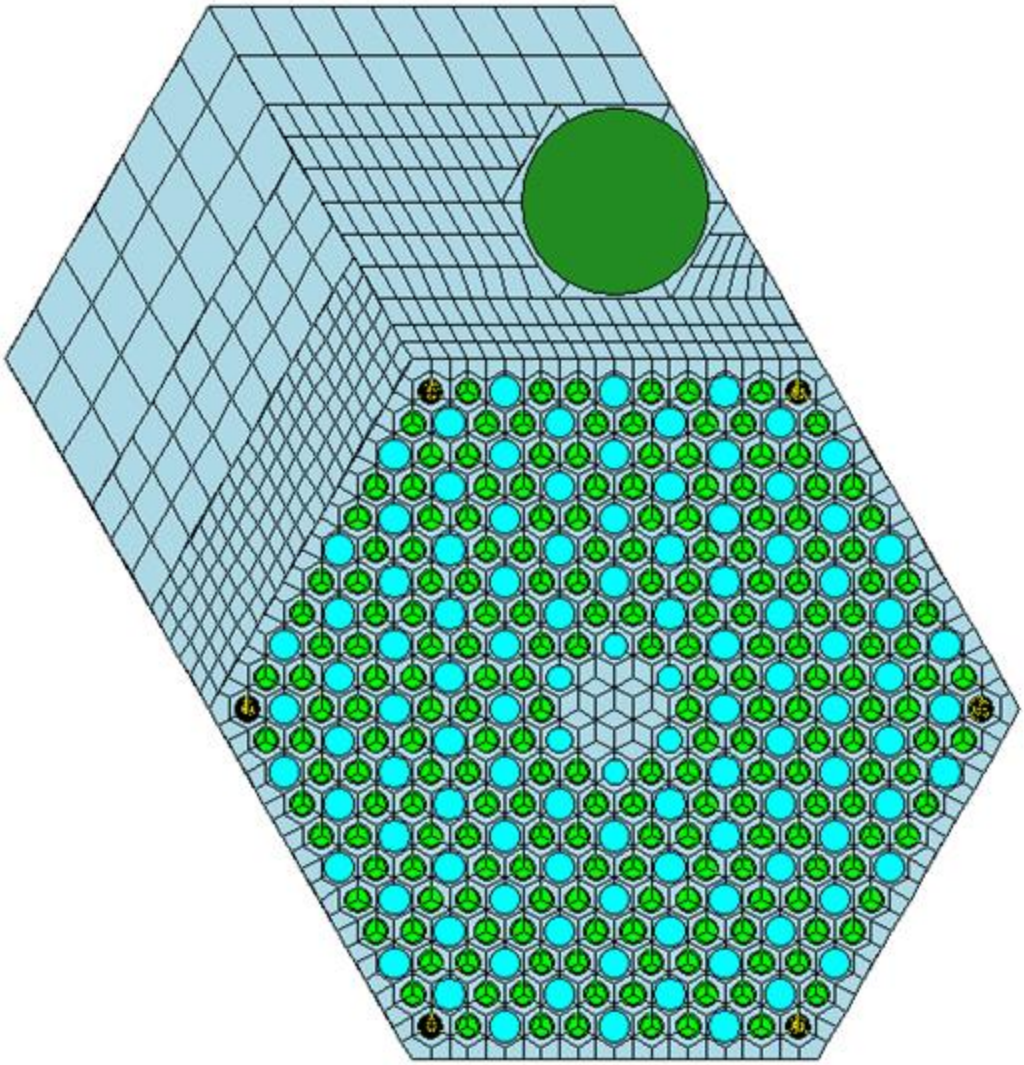

Figure 20. HELIOS model of a full fuel assembly neighboring two 1/3rd reflector blocks

While this model does a better job of capturing the effect of the graphite moderator on the flux distribution, the model's size and mesh requirements demanded the six group condensed cross sections be generated using the HELIOS 47 group library instead of the 190 group library. However, not all of the six group energy bounds are available in the 47 group library. As such, this model was also abandoned, but still provided insight into what an acceptable final lattice model should be. The eigenvalues of this model at temperature points between 385° C and 1085° C are presented in Table 3.

TABLE 3. Eigenvalue estimate for the full fuel assembly neighboring two 1/3rd reflector blocks model at the temperature points between 385° C and 1085° C

Fuel Temperature	Non-fuel Temperature	Eigenvalue
385° C	300° C	1.13266
485° C	400° C	1.12194
585° C	500° C	1.11262
685° C	600° C	1.10430
785° C	700° C	1.09668
885° C	800° C	1.08955
985° C	900° C	1.08313
1085° C	1000° C	1.07664

One-Half Fuel Assembly with One-Sixth Graphite Reflector Lattice

The large model presented in the previous section failed to meet the needs of the benchmark's energy bound requirements. However, the addition of the two partial graphite moderator blocks did indeed provide a more accurate representation of the flux spectrum in the reactor core. Hence, we have taken a subset of the previous problem to use in our lattice calculation. The final model consists of a 1/2 fuel assembly neighboring 1/6th of a graphite block. The HELIOS model of the 1/2 fuel assembly coupled with a 1/6th reflector block is shown in Figure 21.

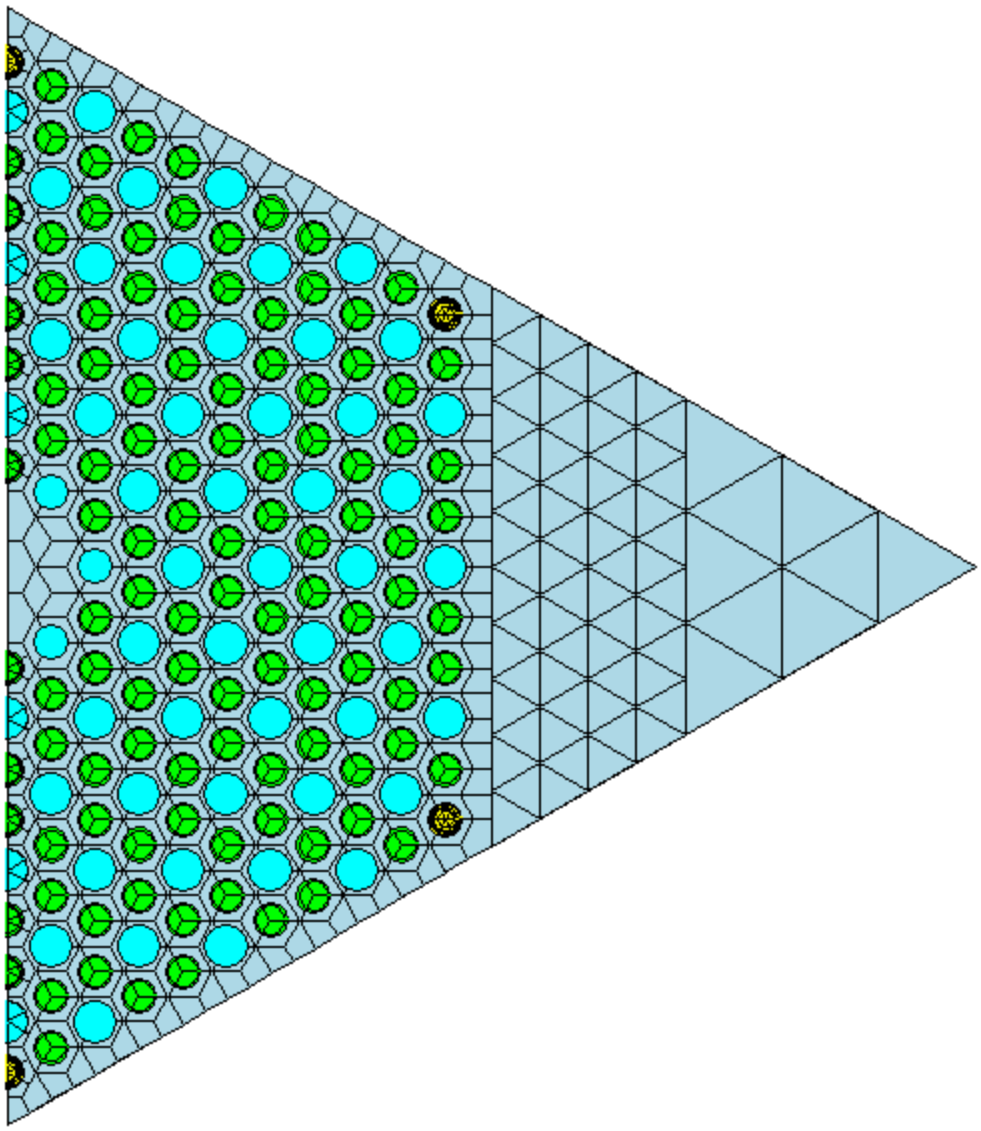

Figure 21. HELIOS model of 1/2 fuel assembly coupled with a 1/6th reflector block

As seen in Figure 21, the model uses the graphite reflector that does not have a control rod channel. The solid graphite block was chosen over the graphite control block in order to maximize the amount of moderating material in the model. The eigenvalues of this model at temperature points between 385° C and 1085° C are presented in Table 4.

