UM-NERS-09-0001

DRAFT

(01/17/2012)

PARCS v3.0
U.S. NRC Core Neutronics Simulator

USER MANUAL

T. Downar

Y. Xu **V. Seker**

Department of Nuclear Engineering and Radiological Sciences

University of Michigan

Ann Arbor, MI

N. Hudson

RES / U.S. NRC

Rockville, Md

TABLE OF CONTENTS

I. INTRODUCTION

PARCS is a three-dimensional (3D) reactor core simulator which solves the steady-state and time-dependent, multi-group neutron diffusion and low order transport equations in orthogonal and non-orthogonal geometries. PARCS is coupled directly to the thermal-hydraulics system code **TRACE** [4] which provides the temperature and flow field information to PARCS during the transient calculations via the few group cross sections. PARCS is also coupled to the systems code **RELAP5** using the PVM message passing interface [3]. PARCS is available as a standalone code for performing calculations which do not require coupling to TRACE or RELAP5. A separate code module, **GENPMAXS** [13], is used to process the cross sections generated by lattice physics codes such as **TRITON** [14], HELIOS, or CASMO into the PMAXS format that can be read by PARCS.

Since the initial release of the NRC version of PARCS in November 1998 [1], there have been numerous coding changes, functional improvements, and code feature extensions. The most significant coding change in version 3.0 of PARCS has been the conversion of the code to Fortran 90. These changes are described in detail in the PARCS Programmers manual [15]. The functional improvements in version 3.0 include a wider variety of multi-group solution kernels and linear solvers. The major calculation features in PARCS which include the ability to perform *eigenvalue* calculations, *transient (kinetics)* calculations, *Xenon transient* calculations, *decay heat* calculations, *pin power* calculations, *etion* calculations, and *adjoint* calculations have been extended to include not just Light Water Reactors, but also the Pressurized Heavy Water and High Temperature Gas Reactors.

A card name based input system is employed in PARCS such that the use of default input parameters is maximized and the amount of the input data is minimized. A restart feature is available to continue the transient calculation from the point where the restart file was written. Various edit options are available in PARCS to show many different aspects of the calculation results. The on-line graphics features of PARCS for either coupled or standalone calculations provide a quick and versatile visualization of the various physical phenomena occurring during the transient calculation. These PARCS features are described in the subsequent sections.

Numerous sophisticated spatial kinetics calculation methods have been incorporated into PARCS in order to accomplish the various tasks with high accuracy and efficiency. For example, the CMFD formulation provides a means of performing a fast transient calculation by avoiding expensive nodal calculations at times in the transient when there is no strong variation in the neutron flux spatial distribution. The temporal discretization is performed using the theta method with an exponential transformation of the group fluxes. A transient fixed source problem is formed and solved at each time point in the transient. For spatial discretization, a variety of solution kernels are available to include the most popular LWR two group nodal methods, ANM [7] and NEM.

Advanced numerical solution methods are used in PARCS in order to minimize the computational burden. The solution of the CMFD linear system is obtained using a Krylov subspace method which utilizes a BILU3D preconditioner [8]. The eigenvalue calculation to establish the initial steady-state is performed using the Wielandt eigenvalue shift method. When using the two group nodal methods, a pin power reconstruction method is available in which predefined heterogeneous power form functions are combined with a homogeneous intranodal flux distribution [9].

PARCS is also capable of performing core etion analysis. Burnup dependent macroscopic cross sections are read from the PMAXS file prepared by the code GENPMAXS and the PARCS node-wise power is used to calculate the region-wise burnup increment for time advancing the macroscopic cross sections. Details of the PMAXS file and the GENPMAXS code are provided in the GENPMAXS manual [13]. An overview of the methods employed in PARCS is given in Section III in order to assist users in choosing the calculation options most suitable to their application and a detailed description of the methods in PARCS is available in the PARCS Theory manual [16].

PARCS was written in FORTRAN90 and its portability has been tested on various platforms and operating systems, to include SUN Solaris Unix, DEC Alpha Unix, HP Unix, LINUX, and various Windows OS (i.e. 95, 98, NT, and 2000).Because of its various functional features, PARCS can be run in numerous execution modes as summarized in Section IV. The rules of the PARCS input system are summarized in Section V. Several sample problems with their appropriate inputs and outputs are provided in Section VI and Section VII. The following section will first provide a brief overview of the important PARCS user features.

II. PARCS FEATURES

The features of PARCS can be categorized into calculations, modeling, and I/O features. The calculation features cover the type of internal calculations that can be performed by PARCS, e.g. eigenvalue calculation or kinetics calculations. The modeling features cover the type of input models can be used in PARCS, e.g. 3D vs. 1D. Lastly, the I/O features cover the input system and output features of PARCS, e.g. the card name-based input system and on-line graphics. This section describes the PARCS features according to this classification. Some input cards relevant to the feature being described here will be mentioned along with the input block name to which they belong. The detailed input system and card description is given in Section IV.

II.A Calculation Features

PARCS is equipped with various calculation modules necessary to predict the global and local response of the reactor in steady-state and transient conditions. The various features of PARCS are described in this section along with the corresponding modules.

II.A.1 Eigenvalue Calculation

PARCS performs the eigenvalue calculation for steady-state reactor analysis or for quasi-static core etion analysis. The eigenvalue calculation also provides the initial steady-state for the transient calculation in which the nu value is adjusted to insure a critical state for the transient fixed source problem. The eigenvalue calculation in PARCS is performed using the Wielandt eigenvalue shift method to accelerate convergence. In addition to the standard ***k-eff calculation*** for a given reactor configuration, criticality searches are available using either the critical boron or critical rod search functions in the **SEARCH** card of the CNTL block input. The algorithms used in these searches are described in the PARCS Theory manual.

II.A.2 Transient Calculation

PARCS solves the time-dependent neutron diffusion and low order transport equations involving both delayed and prompt neutrons. The temporal differencing based on the ***exponential transform*** and the ***theta method*** yields a transient fixed source problem at each time point. The fixed source problem is solved by the CMFD method in which a ***conditional nodal update*** scheme is employed. The temporal discretization schemes can be specified by the **THETA** and **EXPO_OPT** cards in the TRAN input block. Exponential extrapolation to obtain an initial guess at the new time step is also available in the expo_opt card. The conditional update scheme invokes the nodal update only when there are substantial local cross section changes and therefore local flux variations. The control of the conditional update is performed using the **EPS_XSEC** card in the TRAN block. The transient calculation option is turned on and off by the **TRANSIENT** card in the CNTL block.

II.A.3 Xenon/Samarium Calculation

The relatively slow Xenon transient is performed using a quasistatic calculation method that utilizes the eigenvalue problem solver instead of the transient fixed source problem. This neglects the time dependent variation of the delayed neutrons and the number densities of Xenon and Samarium are updated by solving the respective balance equations using the fluxes resulting from the eigenvalue calculation. The Xenon option is specified in the **XE_SM** card in the CNTL block to choose one of 1) ***No Xenon***, 2) ***Equilibrium Xenon***, or 3) ***Transient Xenon*** options.

II.A.4 Decay Heat Calculation

A simplified decay heat model involving six groups of decay heat precursor groups [10] is employed in PARCS. The ***6 group decay heat precursor equation*** is treated in the same way as the delayed neutron precursor equation. The solution of the precursor equation is performed for each node which provides the local decay heat at each time step which is then added to the node-wise fission power to produce the total power. Default values of the fraction and decay constant of the 6 groups are provided for the UO_2 cores operated for a sufficiently long period of time. The option exists for the user to also specify decay heat constants. The decay heat option is handled with the **DECAY_HEAT** card in the CNTL block and the input parameters are specified in the **DHP_BETA** and **DHP_LAMBDA** cards in the XSEC block.

II.A.5 Pin Power Calculation

The principal unknown in the PARCS nodal solution kernel is the node average flux whereas the reactor analyst often is interested in the local pin-wise power distribution. An algorithm was implemented in PARCS to “reconstruct” pin powers using the PARCS nodal solution and the ***heterogeneous power form functions*** provided by the lattice physics code. The homogeneous intranodal flux in PARCS is calculated by finding the ***analytic solution of a 2D fixed source problem*** in which the surface average currents are specified at the four boundaries. The surface average currents are obtained from the converged node average flux distribution at a given

state. The pin power reconstruction is performed for the transient conditions with transient fixed source as well as for the steady-state conditions. The pin power calculation option is turned on and off by the **PIN_POWER** card in the CNTL block and the heterogeneous power form functions are supplied via the PFF block. Corner discontinuity factors can be used to enhance the accuracy of the pin power distribution and they are specified in the **CDF** card in the XSEC block. In order to save computing time for pin power calculation, a subset of fuel assemblies can be selected for pin power calculation in the **PINCAL_LOC** card in the GEOM block. The transient pin power calculation need not be performed at every time step since the pin-to-box factor does not change much unless there is a substantial change in the core configuration. The transient pin power calculation frequency is specified by the **PIN_FREQ** card in the TRAN block.

II.A.6 Adjoint Calculation

The adjoint flux is required primarily for the reactivity edits during the transient calculation and the adjoint calculation is performed at the end of the steady-state calculation with the transpose of the converged CMFD coefficient matrix. The adjoint print option is turned on by the **POPT(5)** option in the **PRINT_OPT** card in the CNTL block.

II.B Modeling Features

The essential problem of modeling in PARCS is to represent the physical reactor system with an approximate numerical model. Among the various fundamental modeling issues in the reactor kinetics calculation are the geometric representation, the cross section representation, and the T-H feedback modeling. PARCS provides a 3D geometric representation that can be reduced as necessary to 2D, 1D, or 0D by the choice of the appropriate boundary conditions. However, special 1D kinetics capabilities are also available for more accurate and versatile 1D modeling. Various geometric representation features will be described in the first and fourth subsections below. The basic cross section representation scheme in PARCS is to functionalize the macroscopic cross sections with linear or quadratic dependence on the T-H state variables, and the PARCS cross section representation schemes are described in the second subsection.

II.B.1 Geometric Representation

In PARCS, the reactor core is modeled by a group of homogeneous computational nodes. Radially, the size of the node is on the order of fuel assembly pitch, while axially the size is 15~30 cm. In the GEOM block, the core radial configuration is specified in the unit of assembly by the **RAD_CONF** card in the GEOM block. The radial node size is then specified by the number of subdivisions of the assembly node using the **NEUTMESH_X** and **NEUTMESH_Y** cards. Therefore the ***number of nodes per assembly*** can be freely chosen as *nsubx*nsuby.* Normally, one or four nodes per assembly is used for practical calculations. However, in principle, it is possible to perform a fine mesh calculation with nodal the geometry input structure. Also by using the assembly configuration as the pin configuration, a pin-by-pin heterogeneous core representation is also possible. The problem symmetry is determined by the boundary conditions specified at the two

boundaries in each direction in the **BOUN_COND** card in the GEOM block. Three boundary conditions are available: zero current, zero flux, and zero incoming current. By choosing the zero current option on the left side boundary, one can construct a ***quarter*** core or a ***half core symmetry*** problem. By taking the top and bottom boundary conditions to be zero current, a ***2D problem*** can be constructed with one plane. Similarly, by taking all the radial boundary conditions to be zero current, a ***1D problem*** can be constructed.

II.B.2 Cross Section Functionalization

PARCS uses macroscopic cross sections which are functionalized on boron concentration (B, in ppm), square root of the effective fuel temperature, moderator temperature and density, void fraction (α) and the effective rodded fractions (ξ). This functionalization has been adequate for the Light Water Reactor, however, additional functionalization has been provided for reactors such as the Pressurized Heavy Water Reactor. Only the ***linear dependence*** of cross sections is considered on these state variables except for the moderator density and void fraction for which the quadratic variation is additionally considered. Symbolically, the cross section functionalization for the LWR can be described as:

$$\Sigma(B, T_f, T_m, D_m, \alpha, \xi) = \Sigma_0 + a_1(B - B_0) + a_2(\sqrt{T_f} - \sqrt{T_{f0}}) + a_3(T_m - T_{m0}) + a_4(D_m - D_{m0}) + a_5(D_m - D_{m0})^2 + a_6\alpha + a_7\alpha^2 + \xi\Delta\Sigma_{CR} \quad (1)$$

The manner in which the coefficients a are computed and tabulated from a given cross section dataset is described in the cross section processing manual GENPMAXS [13]. The fuel temperature, T_f, is the effective doppler fuel temperature and can be computed using either the volume average fuel temperature or a linear combination of the centerline and surface temperatures as described in Reference [11] and in the PARCS Theory Manual. The effective rodded fraction is defined as the product of the volumetric rodded fraction and the flux depression factor that is computed by the ***decusping*** routine for the partially rodded node. For Xenon calculations, the Xenon and Samarium microscopic cross sections are represented in the same form. The base cross sections and the proportionality constants are specified by the **BASE_MACRO, DXS_DPPM, DXS_DTF, DXS_DTM, DXS_DDM, DXS_DDM2, DXS_DVOID, DXS_DVOID2, DELCR_BASE** cards in the XSEC block. Special types of cross section representation for benchmark calculations are also available and are selected by the **FUNC_TYPE** card in the XSEC block (e.g. OECD MSLB (Main Steam Line Break) problem and OECD PBTT (Peach Bottom Turbine Trip) problem). For 1D kinetics, more cross section representation schemes including table forms are available and these are discussed in Section II.B.4.

II.B.3 Thermal-Hydraulics Feedback

PARCS is coupled with the thermal-hydraulics code TRACE or RELAP5 by the **EXT_TH** card in the CNTL block. The coupling between PARCS and TRACE is transparent to the user and activated by setting TRACE Namelist varialble ITDMR=1 and by setting EXT_TH=T and SYSNAME=TRAC in PARCS. The coupling between PARCS and the RELAP5 code is achieved by the interprocess communication protocol, **PVM**. The two processes are loaded in

parallel and the PARCS process transfers the nodal power data to the T-H process. The T-H process then sends back the temperature (fuel and coolant) and density data back to the PARCS process. In PARCS, RELAP5 is activated as the system code by setting SYSNAME=RELAP with EXT_TH=T in the CNTL Block.

In general, the neutronic node structure is different than the T-H node structure. The mapping T-H nodes and neutronic nodes is governed by an interface file called **MAPTAB**. In order to minimize the user effort to prepare the MAPTAB file, **automatic mapping** schemes were developed for the coupled TRACE/PARCS and RELAP5/PARCS code that accept data from code input files to generate the mapping information internally. The MAPTAB file structure and automatic mapping information is described in section V.B.

The time step size used in system T-H calculations is often small because of stability considerations. Because the neutronics solution may not change much over a small time step, a ***skip factor*** was introduced which can be used in the coupled calculation such that the T-H code calls PARCS based on this user-defined frequency. Different skip factors can be specified for the steady state and transient calculations in the **EXT_TH** card.

II.B.4 1D Kinetics

PARCS is equipped with 1D kinetics capabilities for faster execution of some axially dominated transients and also for providing the capability to execute existing TRAC-B 1D kinetics decks. In addition, PARCS has a quasi-static 1D kinetics capability in which the radial flux shape is assumed to be constant or linearly varying between specified points. The following section describes the three 1D kinetics features available in PARCS.

Normal 1D Kinetics: This is the standard 1D kinetics calculation method based on the 1D group constants that were generated and functionalized via planar averaging from a set of 3D steady-state calculations at various core states. The normal 1D kinetics can be invoked by the **ONED_KIN** card in the CNTL block. The 1D group constant can be functionalized by one of the three possible options: a general ***table*** form, a ***polynomial*** form, and a ***linear*** form. The general table form takes the following representation in which the base and rodded cross sections are provided as 2 dimensional tables where the two independent variables are the moderator density and the square root of effective fuel temperature:

$$\Sigma(D_m, T_f, B, \xi) = \Sigma(D_m, T_f) + \sum_{i=1}^{I} \xi_i \Delta\Sigma_{Ri}(D_m, T_f) + (a_1 + a_2(D_m - D_{m0}))(B - B_0) \qquad (2)$$

Note that it also has the boron correction term given only by coefficients. On the other hand the polynomial cross section takes the following form that is consistent with the 1D formulation used in the TRAC-B code.

$$\Sigma(B, T_f, T_m, \alpha, \xi) = \xi(a_1 + a_2\alpha + a_3\alpha^2) + (1-\xi)(a_4 + a_5\alpha + a_6\alpha^2) + a_7(\sqrt{T_f} - \sqrt{T_{f0}}) + a_8(T_m - T_{m0}) + a_9 B \quad (3)$$

The linear form is to use Eq. (1) as the 3D representation. The cross section form is selected by the **XS_FORM** in the ONEDK block and the actual 1D cross section data are given in a separate file designated by the **EXT1DXS** card in the ONEDK block. For accurate conservation of the 3D planar averaged currents in 1D calculation, so called current conservation factors (CCF) can be used in the 1D flux calculation. This option is selected by the **USE_CCF** card in the ONEDK block. Even though the kinetics calculation is performed in 1D, it is possible to perform the T-H calculation in 3D with ***multiple flow channels***. This is possible by assigning predefined radial power shapes so that reconstruction of the 3D power distribution can be done using the planar power determined in the 1D kinetics calculation. The **RAD_WEIGHT** and **CHAN_AREA** cards in the ONEDK block are used for this purpose. Lastly, for 1D bare core modeling, an ***albedo matrix*** can be input at the top and bottom of the core with the **ALBEDO_ZL** and **ALBEDO_ZR** cards in the GEOM block.

TRAC-B 1D Kinetics: PARCS can accept an existing TRAC-B input deck as the 1D kinetics input file. If a file name ***tracin*** exists in the working directory, ***no PARCS input files*** are required. All the kinetics input data are taken from the **POW*** cards provided in the tracin file.

Quasi-static 1D Kinetics: The quasi-static (QS) 1D kinetics feature is unique in PARCS and it requires a normal 3D model including the geometry and the normal cross section data. The neutronics calculation is, however, performed in 1D using the 1D cross sections that are collapsed during the calculation from the 3D nodal cross section distribution and the radial flux shapes which are provided as input. The only assumption involved in the QS1D calculation is that the radial flux shape remains unchanged or only slowly varying. The advantage is faster execution without the need for generating 1D cross sections in advance. Only the radial flux shapes are needed from a set of steady-state calculations. The QS1D option is specified by the **ONED_KIN** card in the CNTL block. The radial flux shapes for each plane are to be specified in a file named ***caseid.shp*** where the caseid is the current case ID.

II.B.5 Core etion Analysis

PARCS performs macroscopic core etion analysis by time advancing burnup dependent macroscopic cross sections. The PARCS node-wise power is used to calculate the region-wise burnup increment which is then used to update the macroscopic cross sections using the PMAXS cross section file. The assembly-wise history effects (e.g. moderator density history, control rod history) are also treated using the local burnup dependence. A more complete description of the burnup algorithm is provided in Section III.I and in the PARCS Theory Manual.

II.C Input Features

The PARCS input system was designed such that it could: 1) maximize default parameters, 2) be free from a predefined input sequence, 3) be easy to detect an input error, 4) be convenient to use descriptive comments and 5) minimize the number of input words. To achieve these goals, a card-name based input system was designed. All the input data are identified by their respective card-names. The following subsection describes the features of the PARCS cardname based input system.

II.C.1 Features of PARCS Cardname Based Input System

1. Input data are given in a ***modular form*** by collecting input data having similar characteristics into the same block. It helps the user prepare the input data in an organized way. The primary blocknames defined are **CNTL, XSEC, GEOM, PARAM, FDBK, TRAN, PFF, ONEDK** and **PLOT**.

2. The input data can be provided in ***either*** a ***single file or*** in ***multiple files***. Thus long and independent input data such as cross sections or power form functions can be placed in separate input files. The names of any files to be read are to be specified in the main input file. For example, the XSEC, GEOM, and FDBK files may be specified as:

```
XSEC
    file ./xsec/XSEC_NEACRP
GEOM
    file ./xsec/GEOM_QC
FDBK
    file ./xsec/FDBK_QC
```

In this example, all cards in **XSEC, GEOM,** and **FDBK** blocks are in three separated files. The paths of these separate files can be absolute path or path relative to running directory.

3. In each block, there are card types identified by an ***alphabetical ID***, e.g. CORE_POWER. Each card type is a string consisting of one or two meaningful words which are at most 10 characters long. If a card type contains two words, they are connected by the underscore (_) character. It helps easy recognition of the cardname.

4. In each card, there are one or more data fields. Each field is separated by one or more blanks. If fewer fields are specified than are required by a card type, default values are assigned to the unspecified data.

5. In general, input cards can be put in any order. However, if there are special relations between cards then the card must be in sequence.

6. The cardname can be specified anywhere in a line other than at the first column which is reserved for the BANG (!), SLASH (/), DOT (.) characters, or for the block name. The BANG character is used for comments, the SLASH character designates the ***end of a case*** and the DOT character designates the ***end of the input***.

7. Characters appearing after the ***BANG character*** in a line are neglected (the entire line is neglected if the BANG character appears in the first column). Thus, ***descriptive comments*** can be placed anywhere after the BANG character except on a pure data line that is a continuation line for a card type.

8. ***Blank lines*** can be placed anywhere.

9. The block name, card name, and any alphabetical input data are ***not case sensitive***.

10. If all the data fields of a card can not be filled in one line and the number of data fields are decided by the previous input data, the ***remaining data*** can be ***continued in subsequent lines***. This applies only when the number of data fields to be read is known from previously read input.

11. The ***input data are echoed in*** the normal ***output*** as soon as they are read in. If there is an input error in a card, no more input processing will be performed. In such cases, the ***last line*** in the input echo would contain an ***error message***. In most cases, some guidance for correcting the input will be provided.

12. If there is a FILE card type in a block, a local file designated by the file name will be read in. After the FILE card, additional input cards can be entered for overwriting specific cards in the local file. The content of the ***local file*** is also ***echoed*** in the normal output followed by a commented FILE card and a horizontal line. A horizontal line will be placed also at the end of the echoed local file.

13. The data after the card name can be entered in ***free format.*** The ***STAR (*) character*** used in the FORTRAN free format can be used for the ***repetition*** of data. For example, 8*1.2 can be used instead of repeating 1.2 eight times. In some cards, a negative number appearing as the second in a pair of integers means a ***serial expansion***. Namely, a list of 2 -7 is equivalent to a list of 2 3 4 5 6 7.

14. If an ***error or warning message*** is produced by the code during the input processing, the ***POUND (#)*** is placed at the first column of the message.

15. If there is a ***contradiction*** in the input, the code will ***respect what comes last***, e.g. in the case that TH_FDBK F and EXT_TH T were both specified, fbdk will be set to T.

16. The first block is a dummy block containing the case title (or description) and the card CASEID card. If a **CASEID** card is omitted, *parcs* will be the default case ID so that the output file name becomes *parcs.out*, *parcs.sum*, etc.

17. The ***output files names*** are produced with proper ***three-character extensions attached to*** the ***CASEID*** input in the title block. The output extensions are described in Table 1. The output files with extensions ‘pkd’, ‘ace’ and ‘1dx’ are not available in the 1D module.

18. The input ends with a **DOT** (.). After a dot at the first column, nothing more is read.

19. When the code detects a ***misspelled card type***, the code will terminate and the list of all the ***available card types*** will be ***printed*** to guide the user in correcting the spelling.

II.C.2 User Interface

PARCS input can be created and edited using the SNAP application programming interface. The details of the PARCS SNAP plug-in are described in section II.E. For the execution of PARCS Standalone on a PC running the Windows operating system, a graphical user interface is available in PARCS. The first dialogue panel appears as in Figure 1.

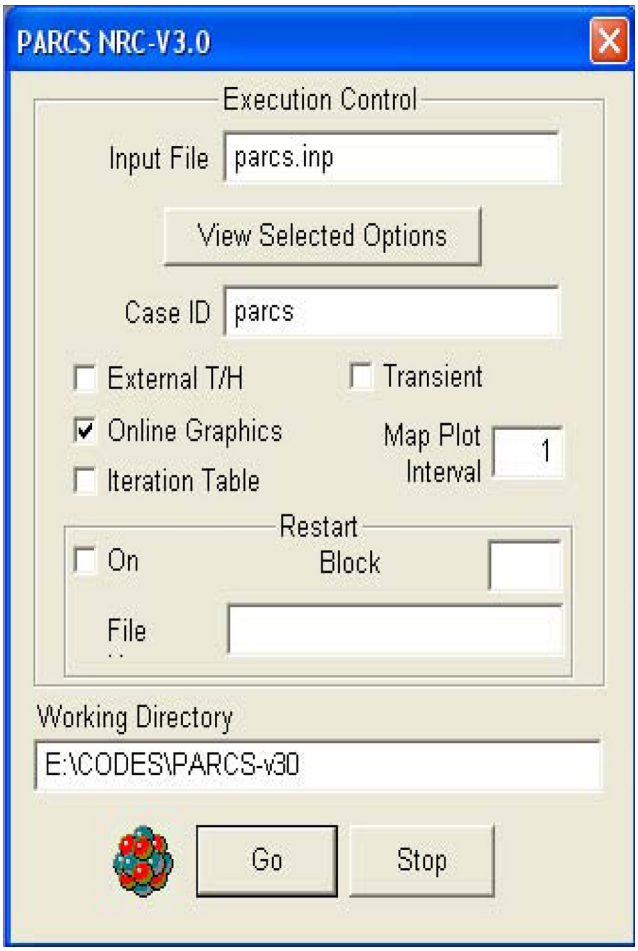


Figure 1. PARCS User Input Interface

This panel displays the default input file name, ***parcs.inp***. The user can choose a different input file name in the first window. Alternatively, if the user specifies a file name on the command line when executing PARCS (e.g. version 3.0 shown in Figure 1), this name will appear in the first panel in place of ***parcs.inp***. If the ***View_Selected_Options*** is clicked after the name of the input file and the working directory is specified, the contents of the input file is first read and the options specified in the input file will be reflected on the panel. For example, the External T/H checkbox will be selected if the EXT_TH card is set true in the CNTL block. Before executing the

code, the user can override what's specified by the input file. Namely, one can change the caseid or the restart block number. Clicking the ***Go*** button after changes initiates the execution.

II.D Output Features

The PARCS output edits were designed to achieve the following four goals: 1) provide an echo and interpreter of all major input data of the code, 2) provide detailed information on various physical phenomena which occur during the transient, 3) provide a separate summary edit file at the end of the run which contains essential information in a compact form, and 4) provide on-line plotting of key parameters such as reactivity and core power to show the progress of the calculation. PARCS generates various output files for later use, e.g. the restart file and the 1D cross section files. In the following, detailed PARCS output features are described.

II.D.1 Primary Output and Summary File

The input echo is provided first in the ***primary output*** and is followed by the ***problem description***. Since the input echo is printed as soon as an input line is read and the code terminates if it encounters an input error, the last line in the input echo can be helpful in finding the input error if there is any. Detailed calculation results are then printed according to the print options chosen. Finally, a ***summary file*** is generated at the end of the execution that lists the primary output parameters in a chronological order. Refer to the detailed list of the available output edits which are given in Table 1. Note that popt(n) given in the last column of the table is the print option to be chosen in the CNTL block (Refer to Table 3).