TABLE 4. Eigenvalue estimate for the 1/2 fuel assembly coupled with a 1/6th reflector block model at the temperature points between 385° C and 1085° C

Fuel Temperature	Non-fuel Temperature	Eigenvalue
385° C	300° C	1.11357
485° C	400° C	1.10249
585° C	500° C	1.09278
685° C	600° C	1.08410
785° C	700° C	1.07605
885° C	800° C	1.06887
985° C	900° C	1.06213
1085° C	1000° C	1.05525

By comparing Table 2 and Table 4, we see that our last model has resolved the issue of under-moderation, as evidenced by the correspondingly higher value of the eigenvalue. By comparing Table 3 and Table 4, we see that the new model is still slightly under-moderated. However, the last model is superior to its predecessor because it allows generation of meaningful condensed six-group cross sections; the reduction in size allowed for the fine group calculation to be carried out using the HELIOS 190 group library.

The model presented in Figure 21 was used to generate the six-group cross section libraries for the fuel, moderator, coolant, and burnable absorber material. In order to generate cross sections for the control material, the model in Figure 21 was adapted to include a control rod. The HELIOS model used to generate the control material cross sections is shown in Figure 22. The eigenvalues of the control model at temperature points between 385° C and 1085° C are presented in Table 5.

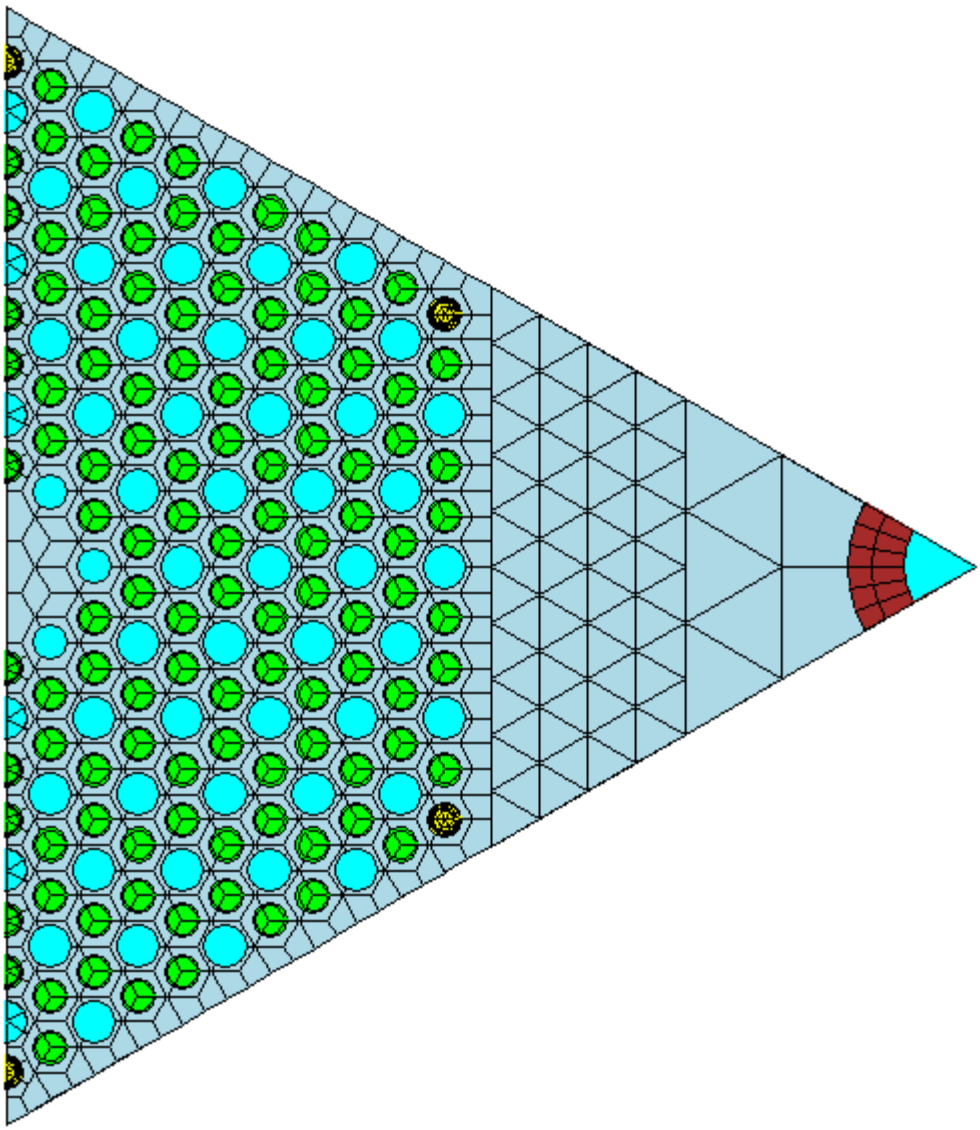

Figure 22. HELIOS model used to generate control material cross sections

TABLE 5. Eigenvalue estimate for the 1/2 fuel assembly coupled with a 1/6th control rod reflector block model at the temperature points between 385° C and 1085° C

Fuel Temperature	Non-fuel Temperature	Eigenvalue
385° C	300° C	0.85541
485° C	400° C	0.84513
585° C	500° C	0.83628
685° C	600° C	0.82837
785° C	700° C	0.82103
885° C	800° C	0.81441
985° C	900° C	0.80817
1085° C	1000° C	0.80166

The condensed six group cross section libraries can be found in Appendices F-M. Lastly, in the MHTGR design, helium is used as the coolant. However, HELIOS does not provide cross section data for He-4. In lieu of helium, very sparse nitrogen was used instead (modeled with a number density of 1E-10 atoms/barn-cm). Hence, the coolant cross sections in the appendices are presented for completeness only.

Coupled Neutron Transport and Thermal Fluids Solution

The cross section libraries developed in this thesis were used by Dr. Kevin Connolly[‡] and Alex Huning[§] to perform coupled neutronics and thermal fluids calculations for the MHTGR design[10]. The solution is obtained by iterating between the COMET solution and the hydraulics code. The first iteration of the COMET solution was obtained by assuming a temperature distribution and solving for the pin fission densities using the corresponding cross section libraries. The converged COMET solution was then used by the hydraulics code to determine a heat generation rate and update the core temperatures. Using the updated core temperature distribution, the cross section values are updated from the appropriate libraries and a new COMET solution was obtained. This iterative process between the two codes continued until the solution was sufficiently converged. The model used in determining the coupled solution is shown in Figure 23.

[‡] Dr. Kevin Connolly is a Postdoctoral Fellow in the Computational Reactor and Medical Physics (CRMP) Laboratory at the Georgia Institute of Technology.
[§] Alex Huning is a PhD student in the Computational Reactor and Medical Physics (CRMP) Laboratory at the Georgia Institute of Technology.

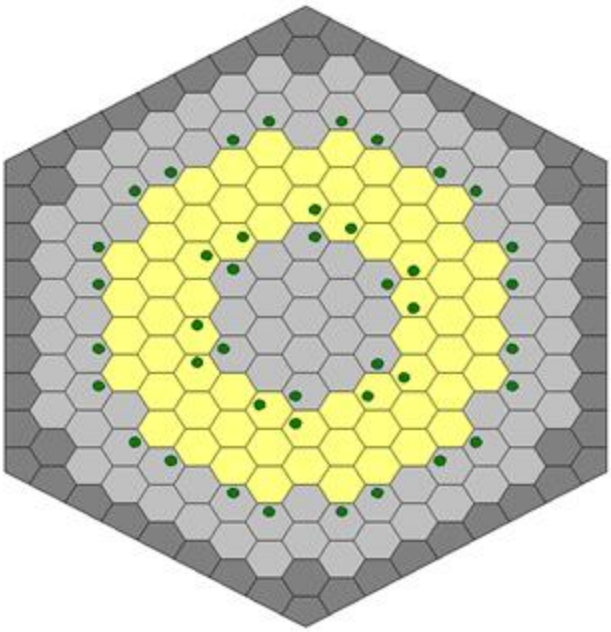

Figure 23. Full core model used to find the coupled transport and thermal fluids solution

The core eigenvalue was determined to be 0.9647092. While the cross sections used in the calculation yield a subcritical uncontrolled core, there are several other factors to consider before simply declaring the lattice model invalid. The two largest error sources on the core eigenvalue come from the homogenization of the TRISO particle fuel and the cross section interpolation between temperature points.

The largest contribution to the core's subcritical state is the homogenization of the TRISO fuel particles. This is a well-known effect, and has been shown to contribute to an underestimate of k_{eff} on the order of 10%[11]. The homogenization is based solely on the fuel particle's constituents, and as such, the scheme largely ignores the self-shielding effect of the heterogeneous material. Thus, the homogenization is unlikely to preserve the correct reaction rate in the fuel particles.

Further, in the full core model, the material temperatures did not conveniently coincide with the cross section library temperature points. In order to obtain values for the cross sections at intermediate temperature points, a linear interpolation between the two nearest libraries was used to estimate the cross sections. Due to the large temperature

steps between cross section libraries, the linear interpolation may not be valid over some or all of the intermediate ranges.

CHAPTER 6

CONCLUSION

In this thesis, we have presented a GUI that drastically improves the COMET user experience. The GUI presented greatly decreases pre-computational complexity by guiding the user through the creation of all COMET input files. The GUI also prevents the user from selecting invalid options through selective input field presentation and automatic input generation whenever possible. The GUI further prevents input errors by providing the user with a visualization of any coarse mesh layout. The GUI was also shown to make manual user output manipulation obsolete by providing a tool that processes the raw COMET output to generate a TecPlot ".dat" file.

In addition, we have also justified a suitable lattice model to generate cross section libraries for the MHTGR benchmark. These multi-group cross section libraries were generated at several temperature points over the designed operating range of the reactor using the lattice depletion code HELIOS. In addition to the cross section libraries, we have provided the material compositions and group energy bounds, allowing others to generate cross section libraries using a model and software of their choosing.

APPENDIX A

EXAMPLE COMET "DAT" FILE

```
FB1 FUEL

RF TEMPLATE "FB1.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   15.24 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

FB2 FUEL

RF TEMPLATE "FB2.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   20.32 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
```

```
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CBA FUEL

RF TEMPLATE "CBA.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   15.24 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CBB FUEL

RF TEMPLATE "CBB.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   15.24 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
```

```
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CBC FUEL

RF TEMPLATE "CBC.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   15.24 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CA1 FUEL

RF TEMPLATE "CA1.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
```

```
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CA2 FUEL

RF TEMPLATE "CA2.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CB1 FUEL

RF TEMPLATE "CB1.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
```

```
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CB2 FUEL

RF TEMPLATE "CB2.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CC1 FUEL

RF TEMPLATE "CC1.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
```

```
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CC2 FUEL

RF TEMPLATE "CC2.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

CC3 FUEL

RF TEMPLATE "CC3.TMP"

PPR    17  /
FUEL TYPE 1  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    265

CELL
249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265
232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
218 219 220 221 222   0 223 224   0 225 226   0 227 228 229 230 231
203 204 205   0 206 207 208 209 210 211 212 213 214   0 215 216 217
186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
174 175   0 176 177   0 178 179   0 180 181   0 182 183   0 184 185
157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
127 128   0 129 130   0 131 132 133 134 135   0 136 137   0 138 139
110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
 93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
 81  82   0  83  84   0  85  86   0  87  88   0  89  90   0  91  92
 64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80
 49  50  51   0  52  53  54  55  56  57  58  59  60   0  61  62  63
 35  36  37  38  39   0  40  41   0  42  43   0  44  45  46  47  48
```

```
 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17

MF1 ASSEMBLY

RF TEMPLATE "MF1.TMP"

PPR    0  /
FUEL TYPE 0  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   15.24 /
SYMMETRY    HALF
NROD    0

MF2 ASSEMBLY

RF TEMPLATE "MF2.TMP"

PPR    0  /
FUEL TYPE 0  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   20.32 /
SYMMETRY    HALF
NROD    0

MCE ASSEMBLY

RF TEMPLATE "MCE.TMP"

PPR    0  /
FUEL TYPE 0  /
LENGTHX   21.40204 /
LENGTHY   21.40204 /
LENGTHZ   23.5973 /
SYMMETRY    HALF
NROD    0
```

APPENDIX B

EXAMPLE COMET "GENRF" FILES

```
CALCTYPE EIGEN
REACTOR PWR
FUNCTION GENRF
DIMENSION 3D
MAW Y
FLUXEXP Y

ANGULAR APPROXIMATION     DPN
DATAFILE "EPR.DAT"

XORD          4 /
YORD          4 /
UORD          2 /
PORD          2 /
EORD          0 /

REDXY 4 /
REDMUPHI 2 /
REDXYMUPHI 0 /


CELL TYPES 9 FB1 FB2 CBA CBB CBC CA1 CA2 CB1 CB2

NPS         30000000 /

#CPU         16 /

ENERGY STRUCTURE
1.0000E-10  6.2506E-07  2.0000E+01  /

NG                       2      /
MS                       1      /
KGRID               0.95  1.0  1.05 /

DATABASE CREATION "RFDB"
RF LOCATION        "RFS"
DATABASE TYPE      "new"
```

```
CALCTYPE EIGEN
REACTOR PWR
FUNCTION GENRF
DIMENSION 3D
MAW Y
FLUXEXP Y

ANGULAR APPROXIMATION     DPN
DATAFILE "EPR2.DAT"

XORD          4 /
YORD          4 /
UORD          2 /
PORD          2 /
EORD          0 /

REDXY 4 /
REDMUPHI 2 /
REDXYMUPHI 0 /


CELL TYPES 6 CC1 CC2 CC3 MF1 MF2 MCE

NPS         30000000 /

#CPU         16 /

ENERGY STRUCTURE
1.0000E-10  6.2506E-07  2.0000E+01  /

NG                       2      /
MS                       1      /
KGRID               0.95  1.0  1.05 /

DATABASE CREATION "RFDB"
RF LOCATION        "RFS"
DATABASE TYPE      "new"
```

APPENDIX C

EXAMPLE COMET "CREATEDB" FILES

```
CALCTYPE EIGEN
REACTOR PWR
FUNCTION CREATEDB
DIMENSION 3D
MAW Y
FLUXEXP Y

ANGULAR APPROXIMATION     DPN
DATAFILE "EPR1.DAT"

XORD          4 /
YORD          4 /
UORD          2 /
PORD          2 /
EORD          0 /

REDXY 4 /
REDMUPHI 2 /
REDXYMUPHI 0 /
CELL TYPES 9 FB1 FB2 CBA CBB CBC CA1 CA2 CB1 CB2
NPS         30000000 /
#CPU         16 /
ENERGY STRUCTURE
1.0000E-10  6.2506E-07  2.0000E+01  /
NG                       2      /
MS                       1      /
KGRID               0.95  1.0  1.05 /

DATABASE CREATION "RFDB"
RF LOCATION        "RFS"
DATABASE TYPE      "new"
```

```
CALCTYPE EIGEN
REACTOR PWR
FUNCTION CREATEDB
DIMENSION 3D
MAW Y
FLUXEXP Y

ANGULAR APPROXIMATION     DPN
DATAFILE "EPR2.DAT"

XORD          4 /
YORD          4 /
UORD          2 /
PORD          2 /
EORD          0 /

REDXY 4 /
REDMUPHI 2 /
REDXYMUPHI 0 /


CELL TYPES 6 CC1 CC2 CC3 MF1 MF2 MCE

NPS         30000000 /

#CPU         16 /

ENERGY STRUCTURE
1.0000E-10  6.2506E-07  2.0000E+01  /

NG                       2      /
MS                       1      /
KGRID               0.95  1.0  1.05 /

DATABASE CREATION "RFDB"
RF LOCATION        "RFS2"
DATABASE TYPE      "old"
```