Table 1. Output Description

Outputs	Description	Activation
Banner	Code name and version	Default
Input Echo	All the input data given in the input file plus the contents of any local file to be included in the input (by the FILE cards)	Default
Problem Description	• Core geometry • Radial node number correspondence • Material compositions • Group constants • Calculation control parameters • Print options • T/H parameters	Default Popt(1) Default Default Default Default Default

Outputs	Description	Activation
Steady-State Results	• Iteration table.	Popt(2)
	• keff, ppm, core power etc.	Default
	• Axially averaged assembly power and pin power distribution	Default
	• Axial power distribution	Default
	• Planar assembly power and pin power distribution	Popt(3)
	• Axial avg. assembly moderator temperature distribution	Popt(10)
	• Axial avg. assembly outlet moderator temperature distribution	Popt(10)
	• Axial moderator temperature distribution	Popt(10)
	• Axial avg. assembly fuel temperature distribution	Popt(10)
	• Axial fuel temperature distribution	Popt(10)
	• Axial avg. assembly fuel centerline temperature distribution	Popt(10)
	• Axial avg. assembly maximum fuel centerline temperature distribution	Popt(10)
	• Axial avg. assembly Xenon/Samarium number density distribuion	XE_SM
	• Planar Xenon/Samarium number density distribution	XE_SM+ Popt(9)
	• Axially averaged assembly flux distribution	Popt(7)
	• Axial flux distribution	Popt(7)
	• Planar assembly flux distribution	Popt(8)
	• Axial avg. assembly precursor density distribution	Popt(7)
	• Collapsed 1-D cross section	Popt(11)
	• Iteration table for adjoint flux calculation	Popt(6)
	• Axial avg. assembly adjoint flux distribution	Popt(6)

Outputs	Description	Activation
Transient Results (at each time step)	• Core state change which drives transient	Default
	• Iteration table	Popt(2)
	• Reactivity (in $) and core power(% total power)	Default
	• Axially averaged assembly power and pin power distribution	Default
	• Axial power distribution	Default
	• Planar assembly power and pin power distribution	Popt(3)
	• Axial avg. assembly moderator temperature distribution	Popt(10)
	• Axial avg. assembly outlet moderator temperature distribuion	Popt(10)
	• Axial moderator temperature distribution	Popt(10)
	• Axial avg. assembly fuel temperature distribution	Popt(10)
	• Axial fuel temperature distribution	Popt(10)
	• Axial avg. assembly fuel centerline temperature distribution	Popt(10)
	• Axial avg. assembly maximum fuel centerline temperature distribution	Popt(10)
	• Axial avg. assembly Xenon/Samarium number density distriuion	XE_SM
	• Planar Xenon/Samarium number density distribution	XE_SM+ Popt(9)
	• Axial avg. assembly flux distribution	Popt(7)
	• Axial flux distribution	Popt(7)
	• Planar assembly flux distribution	Popt(8)
	• Axial avg. assembly precursor density distribution	Popt(7)
Summary Edits (for all time points)	• Overall Summary with the time step - Reactivity (in $) - Power level (% of maximum rated power) - Fxy (box relative power and pin relative power) - Fq - Maximum and average coolant temperature ($^{\circ}C$) - Maximum and average fuel temperature($^{\circ}K$)	Default Default
	• Axial avg. assembly power density summary - Assembly power - Fxy - Fq	 Default
	• Axial power shape	Popt(7)
	• Axial avg. assembly flux distribution	Popt(7)
	• Axial flux shape	

II.D.2 Output Files

Table 2 shows the list of available output files. The three character file extension is attached to the caseid specified in the input to form each file name. The ***pin power file*** contains detailed pin

power information for the assemblies for which the pin power calculation is requested. The detailed pin power option is turned on by **POPT(4)** of the **PRINT_OPT** card in the CNTL block. The ***restart file*** contains the restart information for each block. The frequency of the restart file writing is determined by the **RST_FREQ** card in the TRAN block. A proper block number should be specified in the **RESTART** card in the CNTL block in a restart calculation. The global parameter **plot file** contains global parameter changes vs. time. Core power and reactivity, maximum fuel center-line temperature, and average outlet temperature are written here at each time step. The file is always created in any transient calculation. The radial power/flux shape file contains the shape information needed for the QS1D or normal 1D calculation. The file writing is activated by either **POPT(13)** for the power shape or **POPT(14)** for the flux shape in the PRINT_OPT card. The ***reactivity*** file contains various reactivity components such as Doppler or control rod separated from the total reactivity. The reactivity components provide information useful in understanding the relative importance of various physical phenomena occurring during the transient. The component reactivity edit is activated by **POPT(6)** in the PRINT_OPT card. The XMGR plot file can be used to show the final plot off-line. This file is written on UNIX if the **PLOT_CNTL** card in the TRAN block is activated. The point kinetics data and 1D group constant files are to generate input parameters for lower dimensional models. The file creation is activated by **POPT(11)** and **POPT(12)** for the 1D and Point Kinetics, respectively. The T/H feedback variable file is used to store the feedback related T/H variables at the specified calculated state. The Doppler temperatures and coolant temperatures and densities for each node are written to this file. This file can be used later to combine various T/H conditions to generate 1D cross section at those states. The file creation is activated by the **WRITE_FBV** card in the FDBK block and the file can be read by the **READ_DOPL** and **READ_TMDM** cards.

Table 2. PARCS Output Files

Extension	Description	Extension	Description
out	Primary Output	rho	Feedback Component Reactivity
sum	Summary Output	ace	XMGR Plot Window
pin	Pin Power Output	pkd	Point Kinetics Data
rst	Output Restart	1dx	1D Collapsed Group Constants
plt	Global Parameter Plot Data	dbg	Debug output
shp	Radial Power/Flux Shape	fbv	T/H Feedback variables

II.D.3 On-Line Graphics

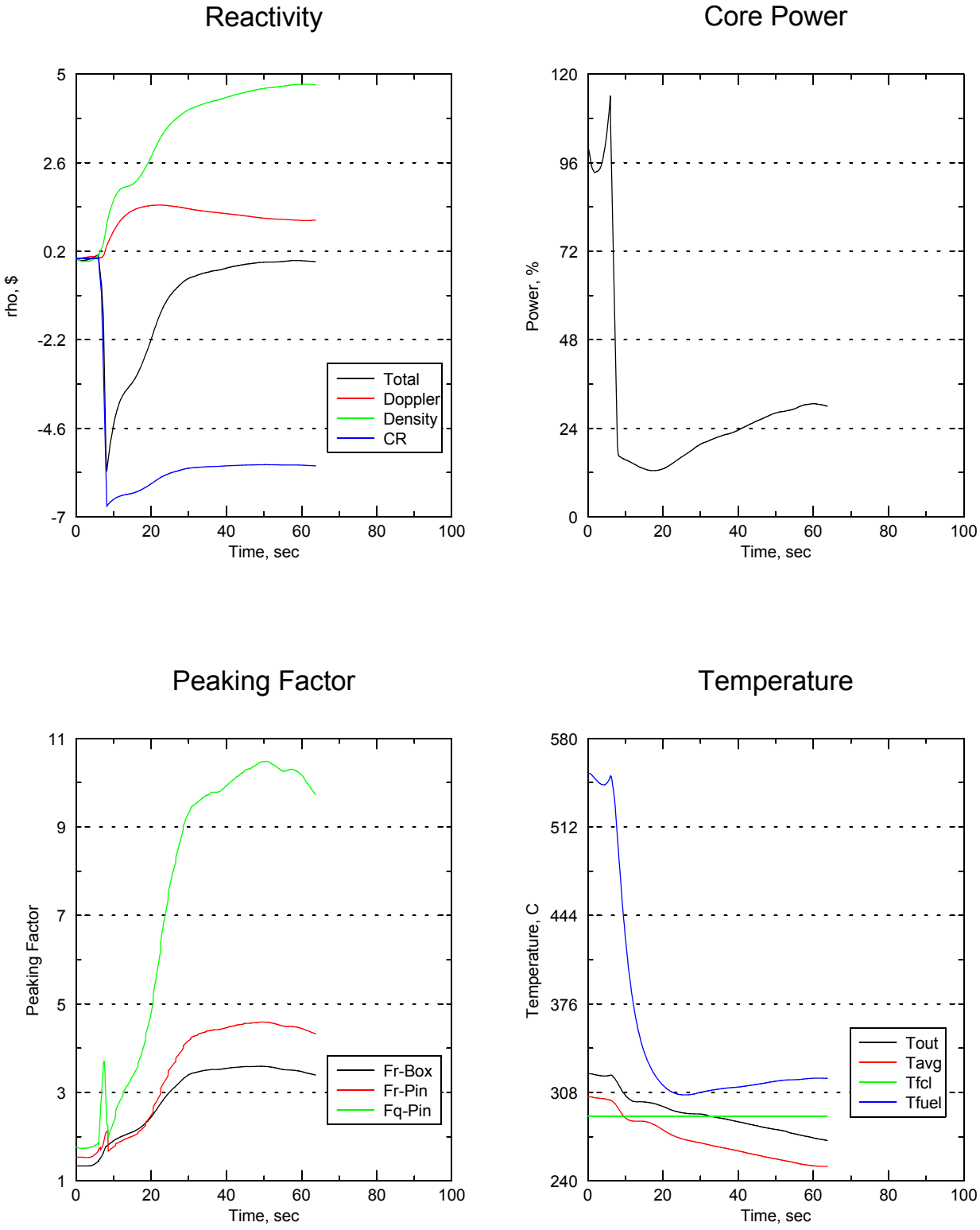
PARCS on-line graphics are available with both the coupled and standalone versions of the code. The TRACE coupled graphics features of PARCS are available through the PARCS Plug-In to SNAP [13] and are described in Section II.E. The standalone graphics features of PARCS are based on XMGR graphics software for the UNIX application and the QuickWin graphics package for the Windows applications and are described below.

Some of the primary transient calculation results such as reactivity, core power, peaking factors, and coolant and fuel temperatures are displayed on-line as the calculation proceeds. The **XMGR** based on-line plot option can be chosen by the **PLOT_CNTL** card in the TRAN block for the XMGR graphics. Figure 2 shows a sample on-line plot obtained for an analysis of a MSLB problem. As shown in Figure 3, the **QuickWin** based graphics provide more extensive and detailed on-line plots based on the directions given in the **PLOT block**. The QuickWin (QW) on-line graphics available in the standalone PARCS utilizes the plotting kernels that were developed by a KAERI engineer, Dr. B. D. Chung. Permission to use those kernels in PARCS was graciously given by him. There are three types of plots available in the PARCS QW graphics: *X-Y plot*, *axial distribution plot*, and *radial map*. The variables that can be plotted are either global such as core power and reactivity or local such as relative nodal power or effective fuel temperature. The local variables can be chosen from a group of PARCS solution variable arrays by designating the location. The location is specified by a 5 digit number in the form of *kklll* where *kk* designate the plane number while *lll* does the radial node index. The *value of zero* for *kk* or *lll* invokes *axially averaged* or *planar averaged values*, respectively. The plotable arrays are relative nodal power (*relp*), fast and thermal neutron fluxes (*flux1* and *flux2*), coolant temperature (*tcool*), coolant density (*dcool*), fuel temperature (*tfuel*), fuel loading pattern (*lp2d*), and control rod positions (*crp-map*).

The X-Y plot is to display a global or a local quantity as a function of time. The global parameters that can be plotted are k-eff, core power level, reactivity, average outlet coolant temperature, component reactivities, peaking factor, and control bank positions. Any local parameters can be plotted with the spatial position specified by ***kklll***. Several curves can be put in one X-Y graph and a maximum of 50 X-Y plots can be put in one window. The choice of the X-axis type is made by the **XTYPE** card in the PLOT block. The ***default x-axis*** variable is ***time*** and its maximum is set by the ***tend*** given in the **TIME_STEP** card in the TRAN block. The **XY** card in the PLOT block selects the variables to be plotted and their minimum and maximum values. The axial power distribution plot is to display the axial profile of a local quantity or a planar averaged quantity. Core average axial power shapes, temperature, void profiles and many more axial plots can be made. The axial plot is controlled by the **AXPLOT** card in the PLOT block.

The radial map shows the radial distribution of local quantities at a selected plane or axially-averaged values. Radial power maps and temperature distributions can be plotted. There are three types of maps available: rectangular maps, contour maps, and filled contour maps. The rectangular map shows colored boxes whose size is the same as a node. The contour and filled color maps draw contour line without and with color filling in between. The radial map is chosen and controlled by the **RECTMAP**, **CONTOUR**, and **BITMAP** cards in the PLOT block. The radial maps are relatively complicated and thus take more computing time than the other plots. To alleviate the radial plotting overhead, the radial maps can be plotted infrequently by using the plot frequency adjustment factor.

Figure 2. XMGR Based On-Line Plot Obtained During a MSLB Transient Calculation



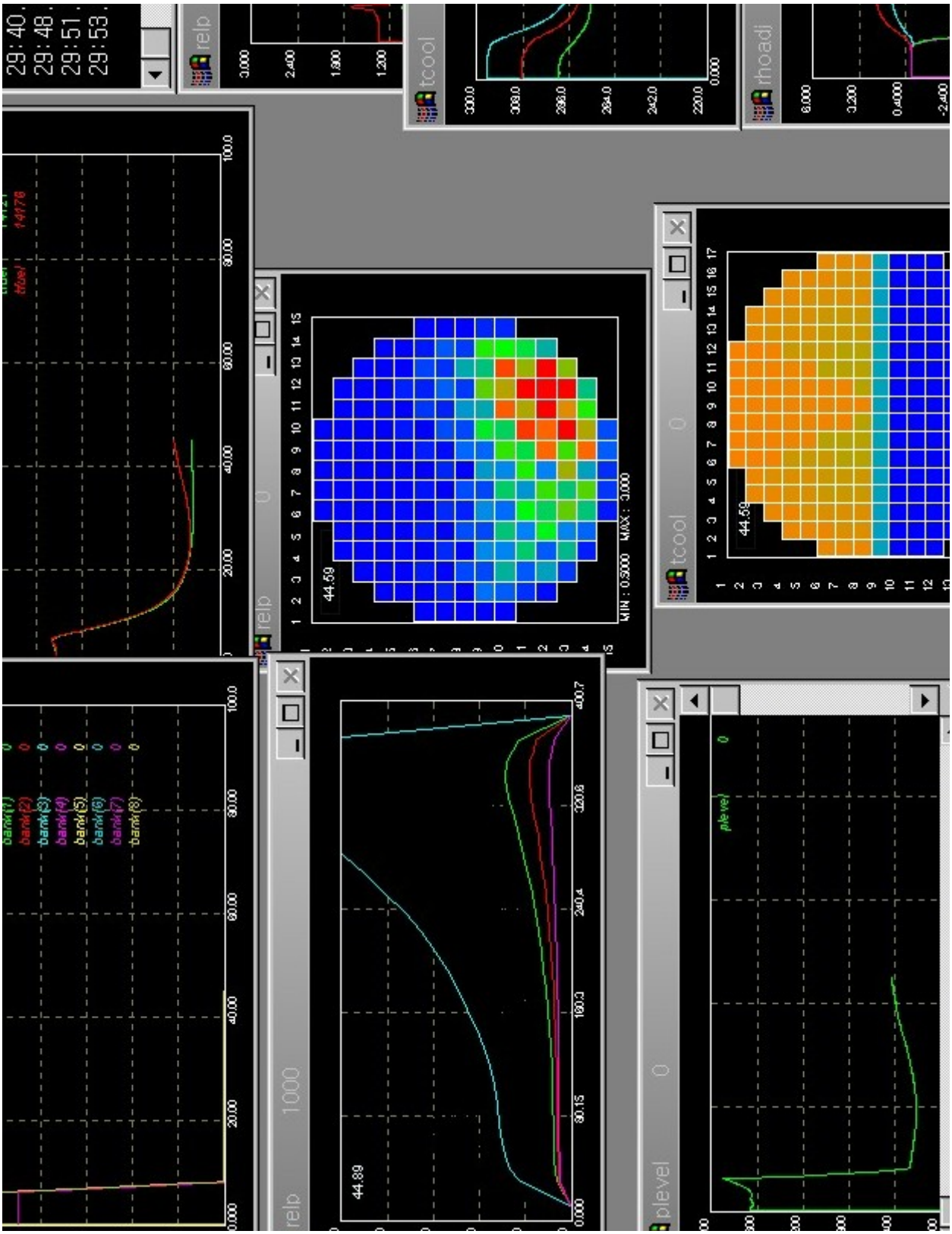


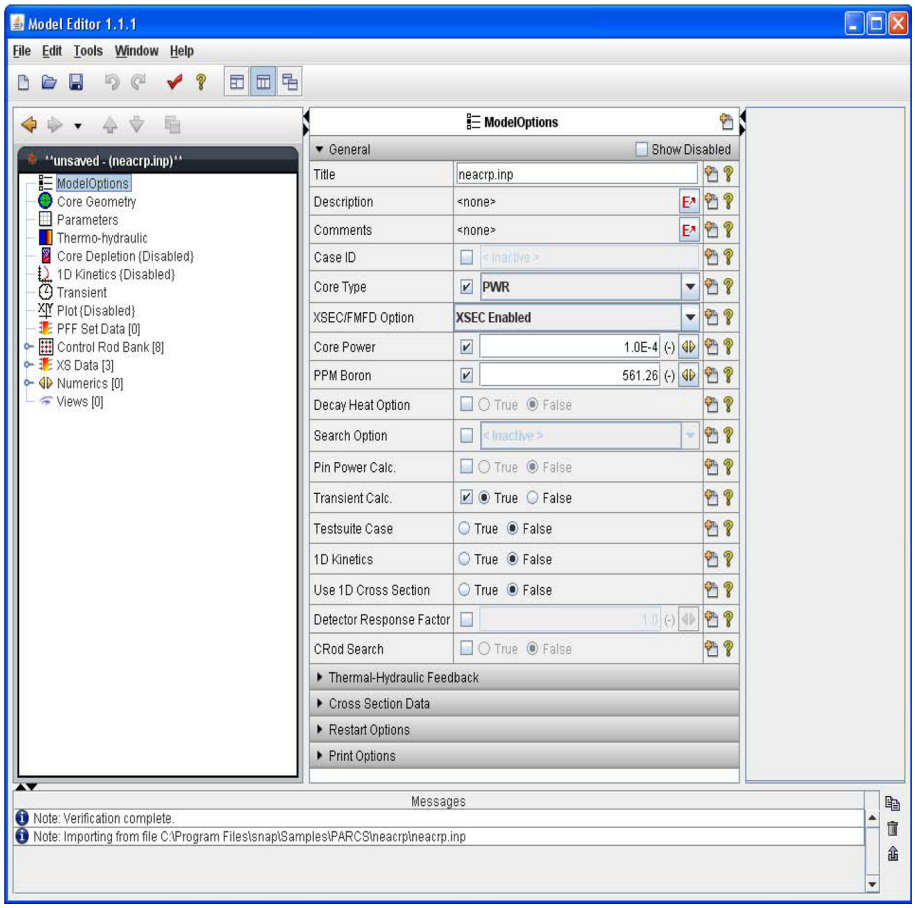
Figure 3. QuickWin Based On-Line Plot Obtained During a MSLB Transient Calculation

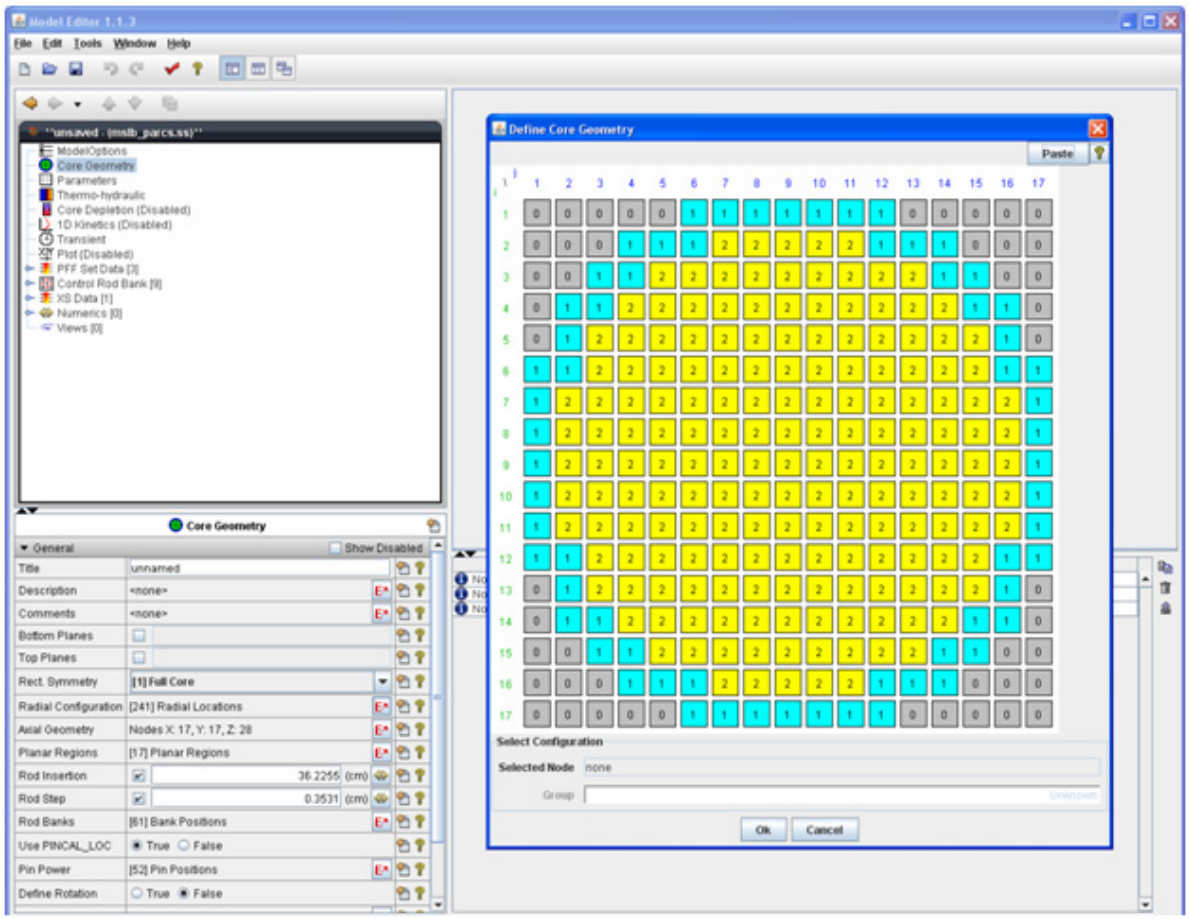
II.E PARCS SNAP Plug-In (To Be Completed)

A PARCS plug-in was developed for the SNAP Applications Program Interface to simplify many of the model development and output visualization/analysis requirements for PARCS applications. Details on the PARCS Snap plug-in are available in the SNAP manual and also on the SNAP website:

http://www.nrcsnap.com/snap/plugins/parcs/index.jsp

The following section will briefly review some of the PARCS features available in SNAP and highlight some of the recent developments.




Model Editor 1.1.3
File Edit Tools Window Help
Core Geometry
Parameters
Thermo-hydraulic
Core Depletion (Disabled)
1D Kinetics (Disabled)
Transient
Plot (Disabled)
Control Rod Bank [9]
Numerics [0]
Views [0]
Core Geometry
General
Show Disabled
Title
unnamed
Description
Comments
Bottom Planes
Top Planes
Rect. Symmetry
[1] Full Core
Radial Configuration
[241] Radial Locations
Axial Geometry
Planar Regions
[17] Planar Regions
Rod Insertion
Rod Step
Rod Banks
[61] Bank Positions
Use PINCAL_LOC
True False
Pin Power
[52] Pin Positions
Define Rotation
Define Core Geometry
Paste
Select Configuration
Selected Node
none
Group
Ok
Cancel

III. METHODS OVERVIEW

PARCS methods are described in detail in the PARCS Theory manual. It reviews the spatial and temporal discretization methods, as well as several auxiliary calculations that are required as part of standard reactor neutronics analysis. The detailed method description is essential to understanding the code's capability and structure. However, most users may not need a detailed understanding of the method, and a brief explanation of the methods relevant to the execution control are sufficient for the efficient use of the code. In the following subsections, the essential aspects of the PARCS calculation methods that are directly related to execution control are explained so that the user can choose proper options to best suit their needs. Note that there are default parameters internally set in the code for the execution control inputs described below so that it is not necessary to specifiy all parameters in the input.

III.A Spatial Discretization Methods

The spatial solution of the neutron flux in the reactor is determined in PARCS using well established numerical methods. This section provides a brief overview of the essential methods used in PARCS, to include theCMFD linear system formulation, the nodal methods available in each geometry as well as the accompanying pin power reconstruction methods, the Krylov CMFD solver, iteration control, and a special 1D kinetics method.

III.A.1 Nonlinear CMFD Method

In PARCS the primary solution algorithm is based on the nonlinear Coarse Mesh Finite Difference (CMFD) formulation. In the CMFD method the core is discretized into coarse mesh, typically the size of a fuel assembly, and a simple finite difference discretization is applied between mesh. A more accurate solution is achieved by using a higher order nodal method to update the current at the interface of all nodes in the core. Each two nodes are represented by the following relation in terms of the node average fluxes of the right and left hand side nodes:

$$J_g = -\tilde{D}_g(\phi_g^R - \phi_g^L) - \hat{D}_g(\phi_g^R + \phi_g^L) \ . \tag{4}$$

Here $\tilde{D}_g$ is the base nodal coupling coefficient that is determined directly from the finite difference formulation and $\hat{D}_g$ is the corrective nodal coupling coefficient that is determined by two-node nodal solutions using the Analytic Nodal Method (ANM) or Nodal Expansion Method (NEM) as described in section III.C. The frequency of the two-node nodal solution is controlled by the nodal update and the frequency of the thermal-hydraulics feedback is controlled by the T-H update. This is discussed in detail in the PARCS Theory Manual. A second solution algorithm is also available in PARCS which is based on a fine mesh finite difference (FMFD) of the entire core and is described in section III.K. In the FMFD method, the CMFD solution is used to accelerate the global fine mesh solution.

In the initial eigenvalue calculation of the nonlinear CMFD method, the nodal update is performed with a specified fixed update frequency during the outer iteration. The default update fre-

quency is 3 so that a nodal update is performed every three outer iterations. A different nodal update frequency can be chosen by the **NLUPD_SS** card in the PARAM block. The T-H update in the steady-state is performed with a frequency based on the nodal update. Namely, the T-H update is performed once per every *n* nodal updates. The default value of *n* is one meaning that the T-H update is synchronized with the nodal update, but a different value can be selected by the **NLUPD_SS** card. There is an additional control parameter in the T-H update for the change in the fuel temperature. If the change is sufficiently small, namely the relative change is less than ***epstf*** in the **CONV_SS** card in the PARAM block, between the two successive T-H calculations, the T-H calculation is considered converged and no more T-H updates are made afterwards.

In the transient calculation as well as in the ***coupled*** steady-state calculation, the nodal update is only employed when there is a substantial change in the nodal cross sections. This is the ***conditional nodal update*** scheme. PARCS monitors the relative change in the total cross section at every node and invokes a nodal update when the change becomes larger than the value specified in the **EPS_XSEC** card in the TRAN block (or ***epstf*** in the coupled steady-state calculation). The default value of ***epsxsec*** is 0.01. Choosing a smaller value causes more frequent nodal updates making the solution more accurate but with more computing time, and vice versa. Once it is decided that the nodal update must be performed for the current time step, the invoking of the actual nodal update during the iteration to solve the transient fixed source problem is controlled by the update frequency and also by the error reduction ratio. By the use of the error reduction ratio a nodal update can be invoked in a fewer number of iterations than the fixed number of iterations specified by the update frequency. The **EPS_ERF** and **NLUPD_TR** cards in the TRAN block specify the error reduction criterion and the fixed nodal update frequency.

The convergence of the iterative CMFD solution is checked with different criteria in the eigenvalue and transient calculations. In the eigenvalue calculation, the convergence of the *k-eff,* the local fission source (infinite norm), and the global fission source (2-norm) are checked against the convergence criteria specified in the **CONV_SS** card in the PARAM block by comparing two successive iterates. This is consistent with convergence algorithms used in other codes. However, in the transient calculations, PARCS employs a unique convergence checking criterion by evaluating the relative residual. Since a fixed source problem of type $Ax=b$ is solved in the transient problem with a fixed right hand side vector b, the relative residual defined by

$$\varsigma_i = \frac{\|b - Ax_i\|_2}{\|b\|_2} \tag{5}$$

can be used as a measure of convergence without the need for comparing two successive iterates. PARCS employs a Krylov method to solve the CMFD linear system and the residual (the numerator in Eq. (5)) is computed as a by-product during the iteration, the relative residual is obtained easily. The relative residual is compared against ***epsr2*** specified in the CONV_TR card in the TRAN block.

III.A. 2 Nodal Methods

Nodal methods are the primary means used in PARCS to obtain higher order solutions to the neutron diffusion equation. Within the framework of the CMFD formulation the nodal method is used to solve the two node problem and to update the nodal coupling coefficient, $\hat{D}_g$, in Eq. (4). The ANM (Analytic Nodal Method) in PARCS has been used most frequently within the Light Water Reactor (LWR) industry to solve the two group diffusion equation. However, methods were added to PARCS in order to address the so-called ***critical node problem,*** which can occur when there is no net leakage out of a node and the ANM matrix becomes singular [7] (also see PARCS Theory Manual). A second nodal method, the Nodal Expansion Method (NEM), is also available which does not have this potential problem, but is less accurate for certain types of problems [7]. A hybrid ANM-NEM method can then be used in which the ANM two-node problem is replaced by a Nodal Expansion Method (NEM) two-node problem for the ***near critical nodes*** [7]. In the hybrid method the user specifies a tolerance on the difference in the node k-inf and k-eff which is used to switch between the ANM and NEM kernels (see **PARAM** card **EPS_ANM**). NEM is also available in a multi-group form for both cartesian and hexagonal geometries. A fine mesh finite difference kernel is available as (FMFD) for both cartesian and cylindrical geometries. The details on the various solution kernels available in PARCS are described in the PARCS Theory manual.