APPENDIX D

EXAMPLE COMET "CMCALC" FILE

```
CALCTYPE EIGEN
REACTOR PWR
SYMMETRY NONE
function CMCALC
dimension 3d
MAW  Y

RF DATABASE  "RFDB.cdf"
KTYPE   ITER

XORD          4 /
YORD          4 /
UORD          2 /
PORD          2 /
EORD           0 /
KGUESS        1.00 /
accelerate    0 /

REDXY      4 /
REDMUPHI   2 /
REDXYMUPHI  0 /

NX    21 /
NY    21 /
NZ     19 /

COARSE MESHES  15 /
CM01 FB1
CM02 FB2
CM03 CBA
CM04 CBB
CM05 CBC
CM06 CA1
CM07 CA2
CM08 CB1
CM09 CB2
CM10 CC1
CM11 CC2
CM12 CC3
CM13 MF1
CM14 MF2
CM15 MCE

FUEL LAYOUT

ZPLANE00
0   0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0
0   0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
0   0 13 13 13 13 13  1  1  1  1  1  1  1 13 13 13 13 13  0  0
0   0 13 13 13  1  1  1  1  1  1  1  1  1  1  1 13 13 13  0  0
0  13 13 13  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13 13  0
0  13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13  0
13 13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
```

```
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13
13 13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13 13
 0 13 13  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13  0
 0 13 13 13  1  1  1  1  1  1  1  1  1  1  1  1  1 13 13 13  0
 0  0 13 13 13  1  1  1  1  1  1  1  1  1  1  1 13 13 13  0  0
 0  0 13 13 13 13 13  1  1  1  1  1  1  1 13 13 13 13 13  0  0
 0  0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
 0  0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0

ZPLANE01
 0  0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0
 0  0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
 0  0 13 13 13 13 13  3  3  3  3  3  3  3 13 13 13 13 13  0  0
 0  0 13 13 13  3  3  5  5  5  5  5  5  5  3  3 13 13 13  0  0
 0 13 13 13  3  5  5  5  4  4  5  4  4  5  5  5  3 13 13 13  0
 0 13 13  3  5  5  4  4  4  3  4  3  4  4  4  5  5  3 13 13  0
13 13 13  3  5  4  5  4  5  4  5  4  5  4  5  4  5  3 13 13 13
13 13  3  5  5  4  4  3  4  3  4  3  4  3  4  4  5  5  3 13 13
13 13  3  5  4  4  5  4  3  4  3  4  3  4  5  4  4  5  3 13 13
13 13  3  5  4  3  4  3  4  4  4  4  4  3  4  3  4  5  3 13 13
13 13  3  5  5  4  5  4  3  4  5  4  3  4  5  4  5  5  3 13 13
13 13  3  5  4  3  4  3  4  4  4  4  4  3  4  3  4  5  3 13 13
13 13  3  5  4  4  5  4  3  4  3  4  3  4  5  4  4  5  3 13 13
13 13  3  5  5  4  4  3  4  3  4  3  4  3  4  4  5  5  3 13 13
13 13 13  3  5  4  5  4  5  4  5  4  5  4  5  4  5  3 13 13 13
 0 13 13  3  5  5  4  4  4  3  4  3  4  4  4  5  5  3 13 13  0
 0 13 13 13  3  5  5  5  4  4  5  4  4  5  5  5  3 13 13 13  0
 0  0 13 13 13  3  3  5  5  5  5  5  5  5  3  3 13 13 13  0  0
 0  0 13 13 13 13 13  3  3  3  3  3  3  3 13 13 13 13 13  0  0
 0  0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
 0  0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0

ZPLANE02
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE03
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
```

```
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE04
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE05
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
```

```
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE06
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE07
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE08
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
```

```
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE09
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE10
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE11
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
```

```
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE12
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE13
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE14
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
```

```
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE15
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE16
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 11 12  9 12  9  6  8 11  8  6  9 12  9 12 11  6 15 15
15 15  6 11  9  7  9  6  9  8  8  8  9  6  9  7  9 11  6 15 15
15 15  6 10  9  8 12  9  6  9  6  9  6  9 12  8  9 10  6 15 15
15 15  6 10 12  8  9  7  9  6  9  6  9  7  9  8 12 10  6 15 15
15 15 15  6 11  8 12  9 12  9 12  9 12  9 12  8 11  6 15 15 15
 0 15 15  6 10 12  8  8  8  7  9  7  8  8  8 12 10  6 15 15  0
 0 15 15 15  6 10 11 12  9  9 12  9  9 12 11 10  6 15 15 15  0
 0  0 15 15 15  6  6 10 10 11 11 11 10 10  6  6 15 15 15  0  0
```

```
 0  0 15 15 15 15 15  6  6  6  6  6  6  6 15 15 15 15 15  0  0
 0  0  0  0 15 15 15 15 15 15 15 15 15 15 15 15 15 15  0  0  0  0
 0  0  0  0  0  0 15 15 15 15 15 15 15 15 15 15  0  0  0  0  0  0

ZPLANE17
 0  0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0
 0  0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
 0  0 13 13 13 13 13  3  3  3  3  3  3  3 13 13 13 13 13  0  0
 0  0 13 13 13  3  3  5  5  5  5  5  5  5  3  3 13 13 13  0  0
 0 13 13 13  3  5  5  5  4  4  5  4  4  5  5  5  3 13 13 13  0
 0 13 13  3  5  5  4  4  4  3  4  3  4  4  4  5  5  3 13 13  0
13 13 13  3  5  4  5  4  5  4  5  4  5  4  5  4  5  3 13 13 13
13 13  3  5  5  4  4  3  4  3  4  3  4  3  4  4  5  5  3 13 13
13 13  3  5  4  4  5  4  3  4  3  4  3  4  5  4  4  5  3 13 13
13 13  3  5  4  3  4  3  4  4  4  4  4  3  4  3  4  5  3 13 13
13 13  3  5  5  4  5  4  3  4  5  4  3  4  5  4  5  5  3 13 13
13 13  3  5  4  3  4  3  4  4  4  4  4  3  4  3  4  5  3 13 13
13 13  3  5  4  4  5  4  3  4  3  4  3  4  5  4  4  5  3 13 13
13 13  3  5  5  4  4  3  4  3  4  3  4  3  4  4  5  5  3 13 13
13 13 13  3  5  4  5  4  5  4  5  4  5  4  5  4  5  3 13 13 13
 0 13 13  3  5  5  4  4  4  3  4  3  4  4  4  5  5  3 13 13  0
 0 13 13 13  3  5  5  5  4  4  5  4  4  5  5  5  3 13 13 13  0
 0  0 13 13 13  3  3  5  5  5  5  5  5  5  3  3 13 13 13  0  0
 0  0 13 13 13 13 13  3  3  3  3  3  3  3 13 13 13 13 13  0  0
 0  0  0  0 13 13 13 13 13 13 13 13 13 13 13 13 13  0  0  0  0
 0  0  0  0  0  0 13 13 13 13 13 13 13 13 13  0  0  0  0  0  0

ZPLANE18
 0  0  0  0  0  0 14 14 14 14 14 14 14 14 14  0  0  0  0  0  0
 0  0  0  0 14 14 14 14 14 14 14 14 14 14 14 14 14  0  0  0  0
 0  0 14 14 14 14 14  2  2  2  2  2  2  2 14 14 14 14 14  0  0
 0  0 14 14 14  2  2  2  2  2  2  2  2  2  2  2 14 14 14  0  0
 0 14 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14 14  0
 0 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14  0
14 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14
14 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14 14
 0 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14  0
 0 14 14 14  2  2  2  2  2  2  2  2  2  2  2  2  2 14 14 14  0
 0  0 14 14 14  2  2  2  2  2  2  2  2  2  2  2 14 14 14  0  0
 0  0 14 14 14 14 14  2  2  2  2  2  2  2 14 14 14 14 14  0  0
 0  0  0  0 14 14 14 14 14 14 14 14 14 14 14 14 14  0  0  0  0
 0  0  0  0  0  0 14 14 14 14 14 14 14 14 14  0  0  0  0  0  0

NORTH  ZERO
SOUTH  ZERO
EAST   ZERO
WEST   ZERO
TOP    ZERO
BOTTOM ZERO

PRINT 2
```

APPENDIX E

MATERIAL SPECIFICATIONS

Unless otherwise specified, natural isotopic abundance of the given element was used.