III.A.3 Pin Power Reconstruction

When using the nodal option in PARCS, it is necessary to invoke the pin power reconstruction module in order to recover fuel pin powers from the nodal solution. Once the nodal flux solution is converged, the surface average currents are all determined. PARCS uses only the currents to obtain intranodal flux distributions when the pin power option is selected. The homogeneous flux solution is based on the ***analytic solution*** of a two dimensional fixed source problem having ***8 boundary conditions*** among which 4 come from the 4 surface current and the other 4 come from the 4 corner point fluxes. The axial transverse leakage and the transient fixed source which are included in the fixed source are represented by a 2 dimensional quadratic polynomial. Since the corner point fluxes are required, they are solved for first by using the corner point balance relations(CPB) which couple all the corner point fluxes at a plane. During the formulation of the CPB equations, the ***corner point discontinuity factors*** (CDF) can be used to enhance the accuracy. The coupled corner point flux linear system is solved by the Gauss-Seidel scheme. Once the corner point fluxes are determined, the homogeneous intranodal fluxes can be obtained independently for each node. The homogeneous flux is then multiplied by the power form functions which are provided for each energy group, typically from a separate lattice calculation. The use of the analytic solution form employing only currents, CDF, and the two group power form functions provide superior accuracies in the pin power calculation as demonstrated in Reference [2]. Note that the ordinary one group power form functions can be used by specifying only the first group values in the PFF block.

III.A.4 Control Rod Cusping Correction

When a node is partially rodded, there appears a so called control rod cusping effect if the control rod cross section is incorporated using the volume fraction only. This occurs inherently

because there is a flux depression in the partially rodded region leading to a smaller control rod worth. The rod cusping problem is addressed in PARCS by solving a ***three node problem*** using a ***fine mesh finite difference method (FDM)***. The three nodes include the upper and lower nodes as well as the partially rodded node. The node average fluxes of the upper and lower nodes are used as constraints. The solution of the three node problem is the intranodal flux and this is used to compute the flux depression factor. The first ***decusping*** option uses only this flux depression factor while there is another option to define axial discontinuity factors from the three node problem for use in the subsequent two-node problems. The first decusping option is sufficiently accurate and must be used in a transient where the control rods are slowly moving or many nodes are partially rodded. It is specified by the DECUSP card in the PARAM block.

III.A.5 1D Nodal Kinetics

The 1D solver uses the same calculation models employed in the 3D PARCS solution to maintain consistency with the 3D module. Namely, the basic solution method for the 1D kinetics equation is the nonlinear analytic nodal method (ANM) and the theta temporal discretization. Due to the use of ANM, the axial node size of the 1D module can be chosen as large as 20-30 cm, yielding only 12 to 25 axial nodes. Also the newly derived current conservation factor (CCF) is introduced which guarantees the same axial currents as the 3D reference values. By using the CCF factor, the 1D kinetics module can reproduce the 3D axial power distribution. This enhances the accuracy and makes it possible to generate the same initial condition as the 3D solution. The solution of the 1D kinetics equation involves a block tridiagonal linear system that is solved directly by using the direct elimination method.

The additional functions of the 1D kinetics module include various 1D cross section representation schemes and multi-channel treatment by using an input specifying radial weighting factors for the corresponding external T/H calculation. In the 1D module, three 1D cross section forms are allowed: the tabular, polynomial, and linear cross section representation schemes. The tabular representation scheme on fuel temperature and moderator density provides a wide range of applicability and enhances the accuracy of the 1D kinetics solution. In addition, multiple control bank modeling is possible and the control rod cusping problem is solved by using a quadratic decusping function. The coefficients of the decusping function can be given for each control rod bank.

The input/output (I/O) formats of the 1D module were made consistent with the 3D module in order to minimize newly defined input cards and also to provide convenient user accessibility. When the 1D module is invoked, the input data necessary for the 1D module is transferred from 3D common blocks to 1D common blocks. After that the 1D module is independently executed in the normal calculation mode without triggering any 3D routines.

III.A.6 Hexagonal Geometry

The hexagonal core calculation method implemented in PARCS is basically the same nonlinear CMFD formulation having a higher order hexagonal nodal coupling kernel which utilizes the triangular polynomial expansion nodal (TPEN) method. Since the CMFD formulation is also used for the cartesian geometry options, the hexagonal and rectangular solvers in PARCS are consistent, in that they share the same problem control logic, driver routines, and variable structures.

There are some notable differences between the two modules, such as the formulation of the nodal kernel. For example, the cartesian solvers use transverse-integrated nodal methods in which the three-dimensional problem is decomposed into three one-dimensional problems. In the hexagonal module, the non-transverse-integrated method TPEN solves a two-dimensional problem directly, rather than solving two coupled one-dimensional problems in each plane as in the cartesian nodal method. In the TPEN method, the three-dimensional problem is first decoupled into a radial and an axial problem that are coupled through transverse-leakages. Radially, the two-dimensional problem for each hexagon is solved by first splitting the hexagon into six triangles and then expanding the two-dimensional intranodal flux solution for each triangle into a two-dimensional third order polynomial.

In order to solve the CMFD linear system for the hexagonal problem, the same Krylov subspace algorithm (BiCGSTAB or GMRES) used for the rectangular problems is employed for hexagonal geometry, but with a simplified diagonal preconditioner. The primary reason for the choice of the diagonal preconditioner rather than the more effective BILU3D preconditioner for rectangular problems was the difficulty of handling various symmetries. In the hexagonal geometry, 1/12, 1/6, 1/3, and 1/2 core problems exists and the symmetry changes the structure of the CMFD matrix. Thus it is nontrivial to construct an incomplete LU factorization scheme that works generally regardless of the symmetry option. On the contrary, the diagonal preconditioner can be easily applied to any type of matrix structure and was chosen here as the preconditioner for the hexagonal problems.

The basic PARCS CMFD calculation logic developed for the rectangular geometry has been retained in the hexagonal geometry solver. Namely, the calculation flow remains mostly unchanged and only the preconditioned equation solver and the nodal kernel differ. For example, the Wielandt method, the temporal discretization scheme (the theta method with exponential transform), and the nonlinear nodal and T/H update logics are commonly used in both geometry solvers.

III.A.7 FMFD Kernel

For some applications (e.g. MOX core analysis) the explicit representation of each fuel pin within the fuel assembly may be warranted and therefore a multigroup fine mesh finite difference (FMFD) kernel was added as another spatial discretization option in PARCS. A separate set of input cards (**FMFD** block) are required to run FMFD in which a pin-wise composition map is specified for each unique assembly type. The FMFD block also includes cross sections and energy group information, and therefore the standard XSEC block is not necessary when executing in the fine mesh mode. Coarse mesh acceleration information is specified using the grid_x, grid_y, neutmesh_x, and neutmesh_y cards. Fuel assembly-wise feedback is default but pin by pin thermal feedback can be applied by the GENINF card, meshth field. The FMFD kernel is available in both diffusion theory and SP3 transport, as described in the next section.

III.A.8 SP3 Transport Kernel

For certain applications in which transport effects become important (e.g. MOX fuel analysis) a Simplified P3 transport option was added to PARCS. The time-dependent SP_3 transport

equations were implemented in PARCS using the conventional approach in which the odd-order angular moments are eliminated to yield a set of coupled diffusion-like equations as shown below in a matrix-equation form:

$$\begin{bmatrix} -D_1^*\nabla^2+\Sigma_r^* & -2D_1^*\nabla^2 \\ -\frac{2}{5}D_1^*\nabla^2 & -\left(\frac{3}{5}D_3^*+\frac{4}{5}D_1^*\right)\nabla^2+\Sigma_t^* \end{bmatrix}\begin{bmatrix} \phi_0^{n+1} \\ \phi_2^{n+1} \end{bmatrix}=\begin{bmatrix} q_0^n-3D_1^*\nabla\cdot q_1^n+S_{0t}^{n+1} \\ q_2^n-\frac{6}{5}D_1^*\nabla\cdot q_1^n-\frac{7}{5}D_3^*\nabla\cdot q_3^n \end{bmatrix},$$

$$D_1^*\equiv\frac{1}{3\Sigma_{tr}^*},\quad D_3^*\equiv\frac{3}{7\Sigma_t^*},\quad \Sigma_\alpha^*=\Sigma_\alpha+\frac{1}{\upsilon\Delta t},\quad q_i^n=\frac{1}{\upsilon}\frac{\phi_i^n}{\Delta t},\quad n=\text{time index}.$$

The first equation is the conventional diffusion equation for the scalar flux (i.e. zero moment flux) which is in the standard form with contributions from the second moment flux. The second moment flux equation is in the same form as the conventional diffusion equation which makes it possible to use the same numerical methods as with the scalar flux with appropriately modified diffusion coefficients. A standard non-linear iteration scheme is used to solve the SP3 equations in which the fine mesh problem is accelerated with a coarse mesh global solution. The SP3 transport option is available in PARCS for both the FMFD and NEMMG kernels.

III.B Temporal Differencing

The temporal differencing scheme used in PARCS is the theta method with the optional exponential transform which is based on the following factorization of the flux:

$$\phi(r,t) = \tilde{\phi}(r,t)e^{w(r)t} \quad . \tag{6}$$

This representation allows the exponential function to carry the fast varying component of the flux and the slowly varying component is left in the phi-tilde function that is discretized by the theta method. The need for keeping the phi-tilde is that it's not possible to find the location dependent frequency $\omega(r)$ exactly. If the exponential transform option is chosen, the approximate value of this is obtained by using the current iterate and previous time step fluxes at every node. The exponential transform option is quite effective for very rapidly varying superprompt critical transients in that it gives an equally accurate solution with a larger time step size than the theta method. The exponential transform and extrapolation option can be specified by the **EXP_OPT** card in the TRAN block while the theta value (default=0.5) can be adjusted for the fully implicit or explicit formulation in the **THETA** card in the TRAN block.

III.C Control Rod Scram Logic

The control rod scram logic in PARCS provides the user with the following control capabilities:

(1) Define a high flux trip set point

(2) Define the delay from the time the trip is set to the time the rods begin to scram

(3) Define the time to scram a rod from the "fully out" to the "fully in" position.

(4) Define one or more "stuck rods".

It should be noted that option (3) will be used to calculate a scram insertion rate, and that regardless of the insertion position of any given rod, all control rods (except those define by option (4)) will be inserted at this rate. The above logic input is implemented as follows:

- if power at time tn is greater than option (1), then set the trip and set tripbeg equal to tn

- if the trip has been set and tn - tripbeg equals option(2), then set the scram and calculate the insertion rate defined by option (3)

- if scram has been activated, insert all the rods (except those defined by option (4)) to the position governed by option (3) and the time step size.

III.D Restart Capability

The restart capability in PARCS allows the user to define a frequency with which the restart data should be written to file. This frequency is input as a multiple of the time step size. For example, if Dt=0.01, Tfinal=0.50, and the restart frequency is set to 10, then 5 restart edits will be performed which correspond to the following time steps: 0.1, 0.2, 0.3, 0.4, 0.5. This restart file can then be utilized to begin another transient from any of the edit points in the existing file.

III.E Neutronic vs. T-H Variable Mapping

When T-H conditions for PARCS are provided by an external systems code (e.g. TRACE), the temperature/fluid condition required at each neutronics node for the feedback calculation consists of the coolant density/temperature and the effective fuel temperature. The nodal power information determined by PARCS is then transferred back to the systems code. During the course of data transfer, the difference in the neutronic and T-H nodalization are reconciled by the mapping scheme described below.

In general, coarser node sizes are used in the core T-H calculation than in the PARCS neutronics calculation. Therefore, a T-H node usually consists of several neutronics node. However, it is possible that a neutronics node can belong to multiple T-H nodes. Because of this possibility, the PARCS T-H variable is obtained as the weighted average of the T-H variables of several T-H nodes as:

$$T_i^P = \sum_{k=1}^{N_i^P} \alpha_{i,j(i,k)}^P T_{j(i,k)}^T \quad . \tag{7}$$

where the superscript P and T stands for PARCS and T-H codes, and j(i,k) is the k-th T-H node number out of the N_i^P T-H nodes belonging to the i-th PARCS node. $\alpha_{i,j}^P$ is the volume fraction of the j-th T-H node in the i-th PARCS node which must sum to unity.

On the other hand, the nodal power of the j-th T-H node is obtained as follows:

$$P_j^T = \sum_{k=1}^{N_j^T} \alpha_{j,i(j,k)}^T P_{i(j,k)}^P \quad . \tag{8}$$

where i(j,k) is the k-th PARCS node number out of the N_j^T PARCS nodes belonging to the j-th T-H node. is the volume fraction of the i-th PARCS node in the j-th T-H node and satisfies the following conditions:

$$. \sum_{j=1}^{N^T} \alpha_{j,i}^T = 1 \quad ; \sum_{k=1}^{N_j^T} \alpha_{j,i(j,k)}^T > 1 \quad . \tag{9}$$

where $\alpha_{j,i}^T$ is the number of all the T-H nodes. The second relation above implies that the T-H node is larger than the PARCS node.

III.F Automatic TH/Neutronics Mapping

An automatic mapping kernel was developed to simplify the creation of a MAPTAB file which maps neutronics and TH information. A detailed description of the MAPTAB format and the automratic mapping kernel is provided in section V.B. This kernel is currently able to manage the following mapping configurations:

(1) Cylindrical T/H volumes from the TRACE vessel component to cartesian neutronic nodes, where *no mapping information* is specified. The weighting factors are computed based strictly on the geometric union of the cylindrical T/H grid and the cartesian neutronic grid.

(2) Cylindrical T/H volumes from the TRACE vessel component to cartesian neutronic nodes, where *a radial map* is used to explicitly specify which radial T/H cell should be coupled to which neutronic node. Specifying this radial map allows the user to bypass the mapping logic which computes weighting fractions based strictly on the geometric union of the T/H and Neutronic grids.

(3) Multiple BWR CHAN components to a 3D neutronic core. This functionality requires that the user input a radial map which specifies the CHAN(s) to be coupled to each neutronic node and with what weighting factor. It is the responsibility of the user to ensure that the geometric volume of each T/H CHAN is consistent with the number of neutronic nodes to which it is assigned.

(4) BWR CHAN component(s) to a 1D neutronic core. This scenario arises from calculations performed with either a TRAC-BF1 input deck (where PARCS processes the 1D kinetics data from the TRAC-BF1 deck and thus does not need a separate PARCS input deck or "MAPTAB" file), or a TRACE deck (where PARCS must process the 1D kinetics data from its own input deck and a "MAPTAB" file is required).

The radial mapping for volumes and heat structures is performed based on one of the mapping configurations listed above, and the axial mapping is performed without user intervention. For the axial mapping, a linear interpolation scheme is used for both the hydraulic cells and the heat structures, which provides a fluid/fuel temperature distribution in the channel which is more accurate than without interpolation. For the mapping of axial hydraulic cells, it is assumed that the fluid conditions exist at the exit of the cell.

The tabular weighting factors required in previous "MAPTAB" files are now no longer necessary. If this data is not input, or if only a radial map is specified, the code will assume that automatic mapping is to be performed. However, if this tabular data is present in the "MAPTAB" file, the auto-mapping logic will be deactivated, and the input weighting factors will be used. Section V.B describes the input structure of the "MAPTAB" file in more detail.

Most 1D routines were written in FORTRAN90 to take advantage of dynamic memory allocation and derived data types. The 1D module thus has different memory addresses even though the same variable names are used as in the 3D routines. Due to the use of dynamic memory allocation, no 1D memory will be allocated during the normal 3D runs so that the addition of the 1D routine will not harm the execution of the 3D module.

The input/output (I/O) formats of the 1D module were made consistent with the 3D module in order to minimize newly defined input cards and also to provide convenient user accessibility. When the 1D module is invoked, the input data necessary for the 1D module is transferred from 3D common blocks to 1D common blocks. After that the 1D module is independently executed in the normal calculation mode without triggering any 3D routines.

III.G Core etion Analysis

The macroscopic etion capability is availiable in PARCS which has the following functionality:

1) Ability to read in the macroscopic cross sections from PMAXS, the XS file prepared by the interface code GENPMAXS

2) Ability to calculate region wise macroscopic cross sections as a function of the history state, such as burnup, moderate density history, control rod history

3) Ability to calculate region wise burnup increment at each step based on the region wise fluxes

The etion module was implemented in PARCS by inserting several entry points in the code:

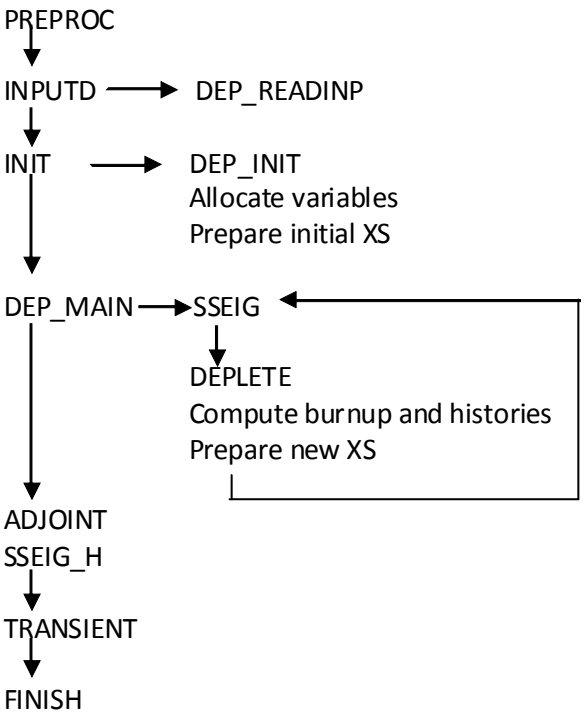


Figure 4. Schematic of implementation of etion Entry Points in PARCS

The etion module is activated in PARCS using the input block which is described in the user input. Utilization of the etion option also requires the use of the two cards in the CNRL block and four cards in the FDBK block.

The burnup distribution is calculated using the fluxes provided by PARCS as follows:

$$\Delta B_i = \Delta B_c \frac{P_i G_c}{P_c G_i}$$

where i : ith etion region, one region is one Z-direction node of a assembly,

ΔB_i : burnup increase of *i-th* region,

ΔB_c : core average burnup increment in one step, specified in ETOR input,

G_i : the heavy metal loading in *i-th* region,

G_c : total heavy metal loading in the core($\sum_i G_i$),

P_i : power in *i-th* region,

P_c : total power in core($\sum_i P_i$)

G_i , P_i can be calculated as following :

$$G_i = \rho_i \sum_{j \in i} V_j \quad ,$$

$$P_i = \sum_{j \in i} V_j \left[\sum_g \kappa\Sigma_{f,g,j} \phi_{g,j} \right] \quad ,$$

where j : *j-th* neutronic node in PARCS,

g : *g-th* energy group,

V_i : volume of *j-th* node, given by PARCS,

ρ_i : heavy metal density in ith region, provided in PMAXS,

$\phi_{g,j}$: fluxes, given by PARCS,

$\kappa\Sigma_{f,g,}$: fission energy XS, given by PARCS.

IV. EXECUTING PARCS

The various methods of executing PARCS are summarized in the following section. The specific method of execution for each of the execution options is explained in the subsequent sections.

IV.A Execution Modes

The execution modes of PARCS are categorized according to whether the calculation is steady state or transient, and 3D or 1D. Table 3 shows the execution mode classifications and the possible calculation cases.

Table 3. Execution Modes of PARCS

		Calculation Option	Input Block	Card	Value
Steady State	3D	1-1) Eigenvalue Search 1-2) Critical Boron Search 1-3) Adjoint Flux	CNTL CNTL CNTL	SEARCH SEARCH PRINT_OPT	KEFF PPM 5
	1D	2-1) Eigenvalue Search 2-2) Adjoint Flux	CNTL CNTL	SEARCH PRINT_OPT	KEFF 5
Transient Calculation	3D	3-1) Control Rod Perturbation 3-2) Boron Perturbation 3-3) Scram 3-4) Decay Heat 3-5) Flow Perturbation	TRAN* TRAN* TRAN CNTL *	MOVE_BANK CHANGE_PPM SCRAM DECAY_HEAT	
	1D	4-1) Control Rod Perturbation 4-2) Boron Perturbation 4-3) Scram without stuck rod 4-4) Decay Heat 4-5) Flow Perturbation	TRAN* TRAN* TRAN CNTL *	MOVE_BANK CHANGE_PPM SCRAM DECAY_HEAT	
* This option can be enabled through TRAC input as well.					

All of these calculation options are compatible with the exception of the eigenvalue search (1-1) and the critical boron search (1-2) for 3D steady-state calculations. Due to the nature of the calculation for these options, they are mutually exclusive.

IV.B PARCS Execution Procedures

This section explains the procedures to execute PARCS on a workstation and/or a PC for the various execution modes described above. PARCS can be executed as a standalone code or in a coupled mode with either TRACE or RELAP5. The suggested procedure for coupled calculations is as follows:

1. Run the Themal-Hydraulics code (RELAP5 or TRACE) in the stand-alone mode for flow initialization (invoking no PARCS calculations) and generate a restart file at the end of the run.

2. Using the above restart file, run the coupled steady state case and generate the steady state restart files for both PARCS and the T-H code. Adjust the ***external T-H skip factor*** so that excessive calls of PARCS are avoided. (Refer to the **EXT_TH** card in the CNTL block ñ ***nskipss*** parameter.)

3. Using the restart files, run the coupled transient case. The first step can be omitted by starting the coupled run directly with the power ramp option defined (*tdmrramp=1* in the TRACE namelist input). This option is valid only during steady-state calculations.

For coupled TRACE executions PARCS is compiled as a static library and for coupled RELAP5 executions PARCS requires the use of PVM message passing. The procedures for each coupled execution will be described in the following section.

IV.B.1 PVM Version

For the PVM coupled execution with RELAP5, PARCS should be compiled on the target platform with the proper platform-dependent compiler directives (it should be noted that the Makefile included with the PARCS distribution should automatically define the necessary directive). After the PARCS executable file has been compiled for the target platform, the user must prepare the input file according to the card-name-based input description given in Section V. Most control input cards have default values, so the responsibility of the user is reduced to preparing only the input cards necessary for solving the specific problem at hand. For problems involving 1D and/or 3D steady state or transient problems, PARCS is run in a coupled mode with RELAP5 and PARCS run simultaneously. Figure 5 below outlines the procedure for performing a coupled analysis using RELAP5 and PARCS.

The following steps are needed to actually perform each coupled run:

1. Open two windows on the screen.
2. Move to the RELAP5 run directory in one window.
3. Move to the PARCS run directory in another window. The *maptab* file described in Section V must exist in this directory, and the name of the file must be listed on the EXT_TH card of the PARCS CNTL block input.
4. Run RELAP5.
5. Run PARCS by specifying the input file name as the argument, namely, ***parcs case.inp***. If

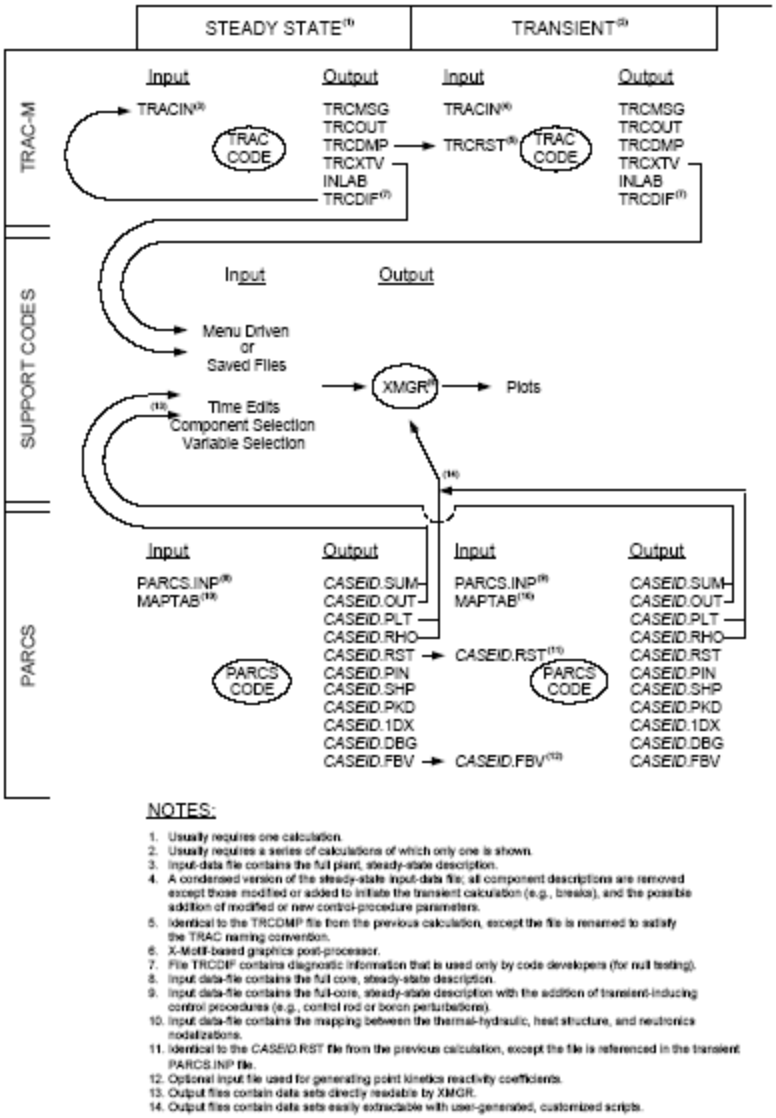
the input file name is omitted, the default file name (***parcs.inp***) will be used. When executing PARCS in the coupled 1D kinetics mode with a TRAC-B deck, no additional PARCS input is necessary. However, the TRAC-B input file named *tracin* must exist in the working directory. Running sequence is the same as the normal coupled run, but with no command line argument (specifying the PARCS input file name).

IV.B.2 Static Library Version

After version 2.6, PARCS can be compiled into both an executable and a static library which will be linked into TRACE executable. For the PARCS executable, the procedures described in the section IV.B.1 are still valid. In order to make a PARCS static library, a compiler directive ìTPMERGEî needs to be set at compile time. And the static library is linked with TRACE into a single TRACE executable. For a coupled calculation, a merged TRACE will call parcs subroutine which is available from the static library, instead of calling PVM library subroutines to communicate with a separate PARCS process. For the merged version, all the input files are same as the ones for the PVM version except that the PARCS input file name should be parcs.inp and it should exists in the same working directory as TRACE

The following steps are needed to actually perform each coupled run:

1. Open a window on the screen, instead of two windows with PVM version.
2. Move to the TRACE run directory. TRACE input file tracin and PARCS input file parcs.inp should exist in this directory.
4. Run TRACE. If it is a coupled calculation with itdmr=1, then TRACE will call parcs subroutine.



NOTES:

1. Usually requires one calculation.
2. Usually requires a series of calculations of which only one is shown.
3. Input-data file contains the full plant, steady-state description.
4. A condensed version of the steady-state input-data file; all component descriptions are removed except those modified or added to initiate the transient calculation (e.g., breaks), and the possible addition of modified or new control-procedure parameters.
5. Identical to the TRCDMP file from the previous calculation, except the file is renamed to satisfy the TRAC naming convention.
6. X-Motif-based graphics post-processor.
7. File TRCDIF contains diagnostic information that is used only by code developers (for null testing).
8. Input data-file contains the full core, steady-state description.
9. Input data-file contains the full-core, steady-state description with the addition of transient-inducing control procedures (e.g., control rod or boron perturbations).
10. Input data-file contains the mapping between the thermal-hydraulic, heat structure, and neutronics nodalizations.
11. Identical to the *CASEID*.RST file from the previous calculation, except the file is referenced in the transient PARCS.INP file.
12. Optional input file used for generating point kinetics reactivity coefficients.
13. Output files contain data sets directly readable by XMGR.
14. Output files contain data sets easily extractable with user-generated, customized scripts.

Figure 5. Summary of Coupled Code Execution Procedures

V. INPUT DESCRIPTION

V.A PARCS Input Card Description

Please refer to Section II.C for input guide lines and rules regarding the specific input cards in this section. The first active (other than comments) input card should be the CASEID card that provides an alphanumeric case ID as the first field. The case ID is used to define the output file names which are created by attaching the three character extensions (Refer to Table 2). Descriptive comments can be placed in the CASEID card. The input includes several blocks starting with the CNTL block and ending with the TRAN block. PARAM, XSEC, GEOM, TH, PFF, PLOT, and ONEDK blocks are the blocks to appear in-between. The cards of each block are described in Tables 4 through 13. Examples of each input card are shown with the syntax. If default values are to be used, the corresponding card can be omitted. It is recommended to use default parameters to make the input compact.