Material Number Densities (atoms/barn-cm)					
	Fuel	Coolant	Moderator	Burnable Absorber	Control
U-235	1.48E-04				
U-238	7.94E-04				
Si	2.80E-03				6.74E-04
O (in UO_2)	1.41E-03				
C	3.27E-03			7.72E-04	1.58E-04
Graphite	4.99E-02		8.72E-02	4.28E-02	1.68E-02
N-14		1.00E-10			
B			8.70E-08	3.09E-03	
B-10					8.06E-03
B-11					8.15E-04
Al-27					4.05E-04
O-16					9.14E-06
Ti					2.28E-04
Cr					1.18E-02
Mn-55					5.17E-04
Fe					2.27E-02
Ni					1.61E-02
Cu-63					2.24E-04

APPENDIX F

385° C CROSS SECTION LIBRARY

Each 6-group cross section library is presented in its own appendix in order of increasing temperature, with the label corresponding to the fuel temperature. The cross sections are presented in the following order:

$$\{\sigma_{cg}\}_{g=1}^{G}, \{\sigma_{fg}\}_{g=1}^{G}, \{\nu_g\}_{g=1}^{G}, \{X_g\}_{g=1}^{G}, \left\{\left\{\{\sigma_{sn}^{g'\to g}\}_{g'=1}^{G}\right\}_{g=1}^{G}\right\}_{n=0}^{N}$$

where G represents the number of energy groups (in all cases, G=6), N is the largest Legendre moment index of the scattering cross section (here, N=1), σ_{cg} is the group g capture cross section, σ_{fg} is the group g fission cross section, ν_g is the fission yield in group g, X_g represents the fission spectrum corresponding to group g, and $\sigma_{sn}^{g'\to g}$ is the n^{th} Legendre moment of the scattering cross section from group g' to g.

Fuel

4.2482E-04	1.2529E-03	1.7523E-02	8.2176E-03	3.0676E-02	6.7353E-02
3.1472E-04	4.8669E-04	4.2068E-03	6.1796E-03	2.5116E-02	5.6132E-02
2.6606E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5993E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0560E-02	2.6315E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9574E-08	7.1281E-03	2.7461E-01	4.0529E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.8990E-03	2.3900E-01	1.8840E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.7697E-02	2.5007E-01	2.3514E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.4398E-05	1.8693E-02	2.5664E-01
2.2526E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6945E-03	1.7759E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0852E-03	1.4157E-02	1.2847E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4218E-03	2.1424E-02	-1.7966E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-7.3465E-03	1.5422E-02	-5.0203E-03
0.0000E+00	0.0000E+00	0.0000E+00	-5.9439E-06	-4.0975E-03	8.7534E-03

Coolant

7.4426E-12	3.1804E-13	5.0945E-12	2.6874E-11	6.1431E-11	1.2690E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0347E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3140E-11	6.9367E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.2978E-11	9.7025E-10	1.4764E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6078E-11	8.8769E-10	6.8511E-12	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.0350E-10	8.8458E-10	1.2700E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.0800E-10	9.0263E-10
2.3307E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0556E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7451E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9645E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9412E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9073E-11

Moderator

4.6861E-07	6.1334E-07	1.0656E-05	5.3388E-05	1.2516E-04	2.6194E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2848E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6648E-02	3.9100E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1924E-02	3.9991E-01	4.9543E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.5898E-03	3.6283E-01	1.8771E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.4313E-02	3.7745E-01	2.5333E-02
0.0000E+00	0.0000E+00	0.0000E+00	4.0645E-05	2.9002E-02	3.9664E-01
2.9539E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6125E-03	2.7878E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5188E-03	2.2248E-02	1.8883E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5217E-03	3.4106E-02	-1.9754E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.1916E-02	2.4164E-02	-6.2390E-03
0.0000E+00	0.0000E+00	0.0000E+00	-9.3995E-06	-6.8596E-03	8.6211E-03

Burnable Absorber

3.7154E-04	4.0344E-03	6.3794E-02	3.4097E-01	7.7458E-01	1.5438E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2247E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0098E-03	2.0838E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1748E-03	2.1430E-01	2.8338E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6621E-03	1.9480E-01	1.4072E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.1988E-02	2.0238E-01	1.7035E-02
0.0000E+00	0.0000E+00	0.0000E+00	1.8012E-05	1.4023E-02	2.0695E-01
1.5849E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3204E-03	1.4676E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7038E-03	1.2043E-02	1.0113E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0111E-03	1.7544E-02	-1.2230E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.5544E-03	1.2499E-02	-3.4970E-03
0.0000E+00	0.0000E+00	0.0000E+00	-4.1958E-06	-2.9790E-03	7.8738E-03

Control

6.0531E-03	5.1900E-02	5.1601E-01	4.3884E+00	1.0076E+01	2.0475E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4799E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0510E-02	6.6340E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8363E-09	4.8834E-03	7.0770E-01	1.3418E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.8393E-04	6.6002E-01	5.7986E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.3260E-02	6.4949E-01	5.5096E-02
0.0000E+00	0.0000E+00	0.0000E+00	5.5297E-06	3.0849E-02	6.3774E-01
3.9885E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0580E-03	1.6874E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8473E-04	1.3170E-02	4.9930E-05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0348E-04	1.5600E-02	-5.2753E-05	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.7988E-03	1.3853E-02	-1.3721E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.2920E-06	-1.0849E-03	1.1971E-02

APPENDIX G

485° C CROSS SECTION LIBRARY

Fuel

4.2498E-04	1.2552E-03	1.7833E-02	8.2610E-03	3.0848E-02	6.8264E-02
3.1478E-04	4.8704E-04	4.2085E-03	6.2211E-03	2.5006E-02	5.5434E-02
2.6611E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5992E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0566E-02	2.6316E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9580E-08	7.1443E-03	2.7484E-01	5.2541E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9042E-03	2.3794E-01	2.3367E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.8313E-02	2.5052E-01	2.9161E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.6090E-05	1.8599E-02	2.5299E-01
2.2531E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6962E-03	1.7762E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0898E-03	1.4118E-02	1.4941E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4198E-03	2.1501E-02	-2.3576E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-7.3628E-03	1.5483E-02	-6.1035E-03
0.0000E+00	0.0000E+00	0.0000E+00	-6.7256E-06	-4.0315E-03	9.8939E-03

Coolant

7.4454E-12	3.1831E-13	5.0881E-12	2.6945E-11	6.1005E-11	1.2552E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0347E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3148E-11	6.9387E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3030E-11	9.7024E-10	1.8485E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6099E-11	8.8517E-10	8.3585E-12	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.0592E-10	8.8801E-10	1.5436E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.0437E-10	8.8092E-10
2.3313E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0561E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7451E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9853E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9248E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9178E-11

Moderator

4.6986E-07	6.1413E-07	1.0653E-05	5.3534E-05	1.2418E-04	2.5751E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2846E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6659E-02	3.9098E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1952E-02	3.9980E-01	6.5038E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.6131E-03	3.5821E-01	2.3562E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.4287E-02	3.7784E-01	3.3556E-02
0.0000E+00	0.0000E+00	0.0000E+00	4.4246E-05	2.9099E-02	3.9145E-01
2.9548E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6154E-03	2.7884E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5269E-03	2.2169E-02	2.2648E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5227E-03	3.4243E-02	-2.7286E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.1954E-02	2.4190E-02	-7.9613E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.0720E-05	-6.7755E-03	1.0809E-02

Burnable Absorber

3.7160E-04	4.0383E-03	6.3750E-02	3.4186E-01	7.6971E-01	1.5264E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2246E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0165E-03	2.0837E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1891E-03	2.1427E-01	3.7137E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6669E-03	1.9250E-01	1.7634E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2014E-02	2.0234E-01	2.1917E-02
0.0000E+00	0.0000E+00	0.0000E+00	1.9600E-05	1.3992E-02	2.0354E-01
1.5854E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3220E-03	1.4679E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7076E-03	1.2012E-02	1.2144E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0102E-03	1.7612E-02	-1.6903E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.5774E-03	1.2585E-02	-4.3943E-03
0.0000E+00	0.0000E+00	0.0000E+00	-4.7860E-06	-2.9486E-03	8.8138E-03

Control

6.0583E-03	5.1955E-02	5.1652E-01	4.4002E+00	1.0009E+01	2.0209E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4797E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0512E-02	6.6362E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8325E-09	4.8965E-03	7.0768E-01	1.6319E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.9121E-04	6.5791E-01	6.7362E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.4281E-02	6.4944E-01	6.7110E-02
0.0000E+00	0.0000E+00	0.0000E+00	6.0360E-06	3.0238E-02	6.2709E-01
3.9917E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0582E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8602E-04	1.3166E-02	5.9956E-05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0387E-04	1.5581E-02	-7.2877E-05	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.8143E-03	1.3903E-02	-1.7258E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.4759E-06	-1.0723E-03	1.2324E-02

APPENDIX H

585° C CROSS SECTION LIBRARY

Fuel

4.2505E-04	1.2566E-03	1.8109E-02	8.2847E-03	3.0685E-02	6.7621E-02
3.1481E-04	4.8718E-04	4.2089E-03	6.2469E-03	2.4870E-02	5.4886E-02
2.6613E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5991E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0569E-02	2.6317E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9583E-08	7.1505E-03	2.7507E-01	6.6547E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9098E-03	2.3805E-01	2.8447E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.9367E-02	2.5124E-01	3.4819E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.7670E-05	1.8421E-02	2.4947E-01
2.2533E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6968E-03	1.7763E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0916E-03	1.4080E-02	1.7099E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4172E-03	2.1560E-02	-2.9650E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-7.3599E-03	1.5570E-02	-7.1845E-03
0.0000E+00	0.0000E+00	0.0000E+00	-7.5609E-06	-3.9548E-03	1.0951E-02

Coolant

7.4467E-12	3.1841E-13	5.0799E-12	2.7005E-11	6.0494E-11	1.2445E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0346E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3151E-11	6.9395E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3050E-11	9.7023E-10	2.3811E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6123E-11	8.8218E-10	1.0039E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.0867E-10	8.9212E-10	1.7838E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.9813E-11	8.6240E-10
2.3315E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0563E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7452E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9945E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9188E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9003E-11

Moderator

4.7041E-07	6.1446E-07	1.0645E-05	5.3664E-05	1.2286E-04	2.5391E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2845E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6664E-02	3.9098E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1964E-02	3.9973E-01	8.6297E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.6371E-03	3.5711E-01	2.9847E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.5611E-02	3.7905E-01	4.2193E-02
0.0000E+00	0.0000E+00	0.0000E+00	4.7406E-05	2.8827E-02	3.8626E-01
2.9551E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6166E-03	2.7887E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5302E-03	2.2091E-02	2.6479E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5224E-03	3.4367E-02	-3.5832E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.1974E-02	2.4240E-02	-9.6963E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.2161E-05	-6.6374E-03	1.2821E-02

Burnable Absorber

3.7163E-04	4.0398E-03	6.3679E-02	3.4258E-01	7.6321E-01	1.5128E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2246E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0198E-03	2.0837E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1947E-03	2.1424E-01	4.9321E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6720E-03	1.9199E-01	2.1957E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2623E-02	2.0278E-01	2.6804E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.0990E-05	1.3848E-02	2.0030E-01
1.5856E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3229E-03	1.4681E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7091E-03	1.1982E-02	1.4224E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0088E-03	1.7668E-02	-2.1967E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.5857E-03	1.2683E-02	-5.2928E-03
0.0000E+00	0.0000E+00	0.0000E+00	-5.4177E-06	-2.9007E-03	9.6857E-03

Control

6.0608E-03	5.1982E-02	5.1675E-01	4.4081E+00	9.9191E+00	1.9996E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4796E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0513E-02	6.6373E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8306E-09	4.9030E-03	7.0767E-01	1.9519E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.9831E-04	6.5654E-01	7.6079E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.5461E-02	6.5039E-01	7.7697E-02
0.0000E+00	0.0000E+00	0.0000E+00	6.5376E-06	2.8884E-02	6.1789E-01
3.9933E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0583E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8667E-04	1.3163E-02	7.0372E-05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0416E-04	1.5578E-02	-9.4769E-05	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.8214E-03	1.3941E-02	-2.0811E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.6701E-06	-1.0518E-03	1.2649E-02

APPENDIX I

685° C CROSS SECTION LIBRARY

Fuel

4.2512E-04	1.2579E-03	1.8368E-02	8.3071E-03	3.0464E-02	6.7132E-02
3.1484E-04	4.8731E-04	4.2090E-03	6.2727E-03	2.4691E-02	5.4467E-02
2.6615E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5991E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0571E-02	2.6318E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9586E-08	7.1563E-03	2.7529E-01	8.0380E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9184E-03	2.3802E-01	3.4179E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.0552E-02	2.5192E-01	4.0427E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.9493E-05	1.8198E-02	2.4602E-01
2.2534E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6974E-03	1.7764E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0932E-03	1.4041E-02	1.9234E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4152E-03	2.1627E-02	-3.6399E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-7.3631E-03	1.5692E-02	-8.2608E-03
0.0000E+00	0.0000E+00	0.0000E+00	-8.4812E-06	-3.8721E-03	1.1938E-02

Coolant

7.4479E-12	3.1851E-13	5.0723E-12	2.7073E-11	5.9920E-11	1.2365E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0346E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3154E-11	6.9403E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3068E-11	9.7020E-10	2.9640E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6158E-11	8.7859E-10	1.2010E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.1197E-10	8.9602E-10	2.0064E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.5107E-11	8.4565E-10
2.3318E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0565E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7452E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9994E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9158E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8741E-11

Moderator

4.7091E-07	6.1477E-07	1.0638E-05	5.3821E-05	1.2143E-04	2.5119E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2845E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6668E-02	3.9097E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1974E-02	3.9967E-01	1.0926E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.6662E-03	3.5706E-01	3.7659E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.7692E-02	3.8041E-01	5.0894E-02
0.0000E+00	0.0000E+00	0.0000E+00	5.0810E-05	2.8456E-02	3.8115E-01
2.9555E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6177E-03	2.7889E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5332E-03	2.2013E-02	3.0241E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5231E-03	3.4516E-02	-4.5619E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.2019E-02	2.4364E-02	-1.1428E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.3785E-05	-6.4854E-03	1.4640E-02

Burnable Absorber

3.7166E-04	4.0412E-03	6.3614E-02	3.4342E-01	7.5577E-01	1.5025E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2245E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0228E-03	2.0837E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1999E-03	2.1423E-01	6.2588E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6796E-03	1.9203E-01	2.7087E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.3563E-02	2.0333E-01	3.1648E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.2468E-05	1.3661E-02	1.9715E-01
1.5858E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3236E-03	1.4682E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7106E-03	1.1952E-02	1.6286E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0078E-03	1.7732E-02	-2.7586E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.6020E-03	1.2807E-02	-6.1888E-03
0.0000E+00	0.0000E+00	0.0000E+00	-6.1189E-06	-2.8442E-03	1.0493E-02

Control

6.0632E-03	5.2007E-02	5.1697E-01	4.4167E+00	9.8179E+00	1.9832E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4795E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0513E-02	6.6382E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8289E-09	4.9088E-03	7.0766E-01	2.2807E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0059E-03	6.5527E-01	8.5994E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.6868E-02	6.5137E-01	8.7527E-02
0.0000E+00	0.0000E+00	0.0000E+00	7.0941E-06	2.7430E-02	6.0948E-01
3.9948E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0583E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8726E-04	1.3159E-02	8.0852E-05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0446E-04	1.5586E-02	-1.1894E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.8303E-03	1.3988E-02	-2.4359E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.8848E-06	-1.0287E-03	1.2942E-02

APPENDIX J

785° C CROSS SECTION LIBRARY

Fuel

4.2518E-04	1.2592E-03	1.8614E-02	8.3358E-03	3.0204E-02	6.6763E-02
3.1487E-04	4.8743E-04	4.2091E-03	6.3056E-03	2.4483E-02	5.4147E-02
2.6616E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5990E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0573E-02	2.6319E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9588E-08	7.1616E-03	2.7550E-01	9.3796E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9284E-03	2.3785E-01	4.0738E-03	5.1340E-09
0.0000E+00	0.0000E+00	0.0000E+00	3.1896E-02	2.5250E-01	4.5974E-02
0.0000E+00	0.0000E+00	0.0000E+00	3.1579E-05	1.7975E-02	2.4263E-01
2.2536E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6979E-03	1.7765E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0947E-03	1.4002E-02	2.1278E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4135E-03	2.1708E-02	-4.3832E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-7.3792E-03	1.5851E-02	-9.3318E-03
0.0000E+00	0.0000E+00	0.0000E+00	-9.5006E-06	-3.7916E-03	1.2867E-02

Coolant

7.4491E-12	3.1859E-13	5.0652E-12	2.7158E-11	5.9336E-11	1.2303E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0345E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3157E-11	6.9409E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3084E-11	9.7017E-10	3.5284E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6199E-11	8.7447E-10	1.4280E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.1581E-10	8.9909E-10	2.2237E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.0890E-11	8.2947E-10
2.3319E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0567E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7453E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0042E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9119E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8494E-11