Table 4. CNTL Cards

Card Type	Field	Default	Description
CORE_TYPE	alwropt	PWR	Core type: PWR = Pressurized Water Reactor BWR = Boiling Water Reactor CANDU = Pressurized Heavy Water Reactor PBR = Pebble Bed Reactor
	`CORE_TYPE BWR`		
CORE_POWER	plevel	100.0	Initial core power level in %
	`CORE_POWER 70.000`		
PPM	ppm	0.0	Initial boron concentration in ppm
	`PPM 1150.0`		
SNAPID	snapid	None	snapid is printed into dep file for SNAP use only.
	SNAPID `"SID"`		
CR_WORTH	crworth	0	0, do not print k-eff into .crw fil, do not evaluate worth for control rod. 1, print k-eff into .crw file, do not evaluate worth for control rod. 2, print k-eff into .crw file, and evaluate worth for control rod.
	CR_WORTH `2`		

Table 4. CNTL Cards

Card Type	Field	Default	Description
TH_FDBK	fdbk	T	T/H feedback option, either T(rue) or F(alse) Note: If Lths=T(rue) in INP_OPT card of block, the fdbk will be set to F(alse). See details in INP_OPT card of block.
	TH_FDBK T		
XE_SM	ixesmopt	0	Xe option for steady state calculation 0-No Xe 1-Equilibrium Xe 2-Transient Xe 3-user input Xe density 4-Equilibrium Xe (this option makes the default of ixetr=2)
	ismopt	ixesmopt	Sm option for steady state calculation, this option must be the same as Xe option or be 0. 0-No Sm 1-Equilibrium Sm(only when ixesmopt=1) 2-Transient Sm(only when ixesmopt=2) 3-user input Sm density(only when ixesmopt=3) 4-Equilibrium Sm(only when ixesmopt=4)
	ixetr	ixesmop if ixesmop<2, 2 other-wise	Xe option for transient calculation 0-No Xe (only when ixesmopt=0) 1-Equilibrium Xe (only when ixesmopt=1) 2-Transient Xe (when ixesmopt>0) 3-user input Xe density (when ixesmopt=3) 4-invariant Xe (when ixesmopt>0)
	ismtr	ixetr if ismopt>0, 0 other-wise	Sm option for transient calculation 0-No Sm (only when ismopt=0) 1-Equilibrium Sm (only when ismopt=1) 2-Transient Sm 3-user input Sm density (when ixetr=3) 4-invariant Sm (when ixetr=4)
	XE_SM 1 0 2 0		
DECAY_HEAT	decheat	F	Decay heat option, T or F
	DECAY_HEAT T		
SEARCH	asrchopt	KEFF	Criticality search option, KEFF, PPM,ROD
	srchktarg	1.00	target keff for ROD search
	SEARCH ROD 0.997		

Table 4. CNTL Cards

Card Type	Field	Default	Description
BANK_POS	crbpos(1:ncrb)	BIG	Control rod bank position in steps withdrawn, **ncrb** is the number of control rod banks
	`BANK_POS 0.0 0.0 0.0 100.0 228.0 228.0` `BANK_POS 3*0.0 100.0 2*228.0`		
BANK_LLT	crbllt(1:ncrb)	0	Furthest step a control rod bank can be inserted during rod search
	`BANK_LLT 3*0.0 20.0 2*228.0`		
BANK_ULT	crbult(1:ncrb)	BIG	Furthest step a control rod bank can be withdrawn during rod search
	`BANK_ULT 3*100.0 200.0 2*228.0`		
BANK_GRP	crbgrp(1:ncrb)	1	Order in which control rods are moved during search
	`BANK_grp 2*1 2 1 2*2`		
PIN_POWER	pin	F	Pin power calculation option, T or F
	`PIN_POWER T`		
EXT_TH	extth	F	External T/H option, T or F (Must be T for coupled TRAC/PARCS runs) Note: If Lths=T(rue) in INP_OPT card of block, the fdbk will be set to F(alse). See details in INP_OPT card of block.
	afn	MAPTAB	File name of the Neutronics - T/H mapping table Refer to Section for detailed contents of the mapping table.
	sysname	TRAC	System T-H Code TRAC for TRAC-E
	nskipss	1	Steady-state external T-H skip factor (PARCS is called by the system code once per every nskipss time steps during the null transient calculation)
	nskiptr	1	Transient external T-H skip factor

Table 4. CNTL Cards

Card Type	Field	Default	Description
	etf	0	Tolerance of Doppler temperature change rate (K/s) used to time advance coulpled calculation for etion
	Mthmatch	1	During steady-state calculation, maxium number of TH steps before data exchange between PARCS and TH code (note: This option is available only in RELAP5).
	`EXT_TH T MAPTAB TRAC 50 1 0.001 0.1 5`		
TRANSIENT	tran	F	Transient calculation option, T or F
	kinopt	0	Kinetic option, 0: 3d spatial kinetics 1: point kinetics with adjoint weighted cross section change as reactivity exclude control rod reactivity component, 2: point kinetics with adjoint weighted cross section change as reactivity, 3: point kinetics with power weighted core average parameter feedback, 4: point kinetics with adjoint fission weighted core average parameter feedback, 5: point kinetics without feedback (user input reactivity), 6: no kinetics,(user input power levels), impose reactivity are acceptable for option
	inicr	T	Flag for force transient start from a critical state.Set it to force to simulate transient start from subcritical state. This option is added for users special requirement and have not been validated.
	`TRANSIENT T 0`		
RESTART	rstrt	F	Restart option
	afn	None	Input restart file, less than 80 characters long
	irstbeg	None	Restart block number from which restart begins
	`RESTART T ssinit/ss.rst 2`		

Table 4. CNTL Cards

Card Type	Field	Default	Description
PRINT_OPT (Print options)	popt(1)	F	Detailed input edit
	popt(2)	T	Iteration history display
	popt(3)	F	Planar power distributions
	popt(4)	F	Detailed pin power distributions
	popt(5)	T	Reactivity edit and adjoint flux
	popt(6)	F	Feedback component reactivity edit
	popt(7)	F	Integrated flux and precursor density edit
	popt(8)	F	Planar flux distributions
	popt(9)	F	Xe/Sm number densities
	popt(10)	F	T/H state variables
	popt(11)	F	1D collapsed group constants
	popt(12)	F	Point Kinetics Data
	popt(13)	F	Radial Power Shape
	popt(14)	F	Radial Flux Shape
	popt(15-19)		Not Used
	popt(20)	F	Single assembly homogenized group constant edit (only for pin-by-pin single assembly calc.)

	Notes:
	1) print options can be placed in several cards. The cards that comes later do NOT overwrite the previous ones.
	2) FORTRAN * format does NOT apply.
	
	Ex:
	`! input iteration planar pin reactivity`
	`! edits table power power adjoint`
	`PRINT_OPT F T F T T`
	`!`
	`! fdbk flux planar t/h`
	`! rho precur flux xe/sm parameters`
	`PRINT_OPT F T F F T`		

Table 4. CNTL Cards

Card Type	Field	Default	Description
ONED_KIN	if1dk	F	Invoke 1D kinetics module, T or F
	dum	None	'QS' for quasi-static mode and 'SA' for stand-alone mode. if dum equals 'QS', then qs1d is T.
	fn	caseid.shp	Input flux shape file name for the quasi-statics mode
	`ONED_KIN T SA` `ONED_KIN T QS demo.shp`		
ONED_XSID (use only for 1D cross section generation, this input controls the GENDA1D job)	icaser	None	Sequential Job Case ID
	iref	None	Reference Case ID for this case
	ifeedbk	None	Index for the kind of feedback or variation job 0 - no feedback or reference 1 - fuel temperature feedback 2 - moderator density feedback 3 - boron variation 7 - control rod insertion variation
	idelete	None	delete the idelete case cross section from the current case(icaser) cross section for the over-lapped control rod variation
	itfuel	None	Index of fuel temperature coordinate in the tabular form cross section set * no meaning if ifeedbk equals 3
	idmod	None	Index of moderator density coordinate in the tabular form cross section set * no meaning if ifeedbk equals 3
	`ONED_XSID 1 1 1 1 1 1`		

Table 4. CNTL Cards

Card Type	Field	Default	Description
ETION		F	Invoke etion option, T or F If is T, cards are required. Under this option, there are two effects on other cards: 1: All XSEC cards except group_spec will be ignored 2: The meaning of iprcomp in GEOM cards is changed.
	espeig	1.0 E-5	Eigenvalue convergence criteria to advance to the next etion step
	tsxs	T	Two step cross section interpolation If T, stores interpolation parameters in memory and reduces computational cost If F, does not store interpolation parameters in memory and increases computational cost
	`ETION T 1.0E-3 F`		

Table 4. CNTL Cards

Card Type	Field	Default	Description
XS_EXTRAP	instrange	0	Cross section extrapolation range for instantaneous variables. This range applies only to the branch type variable for each type of branch. If the reference state value is higher than all the branch values, then the upper limit for the extrapolation is the reference + instrange*(reference- maximum branch value) and the lower limit of the extrapolation is the reference - (1+instrange)* (reference- minimum branch value). If the reference state value is lower than all branches values, then the upper limit for the extrapolation is the reference + (1+instrange)*(maximum branch value -reference) and the lower limit of the extrapolation is the reference - instrange* (reference- minimum branch value). Otherwise, the upper limit of the extrapolation is the reference + (1+instrange)*(maximum branch value -reference) and the lower limit of the extrapolation is the reference - (1+instrange)* (reference- minimum branch value).
	histrange	instrange	Cross section extrapolation range for history variables.
	instpartr	instrange	Partial derivatives of cross section extrapolation range for instantaneous variables. This range applies to all variables. The lower limit will be (1+instpartr)*(minimum branch value) - instpartr*(second minimum branch value). The upper limit will be (1+instpartr)*(maximum branch value) - instpartr*(second maximum branch value).
	histpartr	histrange	Partial derivatives of cross section extrapolation range for history variables.
	XS_EXTRAP 1.0 0.3 0.8 0.2		

Table 4. CNTL Cards

Card Type	Field	Default	Description
ROT_ADF	rotadf	F	Assembly rotation option, T or F
	`ROT_ADF T`		
DETECTOR	detector	F	Detector response calculation, T or F
	fnormd	1	Normalization factor for detector response
	DETECTOR T 5.0E+6		

Table 4. CNTL Cards

Card Type	Field	Default	Description
TREE_XS	Tree	F	Invoke tree structure XS module, T or F If tree is T, the cross sections always provided by either a separate XESC file of etion module. The tree structure cross section format is described in Purdue Macroscopic Cross Section Library Format
	NSet	None	Number of XS sets. if is T, NSet should be the number of fule zones(burnup regions) plus the number of XS sets for reflector regions.
	The following flags indicate use or not use of the value provided by the XS file. If the flag is 'F', then default values will be used. If the values from XS file are the same as the default values, the user may use 'F' to reduce the computational cost.		
	Ladf	T	Assembly discontinuity factor
	Lxes	T	Microscopic cross section of Xe and SM, No default value
	Lded	F	Direct energy deposition fraction, default value 0
	Lj1f	F	J1 factor for minimal critical power ratio, default:1
	Lchi	F	Fission spectrum, default X(1)=1
	Lchd	F	Delay neutron fission spectrum, default Xd(i)=X(i)
	Linv	F	Inverse velocity, no default value, must be 'T' for transient
	Ldet	F	Detector response XS, no default
	Lyld	F	yield values of I, XE, Pm, the default yield values are:0.06386,0.00228,0.0113
	Lcdf	F	Corner discontinuity factor, default 1
	Lgff	F	Group wise power form function, default 1
	Lbet	F	Beta, default:0.0002584,0.00152,0.0013908
	Lamb	F	Lambda, default: 0.0128,0.0318,0.119,0.3181,1.4027,3.9286

Table 4. CNTL Cards

Card Type	Field	Default	Description
	Ldec	F	Decay heat beta and lambda, default: Beta: 2.35402E-02,1.89077E-02,1.39236E-02 6.90315E-03,3.56888E-03,3.31633E-03 Lamb:1.05345E-01,8.37149E-03,5.20337E-04 4.73479E-05,3.28153E-06,1.17537E-11
	Lzdf	F	z-direction discontiuity factor.
	TREE_XS T 1024 T T F F F F F F F F F F F F F		

Table 5. PARAM Cards

Card Type	Field	Default	Description
LSOLVER	linearsolver	2	option for linear solver 1:GMRES 2:bicgstab
	precond	1	reserved for preconditionning option
	ngmresvec	20	number of Stored GMRES vectors
	`LSOLVER 1 1 10`		
N_ITERS	ninmax	 1 2 4	Maximum number of inner iterations BICGSTAB for non-hex geometry BICGSTAB for hex geometry GMRES
	noutmax	500	Maximum number of outer iterations
	`N_ITERS 1 250`		
CONV_SS (Steady-State Convergence Criteria)	epseig	1.0E-6	Eigenvalue (k-effective) convergence criterion
	epsl2	1.0E-5	Global fission source convergence criterion
	epslinf	5.0E-4	Local fission source convergence criterion
	epstf	0.001	Fuel temperature convergence criterion
	`CONV_SS 1.0e-6 1.0e-5 5.0e-5 0.001`		
WIELANDT	eshift	0.04	exp(-eshift) is fraction of Eigenvalue shift
	eshift0	10.0	Factor for eigenvalue evaluation error. If eshift0<=1, then it will be assigned as 10
	targetk	1.0	Target k-eff in a criticality search
	`WIELANDT 0.04 0.1 1.0`		
COSS_RELAX	cossrelax_start	1.0E6	Relaxiation staring time
	cossrelax_param	0.0	Relaxiation parameter
	COSS_RELAX 20.0 0.8		

Table 5. PARAM Cards

Card Type	Field	Default	Description
NODAL_KERN	kernel	hybrid	Nodal kernels: FDM - Finite Difference only HYBRID - ANM/NEM nodal hybrid ANM - Analytic Nodal Method FMFD - Fine Mesh Finite Difference NEMMG - Multigroup NEM TPEN - Triangular Polynomial Expansion Nodal method (Hexagonal Geometry)

	`NODAL_KERN FDM`
	`NODAL_KERN HYBRID`
	`NODAL_KERN ANM`
	`NODAL_KERN FMFD`
	`NODAL_KERN NEMMG`
	`NODAL_KERN TPEN`		

CMFD	cmfd_op	1	1: CMFD with D_ hat 2: CMFD with correction factors for discontinuity factor and diffusion coefficient.
	CMFD 2		
NSPN	npn	1	Solver for multigroup nodal methods 1: Diffusion 3: SP3
NLUPD_SS	nupdcy	3	Nonlinear update cycle (e.g. every 3 outers)
	ninitout	3	Initial outers before the first nonlinear update
	nmulth	1	Number of T/H updates per nodal update
	`NLUPD_SS 10 10 1`		
EPS_ANM	epsanm	0.005	Near-criticality criterion needed for ANM stabilization
	`EPS_ANM 1.0e-06`		
EPS_ERF	epserf	0.005	Error reduction criterion to exit inners
	`EPS_ERF 0.0005`		
DECUSP	idecusp	0	Control rod cusping option 0 - no decupsing 1 - flux shape correction only 2 - axial discontinuity as well (2 is not available in 1D kinetics module)
	`DECUSP 1`		

Table 5. PARAM Cards

Card Type	Field	Default	Description
INIT_GUESS	iguess	1	Initial guess for the axial flux shape 0 - cosine 1 - flat
	`INIT_GUESS 0`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
GROUP_SPEC	mg	2	Number of Groups, If this card is present, the multigroup option, NEMMG, TPENMG is turned on even though the number of groups is 2.
	mge(1)	mg/2	The last fine group number belonging to the first group in the two-group structure.
	GROUP_SPEC 2 1		
FUNC_TYPE	ioptxsf	none	11: mslb xsec 12: vver rod ejection xsec 13: pbtt xsec 14: mslb xsec 15: v1000ct 152: 4-dimensional xsec tables for v1000ct-2 the later fields in this card are used for iop-txsf=152 only
	ncmpur11	843	unrodded cross section sets
	ncmpr11	330	rodded cross section sets
	nfuelxsec	5	fuel temperature points
	ntmodxsec	5	coolant temperature points
	nrhoxsec	6	coolant density points
	nboronxsec	0	boron concentration points
	`FUNC_TYPE 152 840 300 4 4 3 2`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
EFIL_XS_UR	mslbuxpath/pbttuxpath	None	External file for unrodded cross sections. If func_type is 13 (pbttxsec), this entry is the unrodded cross section file for PBTT bencmark. If func_type is 14 (mslbxsec), this entry is the unrodded cross section file for MSLB bencmark.
	`EFIL_XS_UR  './PBTT_xsec_unrodded'`		
EFIL_XS_R	mslbxpath/pbttxpath	None	External file for rodded cross sections. If func_type is 13 (pbttxsec), this entry is the rodded cross section file for PBTT bencmark. If func_type is 14 (mslbxsec), this entry is the rodded cross section file for MSLB bencmark.
	`EFIL_XS_R   './PBTT_xsec_rodded'`		
EFIL_XENON	pbttxepath	None	External file for Xenon Number Density in PBTT Benchmark.
	`EFIL_XENON './3D_Xenon_Number_Density.txt'`		
		none	
REF_COND	ppmref	0.	Reference boron concentration, ppm
	tmref	0.	Reference moderator temperature, $°C$
	dmref	0.	Reference moderator density, g/cm^3
	tfref	0.	Reference fuel temperature, $°C$
	`REF_COND   1650.0   290.0   0.8  500.0`		
COMP_NUM	ic	None	Composition number for which subsequent cards define cross sections. ***Note : composition number is valid until the next comp_num card is read***
	`COMP_NUM   2`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
BASE_MACRO (Base Macroscopic Cross Sections)	sigtr(1,ic)	None	Group 1 transport
	siga(1,ic)	None	Group 1 absorption
	signf(1,ic)	None	Group 1 nu-fission
	sigkf(1,ic)	None	Group 1 kappa-fission
	sig12(ic)	None	Group 1 down-scattering
	sigtr(2,ic)	None	Group 2 transport
	siga(2,ic)	None	Group 2 absorption
	signf(2,ic)	None	Group 2 nu-fission
	sigkf(2,ic)	None	Group 2 kappa-fission
	sigf(1,ic)	None	Group 1 fission*
	sigf(2,ic)	None	Group 2 fission*

	`BASE_MACRO 2.22117e-1 8.71774e-3 4.98277e-3 6.11189e-14 1.82498e-2`
	`8.03140e-1 6.52550e-2 8.39026e-2 1.10152e-12 2.07625e-3 3.495917e-2`
	
	`*optional, but must be present to compute Xe/Sm concentration in ixesmopt=1/2 of XE_SM card of CNTL Block`		

DXS_DPPM	dsigtr(1,1,ic) ... dsigkf(1,2,ic)	9*0.0	Macro XS change per unit ppm change for each of the 9 cross section components
	`DXS_DPPM 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07` `-9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17`		
DXS_DTM	dsigtr(2,1,ic) ... dsigkf(2,2,ic)	9*0.0	Macro XS change per unit moderator temperature change ($°C$) for each of the 9 cross section components
	`DXS_DTM 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07` `-9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17`		
DXS_DDM	dsigtr(3,1,ic) ... dsigkf(3,2,ic)	9*0.0	Coefficient of the **first-orde**r term of the macro XS variation with respect to moderator density change (g/cm^3) for each of the 9 cross section components
	`DXS_DDM 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07` `-9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
DXS_DTF	dsigtr(4,1,ic) ... dsigkf(4,2,ic)	9*0.0	Macro XS change per unit Doppler temperature change ($\sqrt{K}$) for each of the 9 cross section components
	DXS_DTF 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07 -9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17		
DXS_DDM2	dsigtr(5,1,ic) ... dsigkf(5,2,ic)	9*0.0	Coefficient of the **second-order** term of Macro XS variation with respect to moderator density (g/cm^3) for each of the 9 cross section components
	DXS_DDM2 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07 -9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17		
DXS_DVOID	dsigtrdv(1,1,ic) ... dsigkfdv(1,2,ic)	9*0.0	Coefficient of the **first-order** term of Macro XS variation with respect to void for each of the 9 cross section components
	DXS_DVOID 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07 -9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17		
DXS_DVOID2	dsigtrdv(2,1,ic) ... dsigkfdv(2,2,ic)	9*0.0	Coefficients of the **second-order term** of Macro XS variation with respect to void for each of the 9 cross section components
	DXS_DVOID2 3.478090e-08 1.285050e-07 -1.120990e-09 -1.761878e-20 -1.085900e-07 -9.765100e-06 7.088070e-06 -2.430450e-06 -3.190845e-17		

Table 6. XSEC Cards

Card Type	Field	Default	Description
ADF (Assembly Discontinuity Factor)	sigadf(1,1,ic)	1.0	North side Group 1 ADF
	sigadf(1,2,ic)	1.0	North side Group 2 ADF
	sigadf(2,1,ic)	sigadf (1,1,ic)	East side Group 1 ADF, can be omitted in case of surface independent ADF
	sigadf(2,2,ic)	sigadf (1,2,ic)	East side Group 2 ADF, can be omitted in case of surface independent ADF
	sigadf(3,1,ic)	sigadf (2,1,ic)	South side Group 1 ADF, can be omitted in case of surface independent ADF
	sigadf(3,2,ic)	sigadf (2,2,ic)	South side Group 2 ADF, can be omitted in case of surface independent ADF
	sigadf(4,1,ic)	sigadf (3,1,ic)	West side Group 1 ADF, can be omitted in case of surface independent ADF
	sigadf(4,2,ic)	sigadf (3,2,ic)	West side Group 2 ADF, can be omitted in case of surface independent ADF
	`ADF 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00`		
CDF (Corner Discontinuity Factor for Pin Power Calculation)	sigcdf(1,1,ic)	1.0	Group 1 CDF at the assembly corner
	sigcdf(1,2,ic)	1.0	Group 2 CDF at the assembly corner
	sigcdf(2,1,ic)	sigcdf (1,1,ic)	Group 1 CDF at the assembly symmetry line, can be omitted
	sigcdf(2,2,ic)	sigcdf (1,2,ic)	Group 2 CDF at the assembly symmetry line, can be omitted
	sigcdfr(1,1,ic)	sigcdf (1,1,ic)	Group 1 CDF at the assembly corner when rodded, can be omitted
	sigcdf(1,2,ic)	sigcdf (1,2,ic)	Group 2 CDF at the assembly corner when rodded, can be omitted
	sigcdf(2,1,ic)	sigcdfr (1,1,ic)	Group 1 CDF at the assembly symmetry line when rodded, can be omitted
	sigcdf(2,2,ic)	sigcdfr (1,2,ic)	Group 2 CDF at the assembly symmetry line when rodded, can be omitted
	`CDF 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00 1.000000e+00`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
DELCR_COMP (Delta Control Rod Composition)	icr	None	Control Rod Composition number for which subsequent cards define delta cross sections, control rod composition number is valid until the next delcr_comp card is read
	icrcomp(:)	None	Compositions which will use DELCR composition *icr,* negative number appearing as the second in a pair means sequential expansion

	! delcr composition 1 applied to compositions 1 through 5 and 7 through 11
	`DELCR_COMP 1 1 2 3 4 5 7 8 9 10 11`
	`DELCR_COMP 1 1 -5 7 -11 !Compostions that this set applies`		

DELCR_BASE	delcontr(1,icr) ... delconkf(2,icr)	9*0.0	Macro XS change due to control rod insertion
	`DELCR_BASE 3.732200e-03 2.477700e-03 -1.027860e-04 -1.214480e-15 -3.192530e-03 -2.199260e-02 2.558750e-02 -2.823190e-03 -3.702378e-14`		
DNP_NGRP	nprec	6	Number of delayed neutron precursor groups
	`DNP_NGRP 6`		
KIN_COMP (Kinetics Composition)	ick	None	Kinetics composition number for which subsequent cards defines the kinetics data, kinetics composition number is valid until the next kin_comp card is read
	kincomp(:)	None	Composition numbers which will use kinetics composition *ick*, negative number appearing as the second in a pair means sequential expansion
	! kinetics composition1 applied to compositions 1 through 11 `KIN_COMP 1 1 -11 !Compositions that this set applies`		
DNP_BETA	tbeta (1:nprec,ick)	NEACRP Spec.	Delayed neutron fraction (defaults - `0.0002584, 0.00152, 0.0013908, 0.0030704, 0.001102, 0.0002584`)
	`DNP_BETA 0.0002584 0.00152 0.0013908 0.0030704 0.001102 0.0002584`		
DNP_LAMBDA	rambda (1:nprec,ick)	NEACRP Spec.	Delayed neutron precursor decay constant, 1/sec (defaults - `0.0128, 0.0318, 0.119, 0.3181, 1.4027, 3.9286`)
	`DNP_LAMBDA 0.0128 0.0318 0.119 0.3181 1.4027 3.9286`		

Table 6. XSEC Cards

Card Type	Field	Default	Description
NEUT_VELO	tvelo(1:2,ick)	2.8e7 4.4e5	Neutron velocity, cm/sec
	NEUT_VELO 2.8e+07 4.4e+05		
IXEPM_LAM	rlambi	0.28750E-4	Decay constant of I
	rlambxe	0.209167E-4	Decay constant of Xe
	rlambpm	0.355568E-5	Decay constant of Pm
	IXEPM_LAM 0.28750E-04 0.209167E-04 0.355568E-08		
IXEPM_YLD	gammafp(1,ic)	0.06386	Fission yield of I
	gammafp(2,ic)	0.00228	Fission yield of Xe
	gammafp(3,ic)	0.0113	Fission yield of Pm
	IXEPM_YLD 0.06386 0.00228 0.0113		
XESM_MICRO	sigxea(1,ic)	1.05279E2	Group 1 Xe absorption micro xsec, barn
	sigxea(2,ic)	1.45710E6	Group 2 Xe absorption micro xsec, barn
	sigsma(1,ic)	9.07729E1	Group 1 Sm absorption micro xsec, barn
	sigsma(2,ic)	5.52864E4	Group 2 Sm absorption micro xsec, barn
	XESM_MICRO 1.05279E+02 1.45710E+06 9.07729E+01 5.52864E+04		
DXESM_DPPM	dsigxea(1,1,ic)	0.	Group 1 Xe absorption micro xsec change per unit ppm change
	dsigxea(1,2,ic)	0.	Group 2 Xe absorption micro xsec change per unit ppm change
	dsigsma(1,1,ic)	0.	Group 1 Sm absorption micro xsec change per unit ppm change
	dsigsma(1,2,ic)	0.	Group 2 Sm absorption micro xsec change per unit ppm change
	DXESM_DPPM 0.101 2.45E-01 0.99E-01 5.52		
DXESM_DTM	dsigxea(2,1,ic) ... dsigsma(2,2,ic)	4*0.	Xe and Sm absorption micro xsec change per unit moderator temperature change ($^{\circ}C$) for each of the 4 micro components
	DXESM_DTM 0.101 2.45E-01 0.99E-01 5.52		

Table 6. XSEC Cards

Card Type	Field	Default	Description
DXESM_DDM	dsigxea(3,1,ic) ... dsigsma(3,2,ic)	4*0.	Coefficient of the first order variation term of Xe and Sm absorption micro xsec change with respect to moderator density change (g/cm^3) for each of the 4 micro components
	DXESM_DDM 0.101 2.45E-01 0.99E-01 5.52		
DXESM_DTF	dsigxea(4,1,ic) ... dsigsma(4,2,ic)	4*0.	Xe and Sm absorption micro xsec change per unit Doppler temperature change ($\sqrt{K}$) for each of the 4 micro components
	DXESM_DTF 0.101 2.45E-01 0.99E-01 5.52		
DXESM_DDM2	dsigxea(5,1,ic) ... dsigsma(5,2,ic)	4*0.	Coefficient of the **second-order** variation term of Xe and Sm micros with respect to moderator density (g/cm^3) for each of the 4 micro components
	DXESM_DDM2 0.101 2.45E-01 0.99E-01 5.52		
DELCR_XESM	dcontxea(1,icr) ... dcontsma(2,icr)	4*0.	Xe and Sm micro XS change due to control rod insertion, barn
	DELCR_XESM 0.101 2.45E-01 0.99E-01 5.52		
DHP_BETA	decalpha(1:6)	ANL	Decay heat precursor yield fraction (Defaults - 2.35402E-02,1.89077E-02,1.39236E-02, 6.90315E-03,3.56888E-03,3.31633E-03)
	DHP_BETA 2.35E-02 1.89E-02 1.39E-02 6.90E-03 3.57E-03 3.32E-03		
DHP_LAMBDA	decalpha(1:6)	ANL	Decay heat precursor decay constant, 1/sec (Defaults - 1.05345E-01,8.37149E-03, 5.20337E-04,4.73479E-05, 3.28153E-06,1.17537E-11)
	DHP_LAMBDA 1.05E-01 8.37E-03 5.20E-04 4.73E-05 3.28E-06 1.18E-11		
Note) - In 1D kinetics module, the input cards related to cross section set are introduced externally except the cards for kinetics parameters and decay heats.			