Moderator

4.7138E-07	6.1504E-07	1.0631E-05	5.4022E-05	1.2002E-04	2.4915E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2844E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6672E-02	3.9097E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1983E-02	3.9959E-01	1.3136E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.6970E-03	3.5672E-01	4.6800E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0093E-02	3.8158E-01	5.9527E-02
0.0000E+00	0.0000E+00	0.0000E+00	5.4769E-05	2.8104E-02	3.7612E-01
2.9558E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6187E-03	2.7891E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5360E-03	2.1934E-02	3.3817E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5241E-03	3.4697E-02	-5.6595E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.2095E-02	2.4571E-02	-1.3152E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.5613E-05	-6.3409E-03	1.6306E-02

Burnable Absorber

3.7169E-04	4.0425E-03	6.3554E-02	3.4446E-01	7.4817E-01	1.4948E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2245E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0254E-03	2.0837E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.2047E-03	2.1421E-01	7.5506E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6880E-03	1.9195E-01	3.2920E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.4627E-02	2.0380E-01	3.6452E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.4155E-05	1.3475E-02	1.9406E-01
1.5860E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3242E-03	1.4683E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7118E-03	1.1921E-02	1.8279E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0070E-03	1.7807E-02	-3.3773E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.6288E-03	1.2962E-02	-7.0810E-03
0.0000E+00	0.0000E+00	0.0000E+00	-6.8966E-06	-2.7879E-03	1.1250E-02

Control

6.0655E-03	5.2029E-02	5.1717E-01	4.4270E+00	9.7157E+00	1.9705E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4794E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0514E-02	6.6391E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8273E-09	4.9142E-03	7.0765E-01	2.6048E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0137E-03	6.5386E-01	9.7704E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.8431E-02	6.5198E-01	9.7155E-02
0.0000E+00	0.0000E+00	0.0000E+00	7.7131E-06	2.6153E-02	6.0128E-01
3.9963E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0584E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8780E-04	1.3156E-02	9.1178E-05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0476E-04	1.5596E-02	-1.4544E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.8409E-03	1.4049E-02	-2.7895E-03
0.0000E+00	0.0000E+00	0.0000E+00	-2.1199E-06	-1.0060E-03	1.3212E-02

APPENDIX K

885° C CROSS SECTION LIBRARY

Fuel

4.2523E-04	1.2602E-03	1.8833E-02	8.3713E-03	2.9924E-02	6.6483E-02
3.1489E-04	4.8754E-04	4.2089E-03	6.3458E-03	2.4262E-02	5.3901E-02
2.6618E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5990E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0575E-02	2.6320E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9591E-08	7.1666E-03	2.7568E-01	1.0674E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9408E-03	2.3754E-01	4.8157E-03	1.8057E-07
0.0000E+00	0.0000E+00	0.0000E+00	3.3382E-02	2.5296E-01	5.1428E-02
0.0000E+00	0.0000E+00	0.0000E+00	3.4018E-05	1.7765E-02	2.3936E-01
2.2538E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6984E-03	1.7767E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0961E-03	1.3964E-02	2.3186E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4125E-03	2.1803E-02	-5.2209E-04	-1.2673E-07
0.0000E+00	0.0000E+00	0.0000E+00	-7.4077E-03	1.6048E-02	-1.0385E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.0703E-05	-3.7176E-03	1.3741E-02

Coolant

7.4502E-12	3.1867E-13	5.0590E-12	2.7260E-11	5.8765E-11	1.2256E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0345E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3159E-11	6.9416E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3100E-11	9.7013E-10	4.0691E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6247E-11	8.6995E-10	1.6852E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.2009E-10	9.0128E-10	2.4375E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.7195E-11	8.1369E-10
2.3321E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0569E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7454E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0088E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9072E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8256E-11

Moderator

4.7181E-07	6.1529E-07	1.0626E-05	5.4260E-05	1.1867E-04	2.4756E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2843E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6675E-02	3.9097E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1992E-02	3.9952E-01	1.5236E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.7307E-03	3.5611E-01	5.7271E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.2762E-02	3.8255E-01	6.8111E-02
0.0000E+00	0.0000E+00	0.0000E+00	5.9204E-05	2.7791E-02	3.7114E-01
2.9561E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6196E-03	2.7893E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5385E-03	2.1855E-02	3.7171E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5259E-03	3.4901E-02	-6.8663E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.2190E-02	2.4851E-02	-1.4870E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.7645E-05	-6.2089E-03	1.7865E-02

Burnable Absorber

3.7171E-04	4.0437E-03	6.3502E-02	3.4573E-01	7.4071E-01	1.4887E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2245E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0276E-03	2.0837E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.2090E-03	2.1418E-01	8.7921E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.6981E-03	1.9174E-01	3.9491E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.5823E-02	2.0416E-01	4.1229E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.6057E-05	1.3303E-02	1.9102E-01
1.5862E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3248E-03	1.4684E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7130E-03	1.1891E-02	2.0174E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0067E-03	1.7895E-02	-4.0482E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-5.6668E-03	1.3147E-02	-7.9705E-03
0.0000E+00	0.0000E+00	0.0000E+00	-7.7599E-06	-2.7347E-03	1.1971E-02

Control

6.0675E-03	5.2050E-02	5.1737E-01	4.4404E+00	9.6158E+00	1.9604E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4793E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0514E-02	6.6399E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8259E-09	4.9189E-03	7.0764E-01	2.9172E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0215E-03	6.5223E-01	1.1133E-02	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.0217E-02	6.5223E-01	1.0663E-01
0.0000E+00	0.0000E+00	0.0000E+00	8.4152E-06	2.5034E-02	5.9325E-01
3.9976E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0584E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8828E-04	1.3152E-02	1.0110E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0507E-04	1.5614E-02	-1.7404E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.8573E-03	1.4122E-02	-3.1421E-03
0.0000E+00	0.0000E+00	0.0000E+00	-2.3829E-06	-9.8460E-04	1.3466E-02

APPENDIX L

985° C CROSS SECTION LIBRARY

Fuel

4.2529E-04	1.2611E-03	1.9033E-02	8.4156E-03	2.9627E-02	6.6258E-02
3.1492E-04	4.8764E-04	4.2085E-03	6.3951E-03	2.4029E-02	5.3701E-02
2.6620E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5989E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0577E-02	2.6320E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9593E-08	7.1712E-03	2.7583E-01	1.2133E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9567E-03	2.3663E-01	5.7028E-03	8.2988E-06
0.0000E+00	0.0000E+00	0.0000E+00	3.4786E-02	2.5310E-01	5.6463E-02
0.0000E+00	0.0000E+00	0.0000E+00	3.8668E-05	1.7438E-02	2.3658E-01
2.2539E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6988E-03	1.7767E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0974E-03	1.3944E-02	2.3656E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4124E-03	2.1889E-02	-6.5707E-04	-4.4533E-06
0.0000E+00	0.0000E+00	0.0000E+00	-7.4617E-03	1.6271E-02	-1.1216E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.3600E-05	-3.5945E-03	1.4661E-02

Coolant

7.4512E-12	3.1875E-13	5.0536E-12	2.7378E-11	5.8207E-11	1.2216E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0345E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3161E-11	6.9421E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3114E-11	9.7008E-10	4.5771E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6307E-11	8.6507E-10	1.9750E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.2478E-10	9.0271E-10	2.6489E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.3913E-11	7.9816E-10
2.3323E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0570E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7454E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0132E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9017E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8026E-11

Moderator

4.7222E-07	6.1552E-07	1.0622E-05	5.4533E-05	1.1740E-04	2.4629E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2842E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6678E-02	3.9096E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.2000E-02	3.9945E-01	1.7196E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.7683E-03	3.5529E-01	6.9084E-03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.5666E-02	3.8332E-01	7.6657E-02
0.0000E+00	0.0000E+00	0.0000E+00	6.4046E-05	2.7519E-02	3.6621E-01
2.9563E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6204E-03	2.7895E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5408E-03	2.1776E-02	4.0246E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5286E-03	3.5123E-02	-8.1753E-04	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	-1.2296E-02	2.5195E-02	-1.6583E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.9875E-05	-6.0894E-03	1.9348E-02