Table 6. XSEC Cards

Card Type	Field	Default	Description
DDDC	dddc_comp_num	none	Number of compositions for which directional diffusion coefficients will be applied
	dddccfr	none	Factor to be multiplied by the diffusion coefficient in the radial direction
	dddccfz	none	Factor to be multiplied by the diffusion coefficient in the axial direction
	`DDDC 7 0.1 0.5`		

Table 7. GEOM Cards

Card Type	Field	Default	Description
GEO_DIM	nasyx	2	Number of assemblies in x-direction
	nasyy	1	Number of assemblies in y-direction
	nz	1	Number of planes in z-direction
	nzbr	0	Number of planes for bottom reflector
	nztr	0	Number of planes for top reflector
	`GEO_DIM 9 9 20 1 1`		
SYMMETRY	isymmetry	1	Symmetry option for rectangular geometries: 1 == full core 2 == half core 4 == quarter core
RAD_CONF	iradconf (1:nasyx, 1:nasyy)	None	Radial core configuration. Thereare two different means of numbers in this map depended on the reactor core is described by PLANAR_REG cards or ASSY_TYPE cards. If core is described by PLANAR_REG cards, then the number in RAD_CONF means 0 - dummy region 1 - reflector region >1 - fuel region If core is described by ASSY_TYPE cards, then the number in RAD_CONF means 0 - dummy region > 0 - fuel or reflector assembly index. The core must be decribed with ASSY_TYPE cards for the multicyclecalcualtion.

	`RAD_CONF`
	`2 2 2 2 2 2 2 2 1`
	`2 2 2 2 2 2 2 2 1`
	`2 2 2 2 2 2 2 1 1`
	`2 2 2 2 2 2 2 1 0`
	`2 2 2 2 2 2 1 1 0`
	`2 2 2 2 2 1 1 0 0`
	`2 2 2 2 1 1 0 0 0`
	`2 2 1 1 1 0 0 0 0`
	`1 1 1 0 0 0 0 0 0`		

Table 7. GEOM Cards

Card Type	Field	Default	Description
COORDINATE	idum	1	Coordinate system of the problem: 1 == cartesian 2 == cylindrical
GRID_X or GRID_R	hasyx(1:nasyx)	nasyx*10	Mesh spacing in x-direction (cartesian) or r-direction (cylindrical), cm
	GRID_X 10.803 8*21.606 GRID_R 78.6 32.3 24.8 20.9 18.4 6.0 13.0 21.0 20.0 15.0 25.0		
GRID_Y or GRID_THETA	hasyy(1:nasyy)	1	Mesh spacing in y-direction (cartesian) in cm or theta-direction (cylindrical) in degrees
	GRID_Y 10.803 8*21.606 GRID_THETA 1#3.0		
GRID_Z	hz(1:nz)	1	Axial node size, cm
	GRID_Z 10.803 8*21.606		
NEUTMESH_X or NEUTMESH_R	nneutx(1:nasyx)	nasyx*1	Number of neutronic mesh per assembly or coarse mesh in -x or -r direction
	NEUTMESH_X 1 8*2 NEUTMESH_R 1 1 1 1 1 1 1 1 1 1 1		
NEUTMESH_Y or NEUTMESH_THETA	nneuty(1:nasyy)	nasyy*1	Number of neutronic mesh per assembly or coarse mesh in -y or -theta direction.
	NEUTMESH_Y 1 8*2 NEUTMESH_THETA 1*1		
BNDLMESH_X or BNDLMESH_R	nmbx(1:nxb)	nneutx(1:nasyx)	Number of neutronic mesh per bundle in -x or -r direction. The sum of nmbx should bethe same as the sum of nneutx. See note after BNDLMESH_Z
	BNDLMESH_X 1 8*2		
BNDLMESH_Y or BNDLMESH_T	nmby(1:nyb)	nneuty(1:nasyy)	Number of neutronic mesh per bundle in -y or -theta direction. The sum of nmby should be the same as the sum of nneuty. See note after BNDLMESH_Z
	BNDLMESH_Y 1 8*2		

Table 7. GEOM Cards

Card Type	Field	Default	Description
BNDLMESH_Z	nmbz(1:nyz)	nneuty(1:nasyy)	Number of neutronic mesh per bundle in -y or -theta direction. The sum of nmby should be equal to nz. See note below
	BNDLMESH_Z 1 5*2 1		
* Note: BNDLMESH_X(R),BNDLMESH_Y(T) and BNDLMESH_Z define bundles for average power and burnup (and histories). If all default are used then the bundles will be per assembly per plane. With these three cards, the user can define burnup regions which can be the neutronics node, or the assembly node, or some nodes within the same assembly node, or even combinations of some assembly nodes.			
BOUN_COND	ibcx(1:2)	2*0	Boundary conditions for left (1) and right (2) sides in each direction -1: periodic boundary condition, -1 must appeared as pair. such as case 1: ibcx(1)=ibcy(1)=-1, the rest are not -1, in this case the core has 90 degree rotation sysmentry. case 2: ibcx(1)=ibcx(2)=-1, the rest are not -1, in this case the core has peridic boundary condtion on x direction. case 3: ibcy(1)=ibcy(2)=-1, the rest are not -1, in this case the core has peridic boundary condtion on y direction. case 2: ibcx(1)=ibcx(2)=ibcy(1)=ibcy(2)-1, the rest are not -1, in this case the core has peridic boundary condtion on both xand y direction. 0 - reflective 1 - zero flux 2 - zero incoming current 3 - Albedo(=Jin/Jout), when 3 is chosen, ALBEDO_* card is needed.
	ibcy(1:2)	2*0	
	ibcz(1:2)	2*0	
	BOUN_COND 0 2 0 2 2 2		
ALBEDO_ZL, ALBEDO_ZR, ALBEDO_E, ALBEDO_W, ALBEDO_N, ALBEDO_S, ALBEDO_R	alzl(1:ng), alzr(1:ng)	None	albedo for each group, ZL for bottom, ZR for top, R for all radial outer boundary, and E/W/N/S for east/west/north/south surfaces respectivily.
	ALBEDO_ZL 0.18732 1.3925E-01 ALBEDO_ZR 0.18732 1.3925E-01		

Table 7. GEOM Cards

Card Type	Field	Default	Description
PLANAR_REG	ipr	None	Planar region number
	iprcomp (1:nxya,ipr)		Planar region compositions assigned to each non-dummy region of the radial configuration (RAD_CONF), better to be given in a 2D array form (nxya is the number of nonzeros in the RAD_CONF card) If is T in CNTL cards, the regions with same structure but different burnup will be assigned to same composition number.
	PLANAR_REG 2 4 5 4 5 4 5 4 6 2 5 4 5 4 5 4 6 6 2 4 5 4 5 4 5 6 3 2 5 4 5 4 5 6 6 2 4 5 4 5 4 6 3 2 5 4 5 6 6 3 2 4 6 6 6 3 2 6 6 3 2 2 2 2 2		
PR_ASSIGN	izpr(1:nz)	None	Planar region assignment to each plane
	PR_ASSIGN 1 2 15*3 1 ! for 18 planes		
ASSY_TYPE	Iat	None	The assembly type number that this card defines
	icomp(1:nz)	None	The composition numbers specified for each planar level. The * format applies for repetition.
	asstype	FUEL	FUEL/REFL for fuel or reflector assemblies
	assy_type 1 10*1 FUEL assy_type 2 10*2 assy_type 3 10*3 FUEL assy_type 4 10*4 REFL assy_type 5 10*5 REFL assy_type 6 5*4 5*3 REFL		
CR_AXINFO (Control Rod Axial Info.)	crbpos0	0.0	Control rod **full insertion position** from the bottom (PWR) or top (BWR) of the core (including reflector), cm
	crbstep	1.0	Control rod step size, cm
	ncrbstep	none	Maximum number of steps
	CR_AXINFO 25.0 0.15		

Table 7. GEOM Cards

Card Type	Field	Default	Description
BANK_CONF	iradconf (:,1:nasyy)	nxya*0	Control rod banks defined for each non-dummy region of the radial configuration, 0 means no bank defined
	BANK_CONF 1 0 2 0 0 0 3 0 0 0 4 0 0 0 6 0 0 0 2 0 5 0 6 0 6 0 0 0 0 0 4 0 0 0 0 0 0 6 0 7 0 0 0 0 6 0 0 0 0 0 3 0 6 0 0 0 0 0 0 0 0 0 0 0		
PINCAL_LOC	iradconf (:,1:nasyy)	nxya*0	Radial locations at which the pin power calculation is to be performed, any nonzero value turns on pin power calculation at that location
	PINCAL_LOC 1 0 2 0 0 0 3 0 0 0 4 0 0 0 6 0 0 0 2 0 5 0 6 0 6 0 0 0 0 0 4 0 0 0 0 0 0 6 0 7 0 0 0 0 6 0 0 0 0 0 3 0 6 0 0 0 0 0 0 0 0 0 0 0		
CRB_DEF	ncrbtype itype icrbcmp(itype,:) cmplnth(itype,:)	1 1 1 1.0E+30	The number of CRB types defined in this card. CRB type index. The composition ID's for the CRB type itype. The lengths of the compositions.
	CRB_DEF 2 1 0 1 2.994 365.056 2 0 2 1 2.994 14.602 350.454		
CRB_TYPE	icrbtype(1:ncrb)	1	The CRB types for each control rod banks.
	CRB_TYPE 1 2 1 1 1 1 2 1 2 1		
CRB_GTUBE	icrbgt(1:ncrb)	0	The control rod composition index for the guide tube, if present. Note: 0 indicates that the guide tube is not treated
	CRB_GTUBE 1 2 1 1 1 1 2 1 2 1		

Table 7. GEOM Cards

Card Type	Field	Default	Description
ADF_ROT	nrotfa (:,1:nasyy)	nxya*0	The index of assembly rotation : 0/1/2/3 means rotate assembly 0/90/180/270 degree anti-clock wise.
	ADF_ROT 1 2 3 0		
DET_XY_LOC	nxydet	0	Total number of type1 detectors (see note after DET_LOC card for definitition of detector types).
	ndetfa (1:nasyx,1:nasyy)	nxya*0	Radial location at which detector response is to be calculated (any non-zero value turns on detector response calculation at that location, assemblies contributing to the same detector response are grouped by non-zero value)
	DET_XY_LOC 12 1 1 2 2 1 1 2 2 0 0 3 3 0 0 3 3		
DET_Z_LOC	nzdet	0	Total number of levels.
	nzdg	1	Plane grouping.
	kdet(1:nzdet*nzdg)	nxya*0	Axial plane at which detector response is to be calculated.
	DET_Z_LOC 2 2 1 2 5 6		Example note: there are 2 axial detector positions and each position contains 2 planes. The first position contains planes 1 and 2, the second position contains plane 5 and 6.
DET_Z_WEI	Weidet (nzdet*nzdg)	nzdet* nzdg*1.0	Contribution (weight) of the plane to the detector response. Usually this will be the detector height within the plane.This card must be given after DET_Z_LOC card.
	DET_Z_WEI 4*6.0		Example note: The weight of all 4 planes is 6.0.

Table 7. GEOM Cards

Card Type	Field	Default	Description
DET_NAME	i, detame(1:ndetect)	none	Detector number (consistent with the one provided in the DET_XY_LOC card.
	DET_NAME 1 D_16-57 2 D_24-57 3 D_32-57		
DET_LOC	ndetect	0	number of type 2 detectors
	ind	none	index of detector
	direct	none	1/2/3 the detector runs along x/y/z direction
	xpos	none	x-coordinate for starting position of detector (in cm)
	ypos	none	y-coordinate for starting position of detector (in cm)
	zpos	none	z-coordinate for starting position of detector (in cm)
	leng	none	length of detector (in cm)
	radius	none	radius of detector (in cm)
	egrp	ng	the neutron flux energy group used to calculate the detector response
	det_loc 2 1 2 185.740 200.035 495.305 85.73 1.5 2 2 1 214.310 214.313 445.770 85.73 1.5 2		
Note: There are two type of detectors which can be modeled in PARCS. Type 1: LPRM detectors for the BWR which are located at the corners of fuel assemblies. This type of detectors is described with cards det_xy_loc, det_z_loc, det_wei, and det_name. Type 2: Detectors at any location. This type of detector is described with card DET_LOC. These two type of detectors can not appear in same PARCS input.			
CUSTOM_CR	ncrb	none	number of control rod banks
	CUSTOM_CR 2		

Table 7. GEOM Cards

Card Type	Field	Default	Description
CCR_BANK	ib	none	|ib| is the bank index If ib<0, this bank will remain out during scram
	levels	none	Number of levels of the path of this bank. The levels are defined in the following cards.
	gt	0	The control rod composition index for the guide tube. Note: 0 indicates that the guide tube is not treated
			The following fields of this card are repeated for each level
	dist	none	distance from the far end of this level to the tip of the fully inserted rod position
	nodes	none	Number of nodes traversed by this rod bank at this level. "node" sets consisting of three numbers (la, k, f) will be given in this line after the "nodes" entry.
	l	none	assembly index in x-y or hex plane
	k	none	axial plane index
	f	none	total rod fraction when control rod passes through the node
	CCR_BANK -1 3 0 30.0 3 1 3 1.0 2 3 1.0 3 3 1.0 60.0 3 1 2 1.0 2 2 1.0 3 2 1.0 90.0 3 1 1 1.0 2 1 1.0 3 1 1.0		

Table 7. GEOM Cards

Card Type	Field	Default	Description
CANDU_CONF	ixzconf (1:nx, 1:nz)	nx*nz*0	CANDU control rod banks defined for each non-dummy region of the vertical configuration (xz plane), 0 means no bank defined
	CANDU_CONF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 4 4 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 3 0 0 0 0 0 0 0 5 5 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 3 3 0 0 0 0 0 0 0 5 5 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 6 6 0 0 0 0 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 6 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		
CANDU_CONF	ixzconf (1:nx, 1:nz)	nx*nz*0	CANDU control rod banks defined for each non-dummy region of the vertical configuration (xz plane), 0 means no bank defined
	CANDU_CONF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 4 4 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 3 0 0 0 0 0 0 0 5 5 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 3 3 0 0 0 0 0 0 0 5 5 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 6 6 0 0 0 0 0 0 0 0 0 0 0 2 2 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 6 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		
Note) - For 1D kinetics module, the z-direction information from the GEO_DIM, GRID_Z, BOUN_COND, CR_AXINFO cards is transferred to the 1D module.			

Table 8. PFF Cards

Card Type	Field	Default	Description
NPIN_SIDE	npin	None	Number of fuel pins along a side of an assembly
	`NPIN_SIDE 17.0`		
PFF_GEOM	ntype	NODE	Power form function (PFF) geometry, either ASMB or NODE, if NODE, PFFs are given only for the northwest quadrant of the assembly, otherwise for full assembly.
	`PFF_GEOM NODE`		
PFF_COMP	ipff	None	PFF set ID
	iffset(:)	None	Compositions to which the current PFF set applies
	`PFF_COMP 1 4 5 6 10`		
PFF_UNRODD	m	None	Energy group number to which the subsequent unrodded PFF set applies
	ff(m,:,:,ipff)	1.0	Group power form function for each pin. If PFF are specified for only one group, the same PFF's are assigned to the other group

	`pff_unrodd 1 !group 1 of set 1`
	
	`1.1015 1.1011 1.1004 1.0994 1.0983 1.0977 1.0976 1.0975 1.0974`
	`1.1011 1.1005 1.0993 1.0977 1.0959 1.0943 1.0953 1.0953 1.0942`
	`1.1004 1.0993 1.0968 1.0937 1.0918 0.0000 1.0926 1.0927 0.0000`
	`1.0994 1.0977 1.0937 0.0000 1.0903 1.0911 1.0930 1.0932 1.0919`
	`1.0983 1.0959 1.0918 1.0903 1.0910 1.0908 1.0926 1.0927 1.0915`
	`1.0977 1.0943 0.0000 1.0911 1.0908 0.0000 1.0912 1.0913 0.0000`
	`1.0976 1.0953 1.0926 1.0930 1.0926 1.0912 1.0925 1.0925 1.0912`
	`1.0975 1.0953 1.0927 1.0932 1.0927 1.0913 1.0925 1.0925 1.0912`
	`1.0974 1.0942 0.0000 1.0919 1.0915 0.0000 1.0912 1.0912 0.0000`		

Table 8. PFF Cards

Card Type	Field	Default	Description
PFF_RODDED	m	None	Energy group number to which the subsequent rodded PFF set applies
	ff(m,:,:,ipff)	1.0	Group power form function for each pin. If PFF are not specified for rodded configuration, the unrodded PFF's are assigned.
	pff_rodded 1 !group 1 of set 1 1.1015 1.1011 1.1004 1.0994 1.0983 1.0977 1.0976 1.0975 1.0974 1.1011 1.1005 1.0993 1.0977 1.0959 1.0943 1.0953 1.0953 1.0942 1.1004 1.0993 1.0968 1.0937 1.0918 0.0000 1.0926 1.0927 0.0000 1.0994 1.0977 1.0937 0.0000 1.0903 1.0911 1.0930 1.0932 1.0919 1.0983 1.0959 1.0918 1.0903 1.0910 1.0908 1.0926 1.0927 1.0915 1.0977 1.0943 0.0000 1.0911 1.0908 0.0000 1.0912 1.0913 0.0000 1.0976 1.0953 1.0926 1.0930 1.0926 1.0912 1.0925 1.0925 1.0912 1.0975 1.0953 1.0927 1.0932 1.0927 1.0913 1.0925 1.0925 1.0912 1.0974 1.0942 0.0000 1.0919 1.0915 0.0000 1.0912 1.0912 0.0000		

Table 9. TRAN Cards

Card Type	Field	Default	Description
TIME_STEP	tend	None	Transient duration, sec
	delt0	1.0E-30	Initial time step size, sec, Very Small default value to let step size controlled by system code
	tswitch	None	Time when to switch to new time step size, sec
	texpand	None	Expansion factor for new time step size. If texpand> 2, then the time step size will be double at each step until it reach texpand*delt0. If texpand< 0, then the time step size will be change to |texpand|*delt0 immediately.
	tswitch2	None	Time when to switch to new time step size, sec tswitch2> tswitch
	texpand2	None	Expansion factor for new time step size. If texpand2> 2, then the time step size will be double at each step until it reach texpand2*delt0. If texpand2< 0, then the time step size will be change to |texpand2|*delt0 immediately.
	TIME_STEP 100.0 0.01 20.0 10.0		

Table 9. TRAN Cards

Card Type	Field	Default	Description
EXPO_OPT	exptrsf	F	Exponential transform option, T or F
	expextp	T	Exponential extrapolation option, T or F
	`EXPO_OPT F T`		
THETA	cetak	0.5	θ value for kinetics
	cetac	1.0	θ value for coolant T/H
	cetaf	0.5	θ value for fuel heat conduction
	nordprec	2	1or 2, Order of precusor approximation. The transient solution is normally more accurate with option 2, but may cause problem when the time step size change dramatically. Option 1 is more reliable. When cetak==1.0, the defualt value of nordprec will be 1, otherwise the default value is 2
	`THETA 0.5 1.0 0.5`		
CONV_TR (Transient Convergence Criteria)	epsr2	0.001	Residual convergence criterion
	epsl2t	epsl2	Global fission source convergence criterion
	epslinft	epslinf	Local fission source convergence criterion
	epstft	epstf	Fuel temperature convergence criterion
	`CONV_TR 0.001 0.002 1e-04 1e-6`		
NLUPD_TR	nupdcyt	5	Nonlinear update cycle (e.g. every 5 iterations)
	ninitoutt	1	Number of iterations to be performed before the first nonlinear update
	numltht	5	Number of T/H updates per nodal update
	nthmax	10	Maximum number of fuel heat conduction calculations per time step
	`NLUPD_TR 5 1 5 10`		
EPS_XSEC	epsxsec	0.01	Cross section change criterion for requiring at least one nodal update
	`EPS_XSEC 0.01`		

Table 9. TRAN Cards

Card Type	Field	Default	Description
EPS_ERF	epserft	epserf	Error reduction criterion for invoking nodal update during the iteration
	`EPS_ERF 0.0001`		
MOVE_BANK	id	None	the absolute value of id is the ID of the control rod bank to be moved.
	tbank(j,1,id)	None	j-th time point t, sec
	tbank(j,2,id)	None	if id>0, the bank position at time t is the indicated number of steps withdrawn and intepolation will be used to determine the bank position during the transient if id<0, the indicated value is the acceleration at time t which will be used from j-th time point to j+1th time point, or to the end of the transient if there are no further time points after the jth time point
	Note: tbank pairs can be repeated up to mxnptr(=10) times (j=1:mxnptr) `MOVE_BANK 1 0. 0. 0.1 228. !move bank 1 to 228 steps in 0.1 sec`		
CHANGE_PPM	tppm(j,1,id)	None	j-th time point t, sec
	tppm(j,2,id)	None	Boron concentration at time t, ppm
	`CHANGE_PPM 0.0 1500.0 1.0 2000.`		
EXCI_MOD	morder	0	Maximum number of spatial modes for noises. the first mode is random distribution in space, the second mode is in fundamental power shape which is obtained from steady state calculation. the order modes can be harmonics which are given in card HARMON_F
	ltimetab	0	length of time table
	`exci_mod 2 0`		

Table 9. TRAN Cards

Card Type	Field	Default	Description
WHIT_NOI	exctsta	0	white noise starting time
	exctend	2	white noise ending time
	wnfmin	0.05	minimal frequence of white noise, in hz
	wnfmax	5	maximal frequence of white noise, in hz
	wnfstp	0.01	freqency step size in white noise, in hz
	wnfsmooth		j-th time point t, sec
	`whit_noi 1.0 300.0 0.003 12.0 0.003`		
TIME_TAB	excitime (ltimetab)	none	time points for noise perturbation table
	excitime `0 0.1 0.5 1.0 2.0`		
AMPL_TAB	tbampli (ltimetab)	none	amplitude of noise at given time points
	tbampli `1.0 0.5 0.8 -1.0 0.0`		
DM_AMPLM	dmamplm (morder)	0	amplitudes of noise in coolant density for each spatial modes
	dmamplm `0.0000 0.0005`		
TF_AMPLM	tfamplm (morder)	0	amplitudes of noise in fuel temperature for each spatial modes
	dmamplm `0.0000 0.0005`		
HARMON_F	fileharm	none	name of file which contains harmonics for higher order noise distribution
	HARMON_F '../../C14_PARCS_Data/C14P09_simth.har'		

Table 9. TRAN Cards

Card Type	Field	Default	Description
SCRAM	scrmflag	F	Scram option, T or F
	powtrip	None	Core power to initiate trip, %
	delaydel	None	Scram signal delay time, sec
	scramdelt	None	Rod insertion time, sec
	velocitypairs	0	velocity pairs for scram. =0, all control rods except the stuck rods will be inserted with constant speed within 'scramdelt' second. >0, and there is no more data in this card, then 'scramdelt' will be used as the scram velocity in cm/sec. >0, and there are n pairs of data, n=velocitypairs, then control rods will be inserted with step velocities defined by the time-velocity table.
	scramtim(j)	none	j-th time point t, sec
	scramvel(j)	none	velocity which will be used from scramtim(j-1) or the beginning of scram when j=0 to the scramtime(j).
	`SCRAM T 114.0 0.1 1.0`		
IMPOSERHO	rhoimp(j,1)	None	j-th time point t, sec
	rhoimp(j,2)	None	impose reactivity (or power level if kinopt=6)
	`imposerho 0.000000E+00 0.000000E+00` **`imposerho 1.000000E-03 2.532442E-04`** **`imposerho 2.000000E-03 5.697343E-04`** **`imposerho 3.000000E-03 9.885548E-04`**		
PIN_FREQ	npinfreq	10	Pin power calculation frequency (e.g. at every 10 time steps)
	`PIN_FREQ 10`		
RST_FREQ	irstfreq	2**15	Restart file write frequency
	`RST_FREQ 10`		

Table 9. TRAN Cards

Card Type	Field	Default	Description
NODAL_CONV	nodalcnv	F	Nodal convergence check option, T or F. If true, convergence is checked only after a nodal update so that very tight neutronic convergence is achieved
	`NODAL_CONV T`		
PLOT_CNTL	plot	F	On-line 2D XMGR plot option, T or F
	yminv(1)	0.0	Lower limit of the reactivity range, $
	ymaxv(1)	0.1	Upper limit of the reactivity range, $
	yminv(2)	plevel	Lower limit of the core power range, %
	ymaxv(2)	1.1plevel	Upper limit of the core power range, %
	yminv(3)	1.0	Lower limit of the peaking factor range
	ymaxv(3)	4.0	Upper limit of the peaking factor range
	yminv(4)	tin	Lower limit of the temperature range, ($°C$)
	ymaxv(4)	tin+1000	Upper limit of the temperature range, ($°C$)
	`PLOT_CNTL T -0.3 1.2 0. 130. 1. 7. 280. 560.`		
SHAPE_TIME	tshape (1:nshape)	None	Time points to utilize the radial flux shapes
	`SHAPE_TIME 0.0 1.4 10.56 20.5 100.12`		
SUM_EDIT			Summary edit options. Valid only for 3D cases.
	lsumopt(1)	T	Assembly Power Density
	lsumopt(2)	T	Axial Power Distribution
	lsumopt(3)	T	Assembly Flux Distribution
	lsumopt(4)	T	Axial Flux Distribution
	`SUM_EDIT T T T T`		

Table 9. TRAN Cards

Card Type	Field	Default	Description
SUM_STEP	(sumstend(i), nsumint(i)), i=1,...,nsumstp	0	Summary edit frequency. Generate summary edit information every **nsumint (i)** up to transient time of **sumstend(i). When nsumint==0, then the sum output frequency is same as trace graphic output frequency when coupled to trace, and output every calculation step when not coupled.**
	`SUM_STEP  10.0 1.0 100. 2.`		

Table 10. FDBK Cards (Formerly TH cards)

Card Type	Field	Default	Description
FA_POWPIT	powfa	17.67516	Average power of Fuel Assembly at full power, MW. The nominal full power of the core is determined by this value.
	pfa	21.606	FA pitch, cm
	`FA_POWPIT  17.67516  21.606`		

Table 10. FDBK Cards (Formerly TH cards)

Card Type	Field	Default	Description
CDC_DED	CDC_op	0	Coolant density correction option = 0: no correction The following options are used for coupled with TRACE or RELAP5 only = 1: correct with bypass density, where the coolant and bypass flow areas are $\rho_{??????} = \rho_{????????} + \frac{A_{bypass}}{A_{coolant}}(\rho_{??????????} - \rho_{??????})$ available in PMAXS files or CDC_DAT card . the saturated density is also available in PMAXS files which was the bypass density when prepare cross sections. = 2: bypass density asmoderator density which is a seperate feedback variableindepend from coolant density = 3: correct with bypass density and water rod density $\rho_{??????} = \rho_{????????} + \frac{A_{bypass}}{A_{coolant}}(\rho_{??????????} - \rho_{??????}) + \frac{A_{waterrod}}{A_{coolant}}(\rho_{waterrod} - \rho_{??????})$ where the water rod flow area is also available in PMAXS files or CDC_DAT card. = 4: average of bypass and water rod density as feedback variable, moderator density
	DED_op	0	Direct energy deposition options: = 0: energy is deposited to coolant only with a single uniform fraction over the core which is availabe in GAMMA_FRAC card, = 1: energy is deposited to coolant and bypass with 2 uniform fractions over the whole core,which are availabe in GAMMA_FRAC card, = 2: energy is deposited to coolant, bypass, and water rods with 3 uniform fractions over the whole core,which are availabe in GAMMA_FRAC card, =3: energy is deposited to coolant, bypass, and water rods with 3 node-wise fractions,which are availabe in PMAXS files
	CDC_DED 3 2		

Table 10. FDBK Cards (Formerly TH cards)

Card Type	Field	Default	Description
CDC_DAT	byp_dsat	0.0	by-pass water density in cross section calculation, g/cc
	byp_a_frac	0.0	ratio of bypass flow area to coolant flow area
	wr_a_frac	0.0	ratio of water rod area to coolant flow area
	CDC_DAT 0.73 0.3 0.2		
GAMMA_FRAC	fracdc	0.0	Fraction of direct gamma heating in coolant
	fracdvb	0.0	Fraction of gamma direct heating in by-pass
	fracdwr	0.0	Fraction of gamma direct heating in water rods
	GAMMA_FRAC 0.2 0.17 0.01		
UNIF_TH	Dm_u	0.7	Uniform moderator density (g/cc), used when no T/H feedback is present
	Tf_u	626.85	Uniform fuel temperature (c), used when no T/H feedback
	Tm_u	300.0	Uniform moderator temperature (c), used when no T/H feedback
	UNIF_TH 0.7 626.85 300.0		
FLU_TYP	fluid_typ	0	Coolant option: 0: Light Water (P=15.5 MPa, 280 < T [C] < 340 1: Heavy Water (P=11.6 MPa, 260 < T[C] < 320
	fluid_typ 1		
INP_THF	THF_name	none	file name for input TH condition during steady state and transient calculation. The format is the same as the history files. Only PMO is implemented.
	THF_type	none	File type: 0/1: binary/ascii
	INP_THF './Boron.cnc' 1		
Note: All the following cards in this block are former TH cards which are only used for PARCS standalone and are not used in cases with external TH.			