Burnable Absorber

3.7173E-04	4.0448E-03	6.3457E-02	3.4722E-01	7.3352E-01	1.4837E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2245E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0297E-03	2.0836E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.2130E-03	2.1416E-01	9.9729E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.7101E-03	1.9143E-01	4.6818E-03	5.4973E-08
0.0000E+00	0.0000E+00	0.0000E+00	2.7130E-02	2.0442E-01	4.5971E-02
0.0000E+00	0.0000E+00	0.0000E+00	2.8177E-05	1.3148E-02	1.8801E-01
1.5863E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3253E-03	1.4684E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7141E-03	1.1860E-02	2.1938E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0068E-03	1.7992E-02	-4.7782E-04	-4.1292E-08
0.0000E+00	0.0000E+00	0.0000E+00	-5.7117E-03	1.3357E-02	-8.8534E-03
0.0000E+00	0.0000E+00	0.0000E+00	-8.7305E-06	-2.6855E-03	1.2661E-02

Control

6.0695E-03	5.2069E-02	5.1756E-01	4.4554E+00	9.5216E+00	1.9521E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4793E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0514E-02	6.6407E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8246E-09	4.9234E-03	7.0763E-01	3.2212E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0295E-03	6.5049E-01	1.2659E-02	1.1493E-08
0.0000E+00	0.0000E+00	0.0000E+00	3.2136E-02	6.5215E-01	1.1599E-01
0.0000E+00	0.0000E+00	0.0000E+00	9.1844E-06	2.4073E-02	5.8533E-01
3.9990E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0584E-03	1.6875E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8874E-04	1.3149E-02	1.1074E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0538E-04	1.5634E-02	-2.0462E-04	-8.6016E-09
0.0000E+00	0.0000E+00	0.0000E+00	-1.8738E-03	1.4204E-02	-3.4930E-03
0.0000E+00	0.0000E+00	0.0000E+00	-2.6726E-06	-9.6552E-04	1.3706E-02

APPENDIX M

1085° C CROSS SECTION LIBRARY

Fuel

4.2534E-04	1.2619E-03	1.9224E-02	8.4836E-03	2.9273E-02	6.6019E-02
3.1494E-04	4.8774E-04	4.2080E-03	6.4687E-03	2.3751E-02	5.3491E-02
2.6621E+00	2.4324E+00	2.4338E+00	2.4338E+00	2.4338E+00	2.4338E+00
9.6929E-01	3.0709E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.5989E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0579E-02	2.6321E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.9595E-08	7.1760E-03	2.7597E-01	1.3550E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9807E-03	2.3511E-01	6.7785E-03	2.2208E-05
0.0000E+00	0.0000E+00	0.0000E+00	3.6311E-02	2.5296E-01	6.1245E-02
0.0000E+00	0.0000E+00	0.0000E+00	4.5340E-05	1.6971E-02	2.3406E-01
2.2541E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.6992E-03	1.7768E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0987E-03	1.3937E-02	2.2929E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.4141E-03	2.2002E-02	-8.3494E-04	-1.1817E-05
0.0000E+00	0.0000E+00	0.0000E+00	-7.5679E-03	1.6506E-02	-1.1894E-02
0.0000E+00	0.0000E+00	0.0000E+00	-1.7973E-05	-3.4316E-03	1.5639E-02

Coolant

7.4523E-12	3.1883E-13	5.0492E-12	2.7539E-11	5.7601E-11	1.2173E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.0344E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.3164E-11	6.9427E-10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3129E-11	9.7001E-10	5.0072E-12	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6396E-11	8.5930E-10	2.3217E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.3045E-10	9.0350E-10	2.8615E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.0612E-11	7.8238E-10
2.3325E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.0572E-11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.7455E-11	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0170E-11	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8957E-11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.7814E-11

Moderator

4.7265E-07	6.1576E-07	1.0619E-05	5.4905E-05	1.1603E-04	2.4505E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.2842E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.6681E-02	3.9096E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.2008E-02	3.9937E-01	1.9318E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.8204E-03	3.5292E-01	8.4598E-03	1.6837E-05
0.0000E+00	0.0000E+00	0.0000E+00	5.8622E-02	3.8349E-01	8.4505E-02
0.0000E+00	0.0000E+00	0.0000E+00	7.4194E-05	2.6853E-02	3.6211E-01
2.9566E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-4.6212E-03	2.7897E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5432E-03	2.1743E-02	3.9928E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5345E-03	3.5376E-02	-1.0599E-03	-8.8491E-06
0.0000E+00	0.0000E+00	0.0000E+00	-1.2515E-02	2.5572E-02	-1.7871E-02
0.0000E+00	0.0000E+00	0.0000E+00	-2.6066E-05	-5.8326E-03	2.1022E-02

Burnable Absorber

3.7174E-04	4.0460E-03	6.3423E-02	3.4928E-01	7.2566E-01	1.4787E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.2244E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0317E-03	2.0836E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.2171E-03	2.1413E-01	1.1261E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.7281E-03	1.9036E-01	5.6031E-03	9.1711E-06
0.0000E+00	0.0000E+00	0.0000E+00	2.8469E-02	2.0434E-01	5.0255E-02
0.0000E+00	0.0000E+00	0.0000E+00	3.2644E-05	1.2821E-02	1.8548E-01
1.5865E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-2.3258E-03	1.4685E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7152E-03	1.1848E-02	2.1913E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0081E-03	1.8104E-02	-6.0713E-04	-4.8290E-06
0.0000E+00	0.0000E+00	0.0000E+00	-5.8070E-03	1.3572E-02	-9.4753E-03
0.0000E+00	0.0000E+00	0.0000E+00	-1.1445E-05	-2.5794E-03	1.3417E-02

Control

6.0716E-03	5.2088E-02	5.1778E-01	4.4779E+00	9.4169E+00	1.9439E+01
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.4792E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.0514E-02	6.6415E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.8232E-09	4.9280E-03	7.0761E-01	3.4980E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0394E-03	6.4820E-01	1.4573E-02	3.6170E-06
0.0000E+00	0.0000E+00	0.0000E+00	3.4350E-02	6.5161E-01	1.2524E-01
0.0000E+00	0.0000E+00	0.0000E+00	1.0704E-05	2.3031E-02	5.7751E-01
4.0004E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
-1.0584E-03	1.6876E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8921E-04	1.3147E-02	1.1185E-04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-1.0582E-04	1.5664E-02	-2.5758E-04	-1.8970E-06
0.0000E+00	0.0000E+00	0.0000E+00	-1.9088E-03	1.4282E-02	-3.7387E-03
0.0000E+00	0.0000E+00	0.0000E+00	-3.5049E-06	-9.2617E-04	1.3968E-02

REFERENCES

[1] Zhang, Dingkang and Rahnema, Farzad, "An Efficient Hybrid Stochastic/Deterministic Coarse Mesh Neutron Transport Method," Annals of Nuclear Energy, **41**, March 2012.

[2] Zhang, Dingkang and Rahnema, Farzad, "Comet Whole-Core Solution to a Stylized 3-Dimensional Pressurized Water Reactor Benchmark Problem With UO_2 and MOX Fuel," International Conference on the Physics of Reactors, **5**, 3779 (2012).

[3] Grayson, John E., "Python and Tkinter Programming," Greenwich, CT: Manning, 2000.

[4] Shipman, John W., "Tkinter 8.5 reference: a GUI for Python", http://infohost.nmt.edu/tcc/help/pubs/tkinter/web/index.html (Accessed October 2011).

[5] Rossum, Guido van et al., "The Python Language Reference," Python Software Foundation, http://docs.python.org/release/2.7/reference/index.html, July 2010.

[6] Lutz, Mark, "Programming Python," Sebastopol, CA: O'Reilly, 2011.

[7] H. Gougar et al., "Prismatic Coupled Neutronics/Thermal Fluids Transient Benchmark of the MHTGR-350 MW Core Design: Benchmark Definition," Idaho National Laboratory (2010).

[8] Simeonov, T., "Release Notes – Helios System Version 1.8," Studsvik Scandpower Report, SSP-03/221, November 26 (2003).

[9] Lago, Daniel. "Benchmarking the Coarse Mesh Radiation Transport (COMET) Method," Georgia Institute of Technology, November 8, 2013 (expected).

[10] K. J. Connolly, A. J. Huning, F. Rahnema, and S. Garimella, "Coupled Neutron Transport and Thermal Fluids Calculations for the VHTR," Joint International Conference on Supercomputing in Nuclear Applications and Monte Carlo 2013 (SNA + MC 2013), La Cité des Sciences et de l'Industrie, Paris, France, October 27-31, 2013 (accepted).

[11] F.B. Brown, W.R. Martin, W. Ji, J.L. Conlin, & J.C. Lee, "Stochastic Geometry and HTGR Modeling for MCNP5", ANS Monte Carlo 2005 Topical Meeting, Chattanooga TN, April 17-21, 2005.