Table 10. FDBK Cards (Formerly TH cards)

Card Type	Field	Default	Description
N_PINGT	npint	264	Number of fuel pins in a fuel assembly (FA)
	ngt	25	Number of guide and instrumentation tubes
	IN_PINGT 264 25		
PIN_DIM	rs	4.1195	Fuel pellet radius, mm
	rw	4.7585	Cladding outer radius, mm
	tw	0.571	Cladding thickness, mm
	rgt	6.1295	Guide tube outer radius, mm
	PIN_DIM 4.1195 4.7585 0.571 6.1295		
FLOW_COND	tin	286.0	Inlet temperature,°*C*
	fmdotfa	82.12102	Mass flow rate per FA channel, kg/s
	FLOW_COND 286.0 82.12102		
HGAP	hgap	10000.	Gap conductance, J/m^2°*C*
	HGAP 10000.		
N_RING	nr	6	Number of coaxial rings in the pellet region for fuel heat conduction calculation
	N_RING 6		
THMESH_X	nthx(1:nasyx)	nneutx(:)	Number of T/H meshes per assembly mesh in x-direction
	`THMESH_X 1 8*1`		
THMESH_Y	nthy(1:nasyy)	nneuty(:)	Number of T/H meshes per assembly mesh in y-direction
	`THMESH_Y 1 8*1`		
THMESH_Z	junb(1:nzth)	1:nzth	Junction boundary of each T/H layer
	`THMESH_X 1 4 5 6 7 8 9 10 11 12 13 14 17 18`		
FREEZE_TF	freezetf	F	Option to freeze previous fuel temperature
	frozentf	0	Frozen fuel temperature (°*C*)
	FREEZE_TF T 600.0		

Table 10. FDBK Cards (Formerly TH cards)

Card Type	Field	Default	Description
FREEZE_DM	freezedm	F	Option to freeze previous moderator density
	frozendm	0	Frozen moderator density ($g\ cm^3$)
	FREEZE_DM T 0.700		
WRITE_FBV	writefbv	F	Option to write the feedback variables such as Doppler fuel temperature, moderator temperature and density
	fn	caseid.fbv	Output file name for the feedback variables
	WRITE_FBV T a.fbv		
READ_DOPL	readdopl	F	Option to read the Doppler fuel temperatures
	fn	None	Input file name for the Doppler fuel temperatures
	READ_DOPL T a.dop		
READ_TMDM	readtmdm	F	Option to read the moderator temperature and density distribution
	fn	caseid.fbv	Input file name for the moderator temperature and density distribution
	READ_TMDM T a.dm		

Table 11. DEPL Cards

Card Type	Field	Default	Description
INP_HST	InpHst_na	None	Name of Input file which contains history and TH state information
	InpHst_fm	0	0/1/2: binary/Ascii/SIMULATE-3 * Read the note below
	ResP	1	Restart from this point in file InpHst_na. The initial point is point 1.
	INP_HST ‘DEP1.dep’ 1 3 1 2 3		

Table 11. DEPL Cards

Card Type	Field	Default	Description
* Note: The values of the history or TH state are given after the keywords: EXP 3D MAP, HCR 3D MAP, HDC3D MAP, HPC 3D MAP, HTF 3D MAP,HTC 3D MAP, DCO 3D MAP, PCO 3D MAP, TCO 3D MAP, TFU 3D MAP, XEN 3D MAP, SMN 3D MAP These 12 keywords are to be used in PARCS input. Some of the other keywords are equivalent to these keyword, such as: HVO 3D MAP -> HDC 3D MAP HMD 3D MAP -> HDC 3D MAP HSB 3D MAP -> HPC 3D MAP DEN 3D MAP -> DCO 3D MAP SB 3D MAP -> PCO 3D MAP TM 3D MAP -> TCO 3D MAP The units of the history and TH states are: EXP (burnup): MWd/kg HCR (control rod history): none DCO (coolant density): kg/m3 HDC (coolant density history): kg/l PCO,HPC (boron concentration in coolant): ppm XEN,SMN (nuclides densities) 1/cm3 TCO,HTC (coolant temperature): Kelvin TFU,HTF(fuel temperature): Kelvin (Note: The square root of temperatures are used in the code and also in the binary history file. However, in the ASCII history files, the square root of temperatures are converted back to temperature and the temperature values shown are in Kelvin) Option 1, ASCII format is often used for user input history and TH information. The most appropriate methods to set the format of the ASCII history file is to generate a "dep" file by PARCS. Note that there is a factor after the "*** 3D MAP" key word which will be multiplied to all 3D values. The XEN, SMN, TFU and histories are given per fuel region which is one assembly in 1 axial plane. There is no value for reflector regions. The other variables are given for both fuel and reflector regions. The values for all axial levels of an assembly are given in a column from the top level to the bottom level. These columns are listed sequentially with assembly index, 10 assemblies in a block.			

Table 11. DEPL Cards

Card Type	Field	Default	Description
INP_OPT	Lppm	F	T/F : If Lppm==T, the ppm will be read from the restart file InpHst_na and used in the calculation, and the ppm search will be switched off.
	Lcrp	F	T/F : If Lcrp==T, the control rod position will be read from the restart file InpHst_na and will be used in the calculation, and the critical control rod position search will be switched off.
	Lths	F	T/F : If Lths==T, the TH state will be read from InpHst_na and used in the calculation and the TH feed back and the external T/H will be turned off. Although fdbk and extth will be set to false, the input value of these two logical variables will affect the size of the array for T/H variables. If any of these tow logical variables is true in the input file, the T/H variables will be read for each node. If both logical variables are false in the input file, the T/H variable will be read for each fuel assembly node similar to the way in which the burnup is read.
	Lxesm	F	T/F : If Lxesm==T, the densities of Xe and Sm will be read from Inpstt_na and will be used in the calculation, and the Xe/Sm calculation will be switched off.
	INP_OPT F F F F		
TIME_STP	ndep	0	Number of etion steps for each restart
	Days(1:ndep)	None	Days for each etion step if it is positive, otherwise, it is incremental core average bunrup in GWD/MT
	Tpow(1:ndep)	None	Total powers (MW) during each step
	TIME_STP 10 10*30. 10*3000.		

Table 11. DEPL Cards

Card Type	Field	Default	Description
PMAXS_F	ind	none	PMAXS file index. The indices must be in sequential order, 1,2,3 ...n. The data in the ith PMAXS file will be used for the composition i in PLANAR_REG card of GEOM block or composition i in ASSY_TYPE card of HEXGEOM block.
	name	none	PMAXS file name
	i_str	none	Index of branch structure. The indices should be in the range of 1 to ns, where ns is the number of differnt branch structures for all PMAXS files. If the PMAXS files have the same branch structure, they should share the same index
	PMAXS_F 1 '../xsec/fuel1.pmax' 1 PMAXS_F 2 '../xsec/fuel2.pmax' 1 PMAXS_F 3 '../xsec/fuel1.pmax' 2		
UNF_PTH	PTMD	0	Uniform Perturbations of Dm in g/cc
	PTTF	0	Uniform Perturbations of TF in Kelvin
	PTTM	0	Uniform Perturbations of TM in Kelvin
	UNF_PTH 0 0 0		
HST_OPT	LHCR	F	T/F Compute/not histories for CR
	LHDC	F	T/F Compute/not histories for DC
	LHPC	F	T/F Compute/not histories for PC
	LHTF	F	T/F Compute/not histories for TF
	LHTC	F	T/F Compute/not histories for TC
	HST_OPT F F F F F		

Table 11. DEPL Cards

Card Type	Field	Default	Description
OUT_OPT	PPOW	T	T/F print /not power distribution
	PHST	T	T/F print /not History distribution
	PTHS	T	T/F print /not T/H state
	PXESM	T	T/F print /not Xe/Sm densities
	PXSS	F	T/F print /not cross section for each region If PXSS==T, PARCS will stop after printing cross sections
	OUT_ OPT T T F F T		
CORE_MASS	hm_mass	None	total heavy metal mass in reactor core in MT, used by SNAP only
	CORE_MASS 200.0		
BANK_NR	Ncr(1:ncrb)	None	The number of control rods in each bank.
	BANK_NR 4 6 2		
EXCL_BLK	Tbla	0	Layers of top blanket excluded from the average burnup calculation
	Bbla	0	Layers of bottom blanket excluded from the average burnup calculation
	EXCL_BLK 0 0		
SATU_DEN	Dls	0.737	Saturated water density used for core average void fraction
	Dgs	0.03753	Saturated steam density used for core average void fraction
	SATU_DEN 0.737 0.03753		

Table 12. MCYCLE Cards(only for PARCS standalone)

Card Type	Field	Default	Description
BANK_DEF	ind	none	The index of the definition of control bank position in steps withdraws. The indices must be in sequential order, 1,2,3 ...n.
	locmap	BIG	Control rod bank position in steps withdrawn following the index above, ncrb is the number of control rod banks

	`! index locmap`
	`BANK_DEF 1 0 0 0 0 0 0 0 0 0`
	`BANK_DEF 2 10 10 10 10 10 10 10 10 10`		

CYCLE_DEF	ind	none	The index of the definition of etion cycle. The indices must be in sequential order, 1,2,3 ...n.
	`CYCLE_DEF 1`		
DEPL_STEP	Days(1:ndep)	none	Days for each etion step. The number of etion steps, ndep, can be different among CYCLE_DEFs
	`TIME_STEP 1*3 3*43 3*33`		
POWER_LEV	mcplv(1:ndep+1)	plevel	core power level in %
	POWER_LEV 8*95		
FLOW_RATE	mfrat(1:ndep+1)	`mdot-core`	core flow rate in kg/s, used only when coupled with PATHS
	FLOW_RATE 8*3029.0		
INLET_ENT	mient(1:ndep+1)	hin	coreinlet enthalpy in (kJ/kg), used only when coupled with PATHS
	INLET_ENT 8*1210.0		
EXIT_PRES	mepre(1:ndep+1)	Pout	core exit pressure in Pa, used only when coupled with PATHS
	EXIT_PRES 8*6.95E6		
BANK_SEQ	mbseq(1:ndep+1)	none	Control rod bank position in steps withdrawn, ncrb is the number of control rod banks
	BANK_SEQ 1 1 1 1 1 2 2 2		

Table 12. MCYCLE Cards(only for PARCS standalone)

Card Type	Field	Default	Description
LOCATION	locmap	BIG	User defined radial fuel assembly configuration map, indicating the position of each assembly.
	LOCATION 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193		
SHUF_MAP	ind	none	The index of the definition of shuffling pattern. The indices must be in sequential order, 1,2,3 ...n.
	shufmode	1	Shuffling mode selection: 1.reload assembly individually 2.reload with batch average burnup
	shufmap	BIG	Radial fuel assembly reload map, indicating the position of each assembly at End of Cycle (EOC). Negative number presents the fresh fuel
	SHUF_MAP 1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 23 -1 82 -1 27 -1 -1 -1 -1 -1 3 66 9 35 4 41 17 68 5 -1 -1 -1 75 -1 2 50 1 55 7 54 6 -1 89 -1 -1 -1 80 60 20 10 37 18 39 16 30 74 84 -1 -1 -1 62 32 64 46 34 12 25 14 42 58 70 44 72 -1 -1 -1 48 45 78 76 49 31 55 88 86 59 56 -1 -1 -1 96 90 94 19 92 8 129 186 102 175 100 104 98 -1 -1 -1 138 135 108 106 139 163 145 118 116 149 146 -1 -1 -1 122 150 124 136 152 180 169 182 160 148 130 162 132 -1 -1 -1 110 120 164 178 155 176 157 184 174 134 114 -1 -1 -1 105 -1 188 140 187 142 193 144 192 -1 119 -1 -1 -1 189 126 177 153 190 159 185 128 191 -1 -1 -1 -1 -1 167 -1 112 -1 171 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1		

Table 12. MCYCLE Cards(only for PARCS standalone)

Card Type	Field	Default	Description
Note: In order to use multicycle capability in PARCS, the reactore core must be described with ASSY_TYPE cards and not the PLANAR_REG cards. The negative number defining the fresh fuel will affect the ASSY_TYPE card in GEMO or GEMOHEX block. The absolute value of this number must be used as the assembly type number in the field "Iat". For instance, if -5 is defined as one of the fresh fuel types, 5 will be inputted as the type number in ASSY_TYPE card, i.e., assy_type 5 10*3 FUEL			
CYCLE_IND	ind	none	The index of the etion cycle. The indices must be in sequential order, 1,2,3 ...n.
	shuf_ind	none	The index of shuffling configuration selected, with 0 indicating no shuffling required
	cycle_ind	none	The index of cycle configuration selected

	`CYCLE_IND 1 0 1`
	`CYCLE_IND 2 1 2`
	`CYCLE_IND 8 2 2`
	`CYCLE_IND 10 2 2`		

CONV_EC	epsec	0.1	Max burnup convergence criterion (GWG/MT)
	ncycmax	20	Maximum number of cycles
	`CONV_EC 0.1 20`		

Table 13. PLOT Cards (Only for QuickWin Based Graphics)

Card Type	Field	Default	Description
XTYPE	ixtype	0	Type of the x-axis in the X-Y plot 0 - Time 1 - Reserved 2 - Case Index
	x_min	0	Minimum value on the x-axis
	x_max	tend	Maximum value on the x-axis. Equal to the full simulation time if ixtype equals to 0.
	`XTYPE 0 0 100.0` `XTYPE 2 0 5.0`		

Table 13. PLOT Cards (Only for QuickWin Based Graphics)

Card Type	Field	Default	Description
AXPLOT	alpid	None	Alphanumeric ID of the variable for which an axial distribution is made, the same list given for X-Y alpid applies.
	npz	None	Number of axial points plotted
	ncurves	None	Number of curves to be plotted in the same frame
	y_min	None	Minimum y-axis value
	y_max	None	Maximum y-axis value
	idum	None	Dummy
	npskip	None	Plotting skip factor
	kklll (1:npz,1:ncurves)	None	Vector indices to appear in the subsequent *ncurve* lines, each containing *npz* numbers

	`AXPLOT relp 11 2 0.0 2.0 1 0 1`
	`01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000`
	`01121 02121 03121 04121 05121 06121 07121 08121 09121 10121 11121`		

Table 13. PLOT Cards (Only for QuickWin Based Graphics)

Card Type	Field	Default	Description
XY	alpid	None	Alphanumeric ID of the variable for which an X-Y plot is made, one of the following: keff - k-effective plevel - normalized core power level rhoadj - reactivity toutavg - average coolant exit temperature dmrho - density component reactivity tmrho - coolant temperature comp. reactivity tfrho - fuel temperature comp. reactivity crrho - control rod comp. reactivity ppmrho - ppm comp. reactivity crbpos(i) - i-th control bank position tcool - coolant temperature vector dcool - coolant density vector tfuel - fuel temperaure vector relp - relative power density vector flux1 - fast flux vector flux2 - thermal flux vector lp2d - fuel loading pattern crpmap - conrol bank position map
	kklll	None	Vector index designating the location in the core at which the variable is obtained. *kk* designates the plane index and *lll* designate the radial node index. For scalar variables, enter 0.
	y_min	None	Minimum y-axis value.
	y_max	None	Maximum y-axis value.
	iframe	None	X-Y plot frame number to which the curve belongs.
	igraph	None	The color for designated curve number.

	`XY tfuel 014121 250.0 750.0 1 1`
	`XY tcool 001176 220.0 320.0 1 1`
	`XY dcool 017676 600.0 900.0 3 1`
	`XY relp 014121 0.0 3.0 4 1`
	`XY relp 014176 0.0 3.0 4 2`
	`XY plevel 0 0.0 1.2 5 1`
	`XY rhoadj 0 -8.0 6.0 6 1`
	`XY rhodm 0 -8.0 6.0 6 2`
	`XY rhotf 0 -8.0 6.0 6 3`
	`XY rhocr 0 -8.0 6.0 6 4`
	`XY bank(1) 0 0. 1000 9 1`
	`XY bank(2) 0 0. 1000 9 2`		

Table 13. PLOT Cards (Only for QuickWin Based Graphics)

Card Type	Field	Default	Description
RECTMAP CONTOUR BITMAP	alpid	None	Alphanumeric ID of the variable for which a radial map based on rectangles (RECTMAP), or contour (CONTOUR), or color-filled contour (BITMAP) is made, the same list given in X-Y alpid holds.
	npx	None	Number of Data Sets in the x-direction
	npy	None	Number of Data Sets in the y-direction
	z_min	None	Minimum z value where z=f(x,y)
	z_max	None	Maximum z value
	ncolor	None	Color skip factor
	npskip	1	Radial Map Skip Factor, radial maps are updated once per every npskip time steps
	kklll (1:npx,1:npy)	None	Vector indices to appear in the subsequent *npy* lines, each containing *npx* numbers
	RECTMAP tcool 8 7 220.0 300.0 0 1 00000 00000 00000 00000 00000 01001 01002 01003 00000 00000 00000 01008 01009 01010 01011 01012 00000 00000 01019 01020 01021 01022 01023 01024 00000 01032 01033 01034 01035 01036 01037 01038 00000 01047 01048 01049 01050 01051 01052 01053 01062 01063 01064 01065 01066 01067 01068 01069 01079 01080 01081 01082 01083 01084 01085 01086		

* Note that a full core plot can be obtained from a quarter core calculation by placing the quarter core based vector indices in the full core configuration. The radial node numbers for lp2d and crp-map do not count radial reflector nodes. The feedback variables (tcool, dcool, and tfuel), and relative power density (relp) are defined only for T-H nodes. The radial reflectors are not counted in the numbering, but in the coupled case, reflector nodes are assigned a node number.

Table 14. ONEDK Cards

Card Type	Field	Default	Description
EXT_1DXS	ext1dxs	T	Option to use external 1D cross section set
	EXT_1DXS T		

Table 14. ONEDK Cards

Card Type	Field	Default	Description
XS_FORM	ixsform	0	Index for cross section form 0 : table form 1 : polynomial form 2 : linear form
	filename(14)	None	Input file name for cross section set
	`XS_FORM 1 tracin.xs`		
USE_CCF	useccf	F	Option to use CCF
	useccfcr	F	Option to use CCF for control rod
	useccftf, useccfdm, useccfbo, useccftm, useccfpw, useccfbu, useccfxe	all F	These options typically have a very minor impact on the result. Therefore it is valid to choose useccfcr as T to see the CCF effect.
	`use_ccf T T` `use_ccf F`		
CORE_DATA	psys	155.0	System pressure in bar
	bucur	0.0	Current core average exposure(MWD/MTU)
	`CORE_DATA 155.0 15.0`		
CORE_TH	tinsub	0.0	Subcooling of inlet moderator temperature($°C$)
	`CORE_TH 2.0`		
TRAC_INP	tracinp	F	Option to use TRAC input
	filename(17)	None	TRAC input filename
	`TRAC_INP T ../trac/tracin`		
EXT_1DSRC	ext1dsrc	F	Option to use external 1D source for fixed source problem with external source(1D only) (valid for iptype=1 and tran=F)
	filename(18)	None	External 1D source filename
	content of 1D external source file : repeat for k=1, nz k, 1-group source, 2-group source		
	`EXT_1DSRC T ./xsec/xsec.inp`		

Table 14. ONEDK Cards

Card Type	Field	Default	Description
DECUSP_FC	irdfc any CR possible for 1,...,ncrb	None	Control rod ID to set the decusping function coefficients. A quadratic equation of control rod fraction in a node f(x)=a0+a1*x+a2*x*x, 0<f(x)<1, 0<x<1
	dfc(irdfc,0)	0.4917	Zeroth order coefficient
	dfc(irdfc,1)	0.1718	First order coefficient
	dfc(irdfc,2)	0.3364	Second order coefficient
	`DECUSP_FC 1 0.4917 1.718E-01 0.3364`		
RAD_WEIGHT	ifchan1d	F	Option to use channels in 1D kinetics module
	nchan	1	Total number of channels defined in 1D module
	ichweight	1	Index of channel weighting method (1:vol,2:sq-pow,3:user defined)
	itfweight	1	Index of fuel temperature weighting method (1:vol,2:sq-pow,3:user defined)
	filename(16)	None	Filename for power shape
	`RAD_WEIGHT T 3 1 2 ../trac/pow.shp`		
CHAN_AREA	chvfrac (1:nchan)	1 for all channels	Each channel area fraction or channel area in any unit. They are normalized internally.

	`for quarter core of neacrp A1 problem including reflector region`
	`chan_area ! in m^2`
	`0.0116705 0.0233410 0.0233410 0.0233410 0.0233410`
	`0.0233410 0.0233410 0.0233410 0.0233410 0.0233410`
	`0.0233410 0.0233410 0.0233410 0.0233410 0.0233410`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.0466819 0.0466819 0.0466819`
	`0.0466819 0.0466819 0.7469108e-10`		

Table 15. GEOMHEX Cards

Card Type	Field	Default	Description
GEOM_DIM	Nring	1	Number of concentric hexagonal rings in the full core configuration if the symmetry indicator in RAD_CONF card is 'ROT', or 'REFL', or defaulted. Otherwise, the number of rows in the input model.
	Nz	1	Number of planes in z-direction
	nzbr	0	Number of planes for the bottom reflector
	nztr	0	Number of planes for the top reflector
	GEOM_DIM 10 26 1 1		
RAD_CONF	Isymang	None	Input symmetry angle, one of the following four 30 - 1/12 symmetry 60 - 1/6 symmetry 120 - 1/3 symmetry 360 - Full core (180 is not available)
	Astr	ROT	Symmetry indicator, ROT - Rotational Symmetry REFL - Reflective Symmetry A,B,C,D,E for input by rows (See note below)
	Isolang	=isymang	Problem solution angle, same as the input symmetry angle if not specified
	iradconf (1:nasyx,j), j=1,nasyy	None	Rows of assembly types specified in the actual hexagonal core configuration starting from the next line following the RAD_CONF card
	rad_conf 60 rot !1/6 rotation symmetry 2 1 1 3 1 1 5 1 6 1 1 4 3 5 1 1 1 1 1 5 3 1 2 3 5 1 3 1 5 1 4 5 5 5		

Table 15. GEOMHEX Cards

Card Type	Field	Default	Description
Note: The symetry indicator A,B,C,D,E, has their unique meaning when combined with an Input symmetry angle. **Among the 14 the symmetry types list below, only 360A and 120 B are currently active.** 360 A :Full core model, no symmetry. The assemblies in each row must be arranged symmetric about Y-axis which passes though the middle of first row which can center of an assembly or interface of two assemblies. Zeros are used as on the places which will be excluded from calculation.			
180 A: Half core reflective symmetric about the center row. Only the south part of the core and center row will be modeled. The assemblies in each row must be arranged symmetric about Y-axis which passes though the middle of center row (first row in model) which can center of an assembly or interface of two assemblies. Zeros are used as on the places which will be excluded from calculation. 180 B: Half core reflective symmetric about y-axis which passes though center of an assembly on first row. Only east half and center column will be modeled. No zeros need on right end of each row in this type of configurations			
180 C:Half core reflective symmetric about y-axis which passes though interfaces of two assemblies on first row. Only east half and center column will be modeled. No zeros need on right end of each row in this type of configurations 180 D: Half core rotational symmetric about the point in the center of an assembly. Only the east part of the core and center column will be modeled. No zero needed on right end of each row in this type of configurations. 180 E: Half core rotational symmetric about the point on the middle of interface of two assemblies. Only the east part of the core will be modeled. No zero needed on right end of each row in this type of configurations.			
120 A: 1/3 core rotational symmetric about the point on the center of an assembly. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations 120 B: 1/3 core rotational symmetric about the point on a corner point surrounded by three assemblies. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations			
90 A: Quarter core reflective symmetric about center of an assembly. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations 90 B: Quarter core reflective symmetric about the point on middle of interface of two assemblies. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations			

Table 15. GEOMHEX Cards

Card Type	Field	Default	Description
60 A: 1/6 core reflective symmetric about center of an assembly. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations. 60 B: 1/6 core reflective symmetric about corner of three assemblies. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations 60 C: 1/6 core rotational symmetric about center of an assembly. Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations			
30 A: 1/12 core reflective symmetric about center of an assembly.Only the southeast part of the core will be modeled. No zero needed on right end of each row in this type of configurations			
GRID_HEX	hf2f	None	Flat-to-flat distance of the base hexagon, cm
	Ndivhs	1	Number of divisions along the side of the hexagon for TPEN solution, reserved for future use involving finer triangular solutions. Only 1 is valid in Version 2.0
GRID_Z	hz(1:nz)	None	Plane heights in cm, the * format applies for repetition. e.g. 15.0 3*20.0 10.0 = 15.0 20.0 20.0 20.0 10.0
ASSY_TYPE	Iat	None	The assembly type number that this card defines
	icomp(1:nz)	None	The composition numbers specified for each planar level. The * format applies for repetition.
	asstype	FUEL	FUEL/REFL for fuel or reflector assemblies

	`assy_type 1 10*1 FUEL`
	`assy_type 2 10*2`
	`assy_type 3 10*3 FUEL`
	`assy_type 4 10*4 REFL`
	`assy_type 5 10*5 REFL`
	`assy_type 6 5*4 5*3 REFL`		

ALBEDO_R	alxr(1),alxr(2)	0.	Groupwise radial albedos defined as the ratio of net current to surface flux. Typical values are 0 - reflective 0.5 - zero Incoming ∞ - zero Flux
ALBEDO_ZB	alzl(1),alzl(2)	0.	Groupwise axial albedos at the bottom of the core

Table 15. GEOMHEX Cards

Card Type	Field	Default	Description
ALBEDO_ZT	alzr(1),alzr(2)	0.	Groupwise axial albedos at the top of the core
ADF_ROT	nrotfa (:,1:nasyy)	nxya*0	The index of assembly rotation : 0/1/2/3/4/5 means rotate assembly 0/60/120/180/240/300 degree anti-clock wise.
	ADF_ROT 0 2 1 6 3 5		
CR_AXINFO	crbpos0	0.	Control rod full insertion position from the bottom of the problem geometry, cm
BANK_CONF	iradconf (1:nasyx,j) ,j=1,nasyy	nassy*0	Radial configuration of the control rod banks. Input with the same symmetry option as the one used in RAD_CONF.

Table 15 FMFD Cards

Card Type	Field	Default	Description
GROUP_SPEC	mg	2	Number of Groups. If this card is present, the multigroup option is turned on and the cross sections are read in the multigroup form that involves scattering matrices
	mge(1)	mg/2	The last fine group number belonging to the first group in the two-group structure. If not speci-fied, mg/2 is used.
GENINF	npins	none	Number of pin per FA side
	nrefine	1	Number of mesh per pin side
	mmz	1	Number of mesh per axial node
	meshth	1	TH meshes 1: thermal feedback in FA unit npin: pin-by-pin thermal feedbak

METHOD	npn	1	Order of angle 1: diffusion 3: SP_3
	naccel	2	Acceleration method 1: 2G coarse mesh rebalancing (CMR) 2: 2G coarse mesh finite difference (CMFD)
REF_COND	ppmref	0.	Reference boron concentration, ppm
	tmref	0.	Reference moderator temperature, $°C$
	dmref	0.	Reference moderator density, g/cm^3
	tfref	0.	Reference fuel temperature, $°C$
DNP_NGRP	nprec	6	Number of delayed neutron precursor groups
BUCKLING	buckling	0.	Core buckling
NODALZ	is2d1d	F	Activates 2d/1d coupling

Table 15 FMFD Cards (Cont.)

Card Type	Field	Default	Description

<table>
<tr><td rowspan="3">PLANAR_PIN</td><td>ifacomp</td><td>none</td><td>FA composition number</td></tr>
<tr><td>icompf
(1:npin*npin,ipr)</td><td></td><td>Planar region compositions assigned to each non-dummy region of the radial configuration (RAD_CONF) in a 2D array form (npin*npin is the number of non-zeros in the RAD_CONF card)</td></tr>
<tr><td colspan="3">planar_pin 1 !UOX1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 3 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td></tr>
<tr><td rowspan="3">PIN_XSEC</td><td>nmfpin</td><td>none</td><td>File name for pin cross sections</td></tr>
<tr><td>ipincomp</td><td></td><td>Pin composition number</td></tr>
<tr><td colspan="3">pin_xsec fmfd.UOX1.LF8-150b-8g 1</td></tr>
</table>

A schematic depicting the input card planar_pin necessary to provide pin by pin fuel compositions is shown below for a 13 assembly mini-core problem.

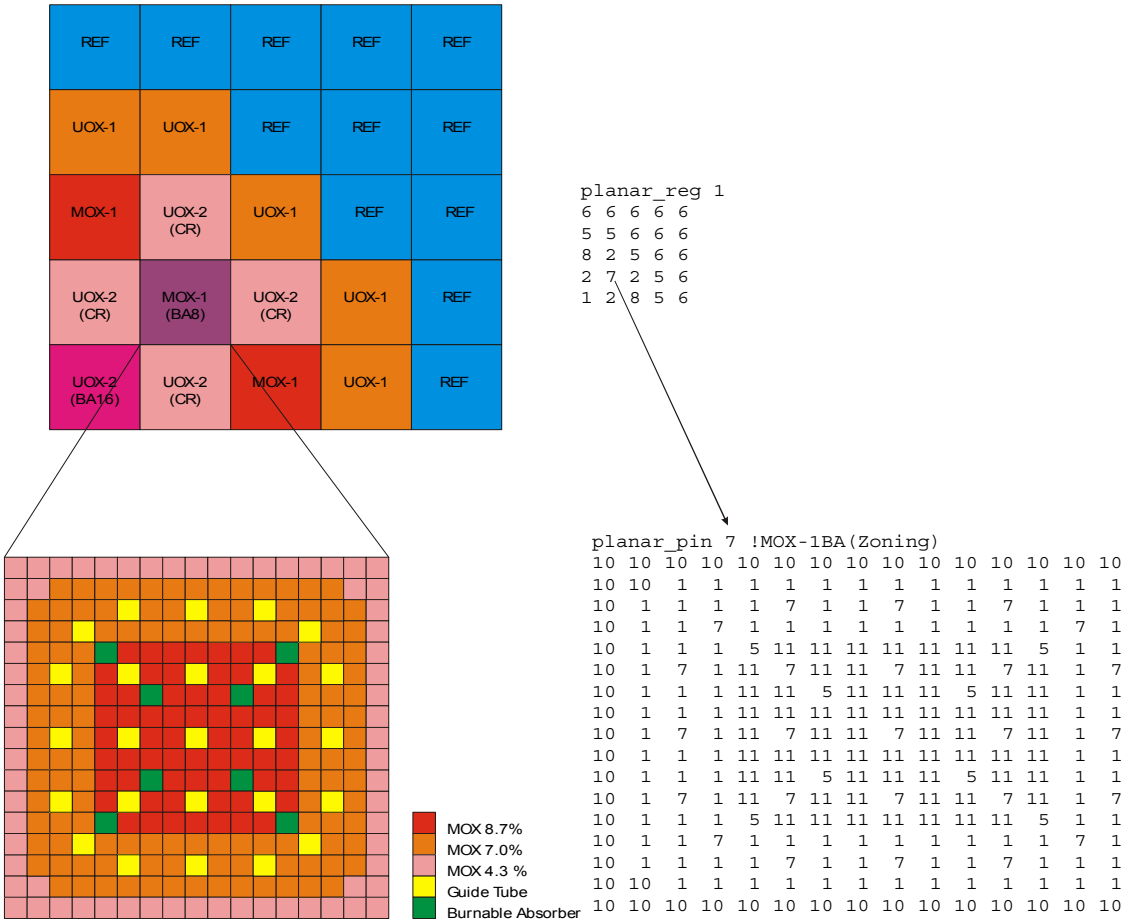


Table 16. Cross Sections Within PIN_XSEC File

Card Type	Field	Default	Description
{pin multigroup cross sections}	sigtr(ig,ic)	0.	Transport cross section
	siga(ig,ic)	0.	Absorption cross section
	signf(ig,ic)	0.	Nu-fission cross section
	sigkf(ig,ic)	0.	Kappa-fission cross section
	sigscat(ig,ig,ic)	0.	Scattering cross section
	rambda(1:nprec,ic)	0.	Delayed neutron precursor decay constant, 1/sec
	beta(1:nprec,ic)	0.	Delayed neutron fraction
	velo(1:mg,ic)	0.	Neutron velocity, cm/sec
	sigchid(1:mg,1:nprec, ic)	0.	Delayed neutron emission spectrum
	sigchi(1:mg,ic)	0.	Fission spectrum
	dsigtr(iv,ig,ic)…. dsigkf(iv,ig,ic), dsigscat(iv,ig,ig,ic)	0.	Macro XS change per unit moderator temperature change for each of cross section components
	dsigtr(iv,ig,ic)…. dsigkf(iv,ig,ic), dsigscat(iv,ig,ig,ic)	0.	Macro XS change per unit Doppler temperature change for each of cross section components
	dsigtr(iv,ig,ic)…. dsigkf(iv,ig,ic), dsigscat(iv,ig,ig,ic)	0.	Coefficient of the second-order variation term of Macro XS with respect to moderator density for each of cross section components
	dsigtr(iv,ig,ic)…. dsigkf(iv,ig,ic), dsigscat(iv,ig,ig,ic)	0.	Macro XS change per unit ppm change for each of cross section components.
	delcontr(iv,ig,ic)…. delconkf(iv,ig,ic), delconscat(iv,ig,ig,ic)	0.	Macro XS change due to control rod insertion

V.B MAPTAB Input Description

The coupling of the thermal-hydraulic mesh to the PARCS neutronic mesh is accomplished through the assignment of mapping weights between the two mesh. These mapping weights, with values between 0 and 1, inclusive, determine the distribution of neutronic power in the thermal-hydraulic and heat structure components, as well as the calculation of thermal-hydraulic feedback in the neutronic nodes. The determination of an accurate set of these weights for a particular problem is one of the most important tasks in achieving accurate coupled code solutions.

V.B.1 Introduction

Two methods are currently available for determining the weights for a given thermal-hydraulic, heat structure, and neutronic nodalization: 1) an explicit weight method in which the user is responsible for generating all weighting factors, and 2) an automated weight method in which the user provides only a minimal amount of mapping information and the code internallly generates the weighting factors. The automated method also generates the ASCII file MAPTAB with mapping information and weights which can then be modified by the user. The explicit and automated weighting methods will be explained in detail below using the the OECD PWR Main Steam Line Break Benchmark.

Regardless of the method used, the first step in developing a set of mapping weights is to match the nodalization used in TRACE with that used in PARCS. It is important to insure that the thermal-hydraulic mesh is a realistic match for the neutronic mesh and vice versa. For example, it is not realistic to model the reactor core with a very coarse thermal-hydraulic mesh (e.g. one ring with three axial levels) and then use a very fine neutronics nodalization (e.g. one node per fuel assembly and 20 axial nodes). Physical insight must be used to choose a meshing for the two codes that will provide solutions in the two fields of consistent accuracy.

V.B.2 Nodalization of the OECD MSLB Benchmark Model

A full description of the OECD MLSB Benchmark problem may be found in the numerous publications resulting from participation in this benchmark effort with TRACE/PARCS. The detailed problem description will not be provided here, however the thermal-hydraulic, heat structure, and neutronic nodalizations for both the second and third exercises will be discussed in enough detail to explain the mapping procedure. Both exercises will be used since they demonstrate different thermal-hydraulic modeling of the reactor core; the TRACE pipe component was used in exercise 2 and the TRACE vessel component was used in excercise 3.

Exercise 3 TRACE Nodalization

The core thermal-hydraulic nodalization of the third exercise of the MSLB benchmark consists of a 3-D VESSEL component with 14 axial levels, 5 radial rings, and 6 azimuthal sectors. The active core region is represented by six (6) of the 14 axial levels in the VESSEL component, each with the same height as was used in the second exercise, 59.52 cm. The three inner-most

radial rings in the VESSEL component represent the flow through the active core region. The barrel-baffle region is represented by the next radial ring, and the downcomer is modelled by the outer-most radial ring. Each axial level is further divided into 6 equal azimuthal sectors of 60 degrees. This configuration creates 30 thermal-hydraulic cells per axial level, with the entire active core region contained in the inner-most 18 cells.

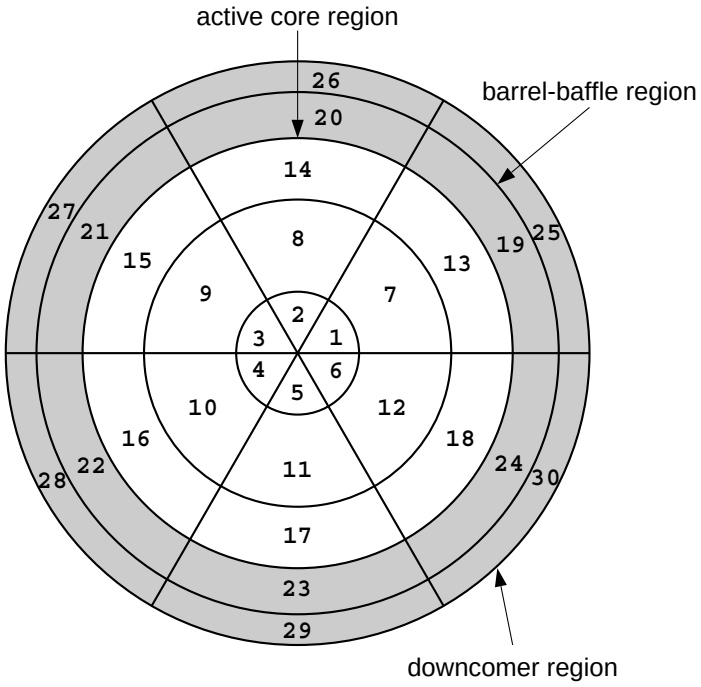


Figure 5. MSLB Exercise 3 VESSEL Component Radial Nodalization

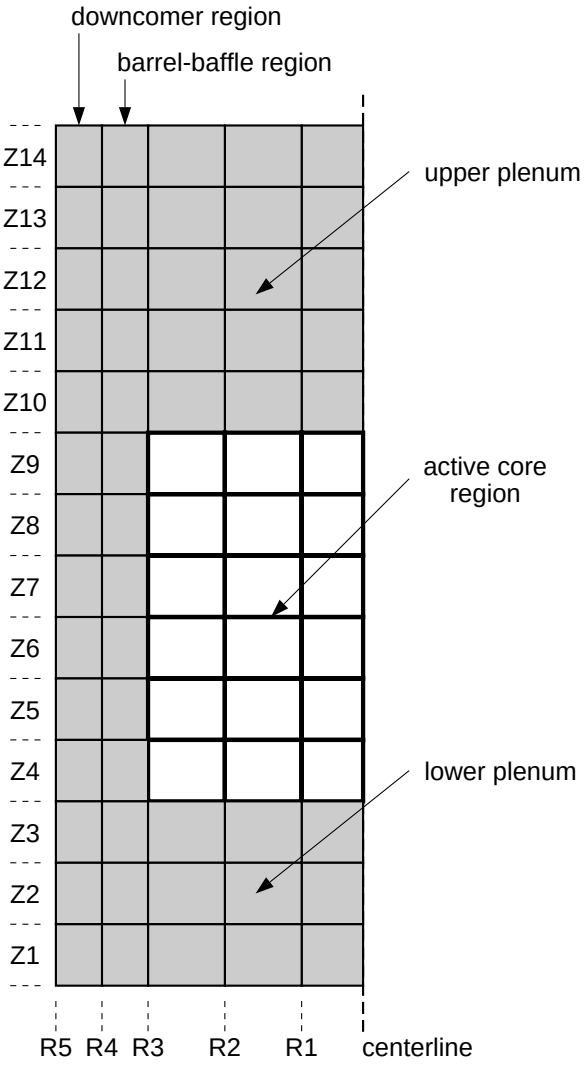


Figure 6. MSLB Exercise 3 VESSEL Component Axial Nodalization

The core heat structure nodalization for this exercise consists of a single heat structure component made up of 18 “average rod” sub-components. A single average rod is modelled in each of the 18 thermal-hydraulic cells making up the active core. The axial nodalization of the heat structures matches that of the cells to which they are coupled, i.e., six (6) axial levels of 59.52 cm each.

Exercise 2 TRACE Nodalization

The core hydrodynamics nodalization for the second exercise of the MSLB benchmark consists of 19 parallel vertical PIPE components to represent the coolant flow through the reactor core. Each PIPE consists of eight (8) cells 59.52 cm in height, as shown in Figure 7. The top and

bottom cells model the axial reflector, while the six (6) middle cells represent the active core region.

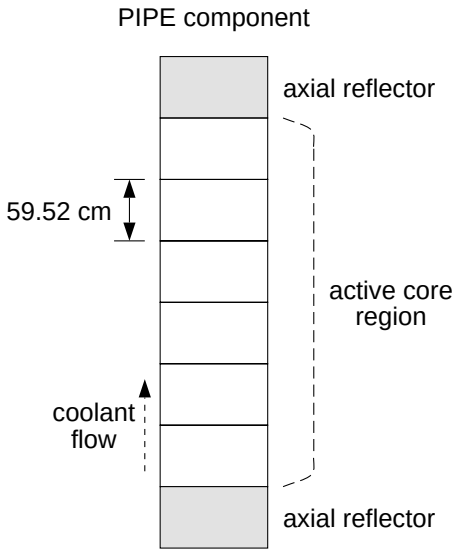


Figure 7. MSLB Exercise 2 PIPE Component Axial Nodalization

Each PIPE models flow through a particular radial region in the core. PIPE components 1-6 model coolant flow through the center of the core; PIPE components 7-12 model flow immediately adjacent to the core center; and PIPE components 13-18 model flow along the periphery of

the core, as shown in the right side of Figure 8. The radial reflector surrounding the core (commonly referred to as the bypass) is represented by PIPE component 19.

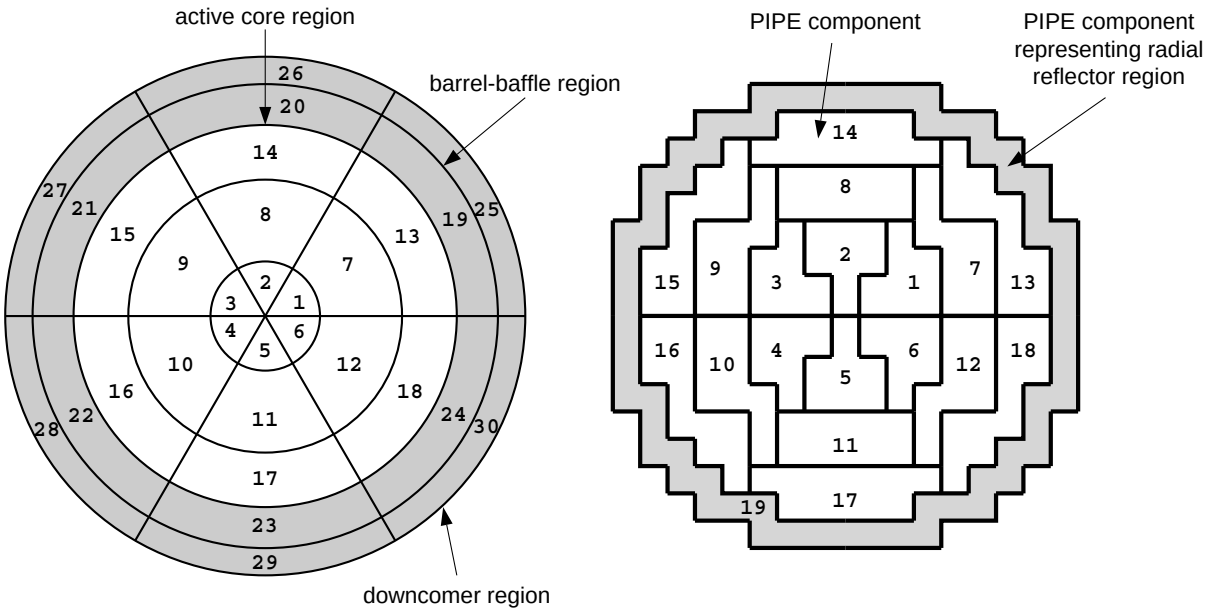


Figure 8. MSLB Exercise 2 PIPE Component Planar Nodalization

The core heat structure nodalization for this exercise consists of 193 heat structure components. Each of the 177 fuel assemblies in the core is represented by its own heat structure, as shown in Figure 9.

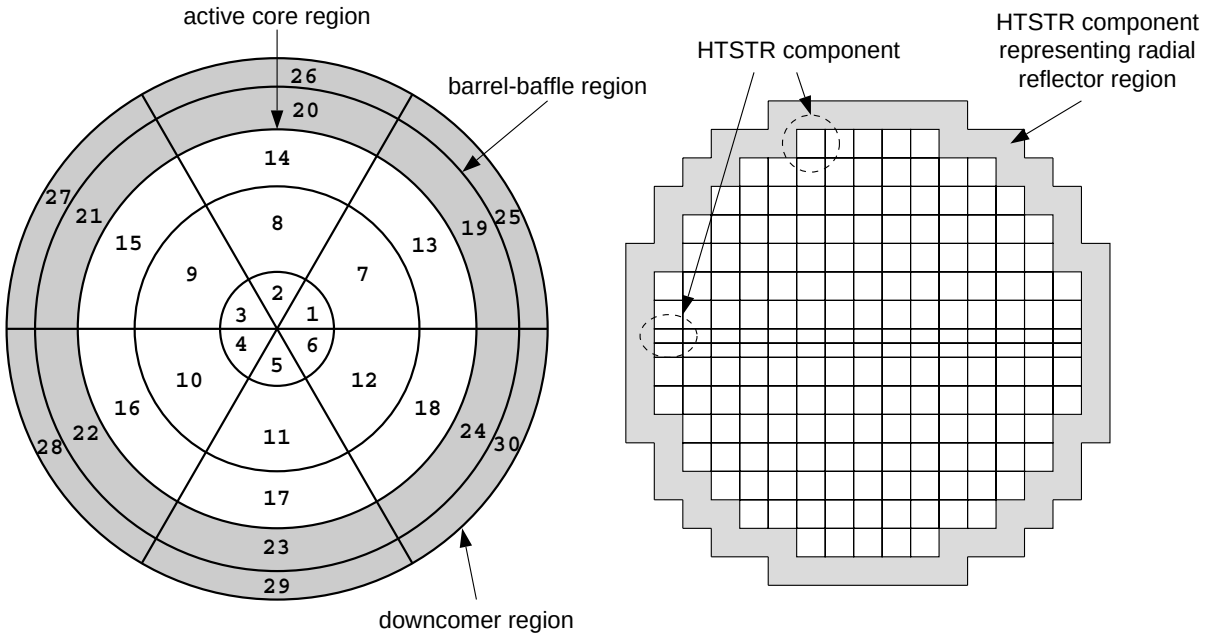


Figure 9. MSLB Exercise 2 HTSTR Component Planar Nodalization

For analysis purposes, the core was divided into six (6) azimuthal sectors, the boundaries of which split the core along its x-axis of symmetry. The layout of the azimuthal sectors from Figure 5 is reflected in the layout of the PIPE boundaries shown in Figure 8. It was decided that the heat structures split by these azimuthal sector boundaries would be divided into two (2) separate heat structures, each representing half the fuel pins making up the entire assembly. This modelling decision made the addition of 15 heat structure components to the TRACE model necessary. Finally, the entire radial reflector was represented with a single heat structure component for consistency with the thermal-hydraulic nodalization, bringing the total number of heat structures in this model to 193 (177+15+1=193).

The axial nodalization of the heat structure components is identical to that of the PIPE components to which they are coupled for the active core region, i.e., six (6) axial levels of 59.52 cm

each, illustrated in Figure 10. The axial reflector regions (both top and bottom) are lumped into the top-most and bottom-most axial levels of the heat structures.

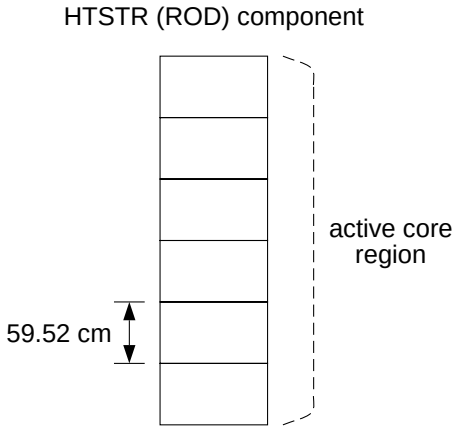


Figure 10. MSLB Exercise 2 HTSTR Axial Nodalization

Exercise 2 and 3 PARCS Nodalization

The neutronics nodalization of the MSLB Benchmark consists of 177 fuel assemblies, with each fuel assembly represented by a single neutronic node. Figure 11 shows the arrangement of the neutronic nodes for each axial plane of the neutronic model.

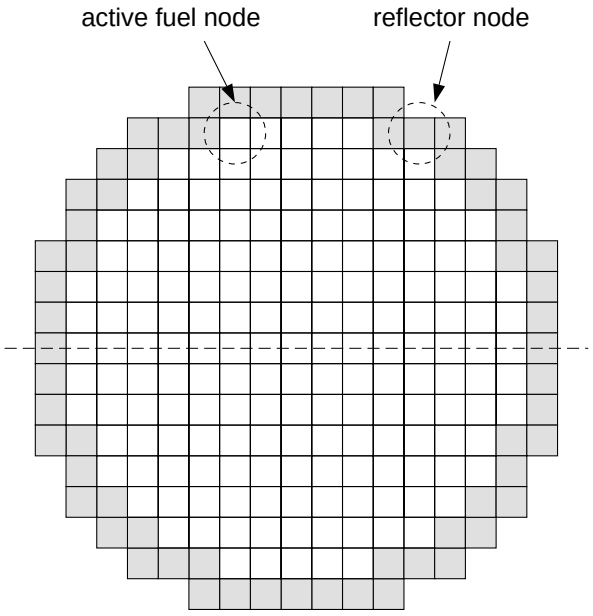


Figure 11. MSLB Exercise 2 and 3 Neutronic Radial Nodalization

Surrounding the fuel nodes, along the periphery of the core, is a shroud of 64 radial reflector nodes, which represent the flow passing directly through the "bypass" region of the core. The axial nodalization of the neutronic model, shown in Figure 12, is somewhat irregular but complies with the benchmark specifications.

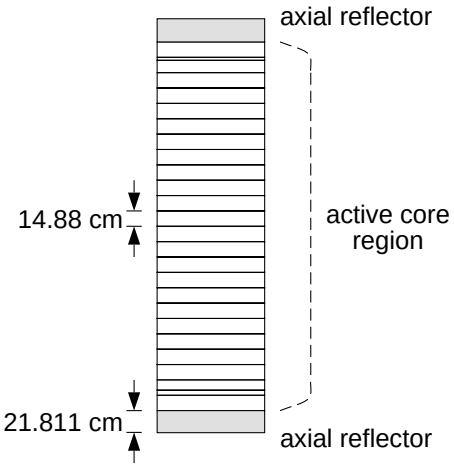


Figure 12. MSLB Exercise 2 and 3 Neutronic Axial Nodalization

A total of 28 axial levels make up the neutronic nodalization, with heights of (from the bottom of the core) 21.811 cm, 14.88 cm, 4.71 cm, 10.17 cm, (20*)14.88 cm, 12.266 cm, 2.614 cm, 14.88 cm, and 21.811 cm. The top and bottom axial levels represent the axial reflector region. The same nodalization was used for both exercises 2 and 3 of the MSLB benchmark problem.

V.B.3 Explicit Weight Generation

The specification of individual weights for mapping thermal-hydraulic and neutronic spatial domains is through the use of the `%TABLE1` and `%TABLE2` cards in the mapping information file. The name of this file is specified on the `CNTL` card in the PARCS input deck. Each line within these tables contains the weighting factor used for mapping a neutronic node to a component in the TRACE input deck (for both thermal-hydraulic and heat structure components). It is the responsibility of the user to calculate the mapping weights for these tables, taking into account both the radial and axial nodalizations of the thermal-hydraulic and neutronic models and the manner in which they "fit" together. Due to the repetitive nature of explicit weight generation, it is generally easier to split the generation of weights into two separate phases when constructing them manually. The first phase is to determine the radial weights required for mapping the thermal-hydraulic and neutronic spatial domains onto one another. Both thermal-hydraulic and neutronic models typically use the same radial nodalization for each axial level in the model. Therefore, the radial weights will usually be the same throughout the models. The second phase is to calculate the axial weights required for aligning the thermal-hydraulic and neutronic nodalizations. Like the radial nodalizations, it is typical for the axial nodalization of both thermal-hydraulic and neutronic models to be uniform. Therefore, once the axial weighting factors are determined, they are likely to be valid throughout the models. Once both the radial and axial

weighting factors have been determined, the entire set of mapping weights is constructed by multiplying each radial weight by each axial weight.

Determination of the weights must be performed for both thermal-hydraulic (`%TABLE1`) and heat structure (`%TABLE2`) components. The suggested procedure for calculating both the radial and axial weights is outlined below using the second exercise of the MSLB benchmark problem as a working example.

Radial Weight Generation

The generation of the radial weights is often little more than determining (visually) where neutronic nodes fall within the thermal-hydraulic and heat structure nodalization.

Thermal-Hydraulic to Neutronic Radial Weight Generation

For this purpose, Figure 8 and Figure 11 are shown overlayed below. From Figure 13, it can be visually determined that most neutronic nodes fall completely within the boundaries represented by a single thermal-hydraulic PIPE component. For example, PIPE number 8 represents the coolant flow for all 10 neutronic nodes within the confines of its boldface box. For instructional purposes, the 10 neutronic nodes linked to PIPE component 8 are shown in dark grey in Figure 13. The radial weight for each of the neutronic nodes contained within PIPE 8 is 1.0. In fact, all the radial weights are 1.0, with the exception of those corresponding to the neutronic nodes along the x-axis of symmetry.

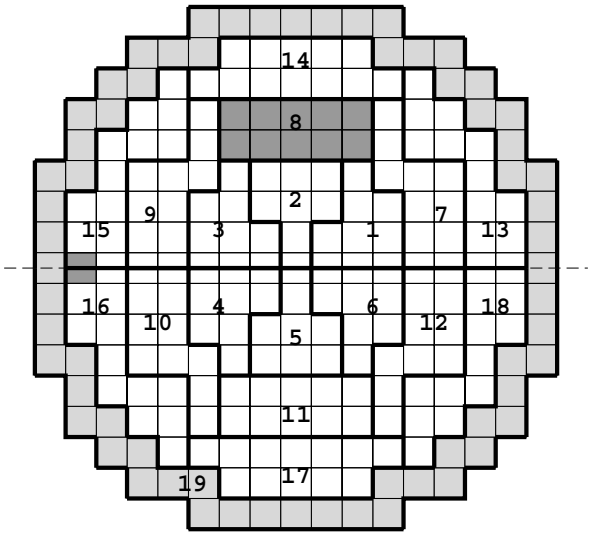


Figure 13. Radial Mapping Visualization for Exercise 2 of MSLB

Each of the neutronic nodes along the x-axis of symmetry is contained by two adjacent PIPE components. Because half of the each neutronic node exists in each of the two PIPE components, each neutronic node along this boundary has a radial weight of 0.5 for each PIPE component to which it is coupled. The sum of the radial weights for each neutronic node must be 1.0. In this

example, the left-most active fuel neutronic node (also shown in dark grey) is mapped to both PIPE numbers 15 and 16 equally. This node, therefore, has a radial weight of 0.5 for PIPE 15 and 0.5 for PIPE 16. It may be easier for the user to think of radial weights as determining what area fraction of each neutronic node lies in the area of the corresponding PIPE.

The radial reflector is less complicated to map. Because there is a single PIPE representing the flow in this region of the core, all neutronic reflector nodes have a radial weight of 1.0 for their mapping to PIPE 19. The reflector nodes along the x-axis of symmetry also have a weight of 1.0 because they are “bound” to the same PIPE (19) on both sides of the axis of symmetry.

A complete set of radial mapping weights for the thermal-hydraulic components of the second exercise of the MSLB benchmark is shown below in an excerpt from a customized FORTRAN code for building this mapping. It shows a radial map of the neutronic model, with the neutronic nodes represented by comma-delimited numbers. The numbers indicate the PIPE component to which each neutronic node is coupled radially. Note the comment indicating the location of the x-axis of symmetry in the radial map. The neutronic nodes adjacent to this line of symmetry are coupled to two (2) different PIPE components, which will be reflected in the value of the mapping weights. Immediately following the radial map is the set of mapping weights corresponding to this arrangement. Again, each neutronic node is represented in the map by a comma-delimited number, which is the mapping weight for that neutronic node. Together with the PIPE component to which a neutronic node is coupled, the weighting factor defines the radial mapping for each neutronic node.

```
c Radial Volume to Node Mapping
c
      rmap_th2n=(/         19,19,19,19,19,19,19,
     &               19,19,19,14,14,14,14,14,19,19,19,
     &            19,19,15,14,14,14,14,14,14,14,13,19,19,
     &         19,19,15,15, 9, 8, 8, 8, 8, 8, 7,13,13,19,19,
     &         19,15,15,15, 9, 8, 8, 8, 8, 8, 7,13,13,13,19,
     &      19,19,15, 9, 9, 9, 3, 2, 2, 2, 1, 7, 7, 7,13,19,19,
     &      19,15,15, 9, 9, 3, 3, 2, 2, 2, 1, 1, 7, 7,13,13,19,
     &      19,15,15, 9, 9, 3, 3, 3, 2, 1, 1, 1, 7, 7,13,13,19,
     &      19,15,15, 9, 9, 3, 3, 3, 2, 1, 1, 1, 7, 7,13,13,19,
c x-axis of symmetry located here
     &      19,16,16,10,10, 4, 4, 4, 5, 6, 6, 6,12,12,18,18,19,
     &      19,16,16,10,10, 4, 4, 4, 5, 6, 6, 6,12,12,18,18,19,
     &      19,16,16,10,10, 4, 4, 4, 5, 5, 5, 6, 6,12,12,18,18,19,
     &      19,19,16,10,10,10, 4, 5, 5, 5, 6,12,12,12,18,19,19,
     &         19,16,16,16,10,11,11,11,11,11,12,18,18,18,19,
     &         19,19,16,16,10,11,11,11,11,11,12,18,18,19,19,
     &            19,19,16,17,17,17,17,17,17,17,18,19,19,
     &               19,19,19,17,17,17,17,17,19,19,19,
     &                     19,19,19,19,19,19,19               /)

      rwf_th2n=(/          1.,1.,1.,1.,1.,1.,1.,
     &               1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &            1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      .5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,
c x-axis of symmetry located here
     &      .5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &            1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &               1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &                     1.,1.,1.,1.,1.,1.,1.               /)
```

As discussed above, the weighting factors for the neutronic nodes along the x-axis of symmetry are coupled to more than one PIPE component, as indicated by the 0.5 weighting values.

Each of these neutronic nodes has two (2) entries on both radial maps in order to define its mapping completely, since it was stated that the sum of the weighting factors for each neutronic node must add to unity (1.0).

Heat Structure to Neutronic Radial Weight Generation

A similar procedure should be used for generating the radial weights for mapping the neutronic domain onto the heat structure domain. For the MSLB problem, most neutronic fuel nodes will have a weight of 1.0 since each fuel node is represented by a single heat structure component. Neutronic nodes along the x-axis of symmetry are a source of complications because the heat structure nodalization is not congruent with the neutronic nodalization. As stated above, the heat structure components along this axis are half-sized with respect to heat structure components elsewhere in the core. Therefore, the neutronic nodes along the x-axis of symmetry are mapped to a pair of heat structure components, and the corresponding radial weight for these neutronic nodes is 0.5 for each heat structure component in exactly the same manner as was done for the PIPE component mapping.

The heat structure radial mapping weight for the radial reflector is exactly the same as for the thermal-hydraulic mapping. The radial reflector is represented in its entirety by a single PIPE component and a single heat structure component. Therefore, the radial mapping weight for all neutronic reflector nodes to the radial reflector heat structure components is 1.0.

The radial mapping information for the second exercise of the MSLB benchmark problem is shown in the map below. The numbers in this map indicate the heat structure component number(s) to which each neutronic node is mapped.

```
c Radial Heat Structure to Node Mapping
      rmap_hs2n=(/              993,993,993,993,993,993,993,
     &                 993,993,993,801,802,803,804,805,993,993,993,
     &              993,993,806,807,808,809,810,811,812,813,814,993,993,
     &           993,993,815,816,817,818,819,820,821,822,823,824,825,993,993,
     &           993,826,827,828,829,830,831,832,833,834,835,836,837,838,993,
     &      993,993,839,840,841,842,843,844,845,846,847,848,849,850,851,993,993,
     &      993,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,993,
     &      993,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,993,
     &      993,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,993,
c x-axis of symmetry located here
     &      993,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,993,
     &      993,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,993,
     &      993,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,993,
     &      993,993,942,943,944,945,946,947,948,949,950,951,952,953,954,993,993,
     &          993,955,956,957,958,959,960,961,962,963,964,965,966,967,993,
     &          993,993,968,969,970,971,972,973,974,975,976,977,978,993,993,
     &              993,993,979,980,981,982,983,984,985,986,987,993,993,
     &                  993,993,993,988,989,990,991,992,993,993,993,
     &                          993,993,993,993,993,993,993                /)

      rwf_hs2n=(/          1.,1.,1.,1.,1.,1.,1.,
     &               1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &            1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      .5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,
c x-axis of symmetry located here
     &      .5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,.5,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &      1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &         1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &            1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &               1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     &                     1.,1.,1.,1.,1.,1.,1.               /)
```

The values of the weights for defining the mapping between the heat structure components and the neutronic nodes are the same as were defined for the mapping of the thermal-hydraulic components. Just as each neutronic node along the x-axis of symmetry was coupled to two (2) PIPE components, each node along this axis is also coupled to two (2) heat structure components. For this reason, the mapping weights for both thermal-hydraulic and heat structure components are identical. This can be seen in the listing of the mapping weights themselves.

Axial Weight Generation

Determination of the axial weights uses a procedure similar to the generation of the radial mapping weights. However, it is not unusual for the thermal-hydraulic, heat structure, and neutronic nodalizations to differ completely in the axial direction. In most cases, uniform axial weights are used throughout the entire core, i.e., every neutronic node uses the same axial weight since the axial nodalization is typically uniform throughout the core. Because this is the case, any small error in the axial weights is propagated throughout the entire core with little indication of anything wrong.

The weights generated for the mapping of the thermal-hydraulic and heat structure nodalizations onto the neutronic nodalization are two-way. The weights that determine how thermal-hydraulic and heat structure component properties factor into reactivity feedback in the neutronics calculation are also used for determining how neutronic power is distributed throughout both thermal-hydraulic and heat structure components.

The thermal-hydraulic properties required to calculate feedback within PARCS are cell-centered or cell-averaged quantities: liquid temperature, liquid and vapor densities, void fraction, and boron concentration. The properties obtained from heat structure components -- volume-averaged fuel temperature, fuel centerline temperature, and fuel surface temperature -- are also cell-centered quantities. Finally, the power calculated by PARCS is calculated at the center of each neutronic node. Since all quantities are represented at the center of their respective volumes/nodes, the calculation of the axial weights is mainly a task of determining how the centers of the thermal-hydraulic and heat structure component cells align with the centers of the neutronic nodes. The suggested procedure for resolving the axial mapping weights is described below.

Thermal-Hydraulic to Neutronic Axial Weight Generation

Figure 14 below shows the axial nodalization of the PIPE components for the second exercise of the MSLB benchmark problem aligned with the neutronic nodalization. The PIPE cells numbers are indicated in the center of each cell, while the neutronic axial node is along the right

side of the neutronic nodalization. Note that for brevity, not every axial node in the neutronic model is labelled.

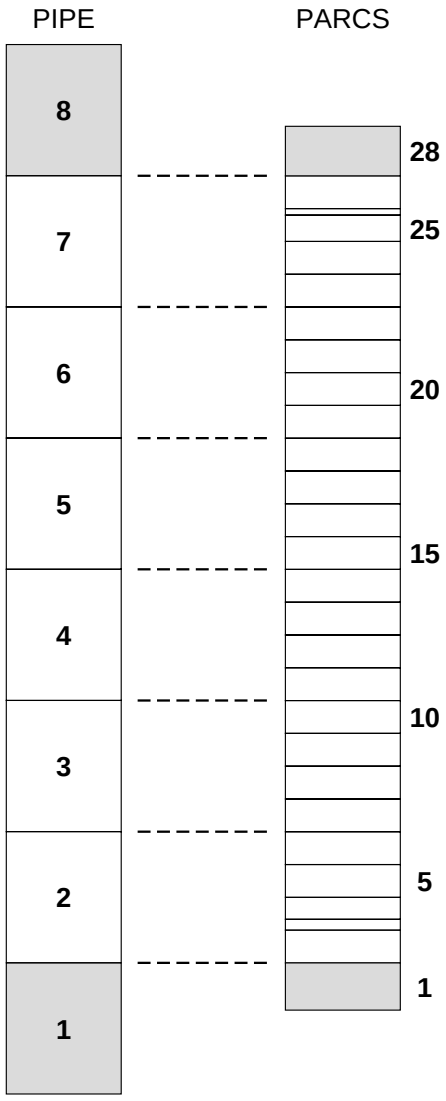


Figure 14. Axial Alignment of MSLB Exercise 2 Thermal-Hydraulic and Neutronic Models

It can be seen from Figure 14 that the bottom reflector neutronic node is mapped to cell 1 of the PIPE component, as was described in Section above. Since the nodalization of the neutronics model was provided in the MSLB benchmark specifications, there is a mis-match of neutronic and thermal-hydraulic node volumes for the axial reflector nodes. This inaccuracy does not introduce any error, as the nodalization makes these neutronic nodes of sufficient thickness to be considered infinite reflectors. Therefore, increasing their volume to match that of their respective thermal-hydraulic node will have no impact on the solution. Neutronic axial levels 2 through 6

(inclusive) should be mapped to cell 2 of the PIPE component. The rationale for this mapping decision is that these neutronic axial levels are “contained by”, i.e., align with, cell 2. Note that even though neutronic axial levels 3 and 4 are not of equal height (discussed in Section), they are still geometrically contained by this PIPE cell. Neutronic levels 7 through 10 (inclusive) should be mapped to PIPE cell 3. The procedure continues for the remainder of the axial levels in the core. Neutronic levels 23 through 27 (inclusive) are mapped to PIPE cell 7, and the top axial reflector level is represented by PIPE cell 8.

Once it has been determined which neutronic axial layers are coupled to which thermal-hydraulic nodes, the final step is the calculation of the values of the axial mapping weights themselves. In the case of the MSLB benchmark problem, the axial nodalizations of both the thermal-hydraulic and neutronic models align exactly with no overlap. For this reason, all axial mapping weights for all neutronic axial levels are 1.0. The value of the mapping weight can be interpreted in two ways. It is the fraction of the thermal-hydraulic feedback that a particular neutronic node receives from its associated thermal-hydraulic cell. Also, the weight specifies the fraction of the total neutronic power generated in a particular node that is deposited into its associated thermal-hydraulic cell.

The complete set of axial mapping weights for coupling thermal-hydraulic components with the neutronics model is shown below. The axial mapping of the neutronic levels onto the the hydrodynamic nodalization is shown using comma-delimited numbers. The numbers indicate the cell number in the PIPE component to which the neutronic level is coupled. Immediately following the axial map is the set of mapping weights corresponding to this arrangement. As was stated above, since the nodalizations align exactly with no overlap, the axial weights are all 1.0.

```
c Axial Volume to Node Mapping
      zmap_th2n=(/  1,
     &              2, 2, 2, 2, 2,
     &              3, 3, 3, 3,
     &              4, 4, 4, 4,
     &              5, 5, 5, 5,
     &              6, 6, 6, 6,
     &              7, 7, 7, 7, 7,
     &              8  /)
      zwf_th2n=(/  1.0,
     &             1.0, 1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0, 1.0,
     &             1.0 /)
```

Heat Structure to Neutronic Axial Weight Generation

The same procedure is used for the calculation of the axial weights between heat structure components and the neutronic model. The axial nodalization of the heat structure components is aligned with the neutronic axial nodalization in Figure 15 below.

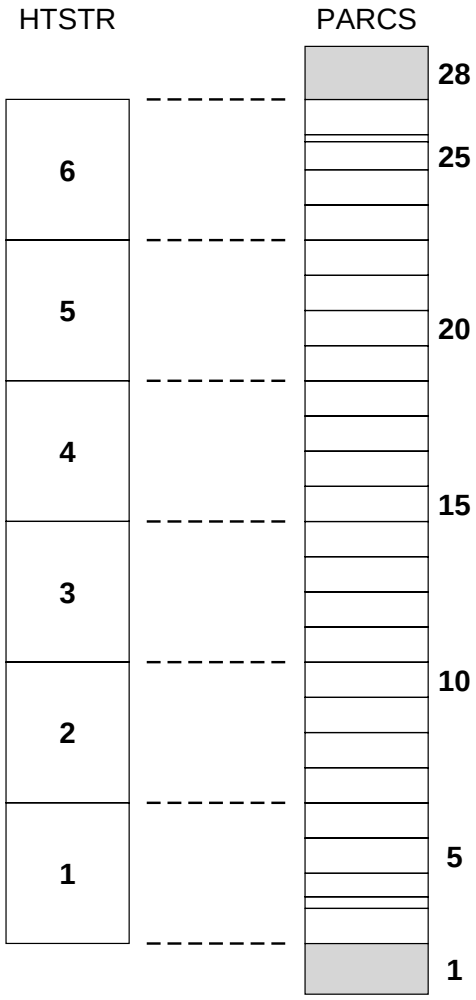


Figure 15. Axial Alignment of MSLB Exercise 2 Heat Structure and Neutronic Models

The lumping of the axial neutronic reflector layers into the bottom and top heat structure axial layers is illustrated in Figure 15. Since fuel temperature has no effect on the reflector cross sections, this modelling decision is an acceptable one with no effect on the final results. From the figure above, one can determine that neutronic axial layers 2 through 6 (inclusive) are "contained" by axial node row 1 in the heat structure component. Likewise, neutronic layers 7 through 10

(inclusive) are coupled to heat structure axial node row 2. The remainder of the heat structure to neutronic mapping uses the same procedure as was detailed above in the thermal-hydraulic to neutronic mapping in Section .

The complete set of axial mapping weights for coupling the neutronic and heat structure nodalizations is shown below, using the same format as for the hydrodynamic axial mapping weights. As was stated above, the top and bottom axial reflectors were not explicitly modelled by a heat structure node. These neutronic reflector nodes were lumped into the top- and bottom-most heat structure nodes, as can be observed in the mapping below.

```
c Axial Heat Structure to Node Mapping
      zmap_hs2n=(/  1,
     &              1, 1, 1, 1, 1,
     &              2, 2, 2, 2,
     &              3, 3, 3, 3,
     &              4, 4, 4, 4,
     &              5, 5, 5, 5,
     &              6, 6, 6, 6, 6,
     &              6  /)
      zwf_hs2n=(/  1.0,
     &             1.0, 1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0,
     &             1.0, 1.0, 1.0, 1.0, 1.0,
     &             1.0 /)
```

Putting It All Together

Once the radial and axial weights have been generated for both the hydrodynamic- and heat structure-to-neutronic mesh mapping, the final task is to construct a list of the exact mapping weights between each neutronic node and its coupled hydrodynamic and heat structure components. The `%TABLE1` and `%TABLE2` cards are used in the mapping input file for specifying the mapping weights for hydrodynamic and heat structure components, respectively.

%TABLE1 Card

This card relates to the mapping between hydrodynamic volumes and neutronic nodes. Each line of data which follows this card is read in free format and contains five (5) numbers per row (integer, integer, integer, integer, real) corresponding to:

Integer #1: *TRACE Hydraulic Component Number*

This value should correspond to that specified by the user in the TRACE input deck for the specific component (e.g. *vessel*, *chan*, or *pipe*).

Integer #2: *Component Cell Number*

For the *vessel* component, this number should correspond to the radial cell number in the T/H plane. For *chan* or *pipe* components this number should correspond to the cell number within the *chan* or *pipe.*

Integer #3: *Component Axial Level*

For the *vessel* component, this number is the axial plane number. For *chan* or *pipe* components, this number should be “0”.

Integer #4: *PARCS Node Number*

Real #1: *Weighting Factor*

The sum of the input weighting factors for a particular PARCS node number should be equal to 1.0.

The weighting factor is determined from the product of the corresponding radial and axial weights for the particular hydrodynamic volume and neutronic node in question.

Example:

```
%TABLE1
     51        1        0        1    1.0000
     51        1        0        2    0.5000
     52        1        0        2    0.5000
     52        1        0        3    1.0000
```

`%TABLE2 Card`

This card relates to the mapping between heat structures and neutronic nodes. Each line of data which follows this card is read in free format and contains five numbers per row (integer, integer, integer, integer, real) corresponding to:

Integer #1: *TRACE Heat Structure Component Number*

This value should correspond to that specified by the user in the TRACE input deck for the specific component (e.g. *rod*, *slab*, *htstr*, or *chan*).

Integer #2: HS *Average ROD/SLAB/HTSTR Number*

This value is the rod group number for the heat structure component specified in the first integer field.

Integer #3: *Component Axial Level*

This value is the axial level within the heat structure rod specified by the first two integer fields.

Integer #4: *PARCS Node Number*

Real #1: *Weighting Factor*

The sum of the input weighting factors for a particular PARCS node number should either be equal to 1.0 or 0.0. If the sum is equal to 0.0 for any PARCS node, then it is assumed that this node is not connected to any heat structure.

Note: The PARCS node numbers to be used in TABLE1 and TABLE2 should be consistent with those used in the PARCS code, which utilizes a plane ordering, as shown below:

$$\text{Node Ordering} = \left[\left[N_1^1 \ \ldots \ N_L^1\right] \cdots \left[N_1^K \ \ldots \ N_L^K\right]\right]$$

where,

$$N_l^k = ((k-1)\times L + l) \qquad (l = 1, 2, \ldots L; k = 1, 2 \ldots K)$$

and ***L*** corresponds to the number of nodes in a plane and ***K*** corresponds to the number of planes.

Example:

```
%TABLE2
     51        1        1        1    1.0000
     51        1        1        2    0.5000
     52        1        1        2    0.5000
     52        1        1        3    1.0000
```

V.B.4 VOLRMAP1 Card

This card specifies the type of component to which PARCS is coupled (e.g. *vessel* or *chan*). If "vessel" is input, the 2nd word must be the vessel component number. If "chan" is input, no component number should follow. The component numbers for chans will be taken from VOLRMAP2.

Example:

```
%VOLRMAP1
chan
```

V.B.5 VOLRMAP2 Cards

These cards specify the radial cell numbers to be coupled to each PARCS radial node. For *vessel* components, these numbers are the relative cell numbers in the r-theta (or x-y) plane. For *chan* components, these numbers are the actual *chan* number. The format of the map is as follows:

(1) The first row (line) of the map must contain a "0" in the first column followed by the numbers which relate to the column index in the neutronic plane.

(2) In each line that follows, the first column contains the row number for the neutronic plane, followed by the mapped cell numbers. NOTE: place holders (for non-node locations) are input using any character besides 0-9.

(3) Secondary maps can be entered, and will be detected when the first column of a processed line contains a "0" (indicating that column indices are to be read from this line).

Example:

```
%VOLRMAP2
0   1   2   2   3
1  51  51  52  52
2  51  51  52  52
2  53  53  54  54
```

```
3   53   53   54   54
```

V.B.6 VOLRMAP3 Cards

These cards specify the radial weighting factors for the map input with the VOLRMAP2 cards. The input format for these cards is the same as that for VOLRMAP2. It is necessary that the input radial form of VOLRMAP2 and VOLRMAP3 match exactly. The first line of these cards is the same as the first line of the VOLRMAP2 cards.

Example:

```
%VOLRMAP3
0    1     2     2     3
1   1.0   0.5   0.5   1.0
2   0.5   0.25  0.25  0.5
2   0.5   0.25  0.25  0.5
3   1.0   0.5   0.5   1.0
```

V.B.7 DOPL Card

This card specifies the option for calculating the Doppler fuel temperature feedback. Either the volume average fuel temperature or a linear combination of the fuel centerline and surface temperatures can be used for calculating the effective temperature. The volume-averaged fuel temperature is specified using AVG on the DOPL Card and the linear method is specified using LINC on the DOPL Card, where the parameter ω specifies the weighting of the fuel centerline, T_f^0 , and fuel surface temperature, T_f^s :

$$T_{Dopl} = (1-\omega)T_f^0 + \omega T_f^s,$$

A default of $\omega = 0.7$ is used for cylindrical fuel pins. When specifying the linear combination option, the weighting factor, ω, must also be provided on the card. Use of the average fuel temperature option requires no such option.

Examples:

```
%DOPL
 LINC  0.7

%DOPL
AVG
```

V.B.8 TRIP Card

This card specifies which TRACE control system trip ID will be used for signaling reactor scram and requires only the integer ID number of the trip in the TRACE model to be monitored for scram simulation.

Example:

```
%TRIP
 2
```

V.B.9 REFLPROP Card

This card specifies fixed reflector properties which will be used for reflector nodes if they are not mapped to TRACE components. This card contains 5 real numbers:

```
        tcoolrefl  tfuelrefl dcoolrefl vcoolrefl  ppmrefl
The following are the descriptions for these numbers

tcoolrefl : coolant temperature in Kelvin
tfuelrefl : fuel temperature in Kelvin (currently not used)
```

dcoolrefl : coolant density in kg/m^3

```
vcoolrefl : void fraction
ppmrefl   : solube born concentrantion in ppm
```

Example:

```
%REFLPROP
 560.0  560.0 700.0 0.0 0.0
```

V.B.10 MAPTAB Examples

Three examples of MAPTAB input are shown below for the same 2-D mapping scheme. The first two examples demonstrate the use of the VOLRMAP series, and the third example demonstrates the use of the TABLE series. For the VOLRMAP series, the first example uses one radial map each for VOLRMAP2 and VOLRMAP3 to specify the T/H to neutronic mapping. The second example uses 4 radial maps each for VOLRMAP2 and VOLRMAP3 to input the same mapping. Note the use of the asterisk ("*") character as a placeholder in VOLRMAP2 and VOLRMAP3 in example 2, which indicates no additional mapping information is provided for the corresponding neutronic node.

Example #1:

```
*
* Method of Calculating Doppler Temperature
*   LINC: Linear Combination (requires weighting factor)
*    AVG: Average Temperature
*
%DOPL
* LINC  0.7
 AVG
*
* Trip Unit Number for TRACE
*
```

```
%TRIP
 2
%VOLRMAP1
chan
%VOLRMAP2
0   1   2   2   3
1  51  51  52  52
2  51  51  52  52
2  53  53  54  54
3  53  53  54  54
%VOLRMAP3
0   1    2    2    3
1  1.0  0.5  0.5  1.0
2  0.5  0.25 0.25 0.5
2  0.5  0.25 0.25 0.5
3  1.0  0.5  0.5  1.0
```

Example #2:

```
*
* Method of Calculating Doppler Temperature
*   LINC: Linear Combination (requires weighting factor)
*    AVG: Average Temperature
*
%DOPL
* LINC  0.7
 AVG
*
* Trip Unit Number for TRACE
*
%TRIP
 2
%VOLRMAP1
  chan
%VOLRMAP2
0   1   2   3
1  51  51  52
2  51  51  52
3  53  53  54
*
0   1   2   3
1   *  52   *
2  53  52  54
3   *  53   *
*
0   1   2   3
1   *   *   *
2   *  53   *
```

```
3   *   *   *
*
0   1   2   3
1   *   *   *
2   *  54   *
3   *   *   *
%VOLRMAP3
0   1    2    3
1  1.0  0.5  1.0
2  0.5  0.25 0.25
3  1.0  0.5  1.0
*
0   1    2    3
1   *   0.5   *
2  0.5  0.25 0.5
3   *   0.5   *
*
0   1    2    3
1   *    *    *
2   *   0.25  *
3   *    *    *
*
0   1    2    3
1   *    *    *
2   *   0.25  *
3   *    *    *
```

Example #3:

```
*
* Method of Calculating Doppler Temperature
*   LINC: Linear Combination (requires weighting factor)
*    AVG: Average Temperature
*
%DOPL
* LINC  0.7
 AVG
*
* Trip Unit Number for TRACE
*
%TRIP
 2
*
* Volume to Node Table
*
%TABLE1
     51       1       0       1    1.0000
     51       1       0       2    0.5000
```

```
     52        1        0        2    0.5000
     52        1        0        3    1.0000
     51        1        0        4    0.5000
     53        1        0        4    0.5000
     51        1        0        5    0.2500
     52        1        0        5    0.2500
     53        1        0        5    0.2500
     54        1        0        5    0.2500
     52        1        0        6    0.5000
     54        1        0        6    0.5000
     53        1        0        7    1.0000
     53        1        0        8    0.5000
     54        1        0        8    0.5000
     54        1        0        9    1.0000
*
* Heat Structure to Node Table
*
%TABLE2
     51        1        1        1    1.0000
     51        1        1        2    0.5000
     52        1        1        2    0.5000
     52        1        1        3    1.0000
     51        1        1        4    0.5000
     53        1        1        4    0.5000
     51        1        1        5    0.2500
     52        1        1        5    0.2500
     53        1        1        5    0.2500
     54        1        1        5    0.2500
     52        1        1        6    0.5000
     54        1        1        6    0.5000
     53        1        1        7    1.0000
     53        1        1        8    0.5000
     54        1        1        8    0.5000
     54        1        1        9    1.0000
```

VI. SAMPLE INPUTS

VI.A OECD MSLB Benchmark

VI.A.1 Steady State Input Deck

```
CASEID ss     OECD/NEA MSLB
!*******************************************************************************
CNTL
      ext_th     T        ../rad.map        TRAC   50
      core_power 100.0
      bank_pos   971.0 971.0 971.0 971.0 971.0 971.0 900.0 971.0
      pin_power  F
!                     input  iteration     planar                  adj
!                      edit      table      power        pin       reac
!     print_opt           T          F          T          F          T
      print_opt           F          F          F          F          F
!                       fdbk       flux     planar
!                        rho    precurs       flux         Xe        T/H
      print_opt           F          F          F          F          F

!*******************************************************************************
XSEC
      func_type 11
      dnp_ngrp   6
      dhp_beta   2.35402E-02 1.89077E-02 1.39236E-02 6.90315E-03 3.56888E-03 3.31633E-03
       dhp_lambda 1.05345E-01 8.37149E-03 5.20337E-04 4.73479E-05 3.28153E-06 1.17537E-
11
      kin_comp   1  1 -438
      dnp_beta   0.000153 0.001086 0.000965 0.002019 0.000791 0.000197
      dnp_lambda 0.012818 0.031430 0.125062 0.329776 1.414748 3.822362
      neut_velo  1.83E7 4.01E5

!*******************************************************************************
GEOM
!     file ../GEOM_FC
! ------------------------------------------------------------------------------
 geo_dim 17 17 28
 Rad_Conf
   0   0   0   0   0   1   1   1   1   1   1   1   0   0   0   0   0
   0   0   0   1   1   1   2   2   2   2   2   1   1   1   0   0   0
   0   0   1   1   2   2   2   2   2   2   2   2   2   1   1   0   0
   0   1   1   2   2   2   2   2   2   2   2   2   2   2   1   1   0
   0   1   2   2   2   2   2   2   2   2   2   2   2   2   2   1   0
   1   1   2   2   2   2   2   2   2   2   2   2   2   2   2   1   1
   1   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   1
   1   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   1
   1   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   1
   1   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   1
   1   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   1
   1   1   2   2   2   2   2   2   2   2   2   2   2   2   2   1   1
   0   1   2   2   2   2   2   2   2   2   2   2   2   2   2   1   0
   0   1   1   2   2   2   2   2   2   2   2   2   2   2   1   1   0
   0   0   1   1   2   2   2   2   2   2   2   2   2   1   1   0   0
   0   0   0   1   1   1   2   2   2   2   2   1   1   1   0   0   0
```

```
  0   0   0   0   0   1   1   1   1   1   1   1   0   0   0   0   0
grid_x      17*21.811
neutmesh_x  17*1
grid_y      17*21.811
neutmesh_y  17*1
grid_z      21.811  14.88  4.71  10.17  20*14.88  12.266  2.614  14.88  21.811
Boun_cond   1 1 1 1 1 1
Planar_reg  1
                     24  24  24  24  24  24  24
              24  24  24  24  24  24  24  24  24  24  24
          24  24  24  24  24  24  24  24  24  24  24  24  24
      24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
      24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
 24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
 24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
 24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
 24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
 24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
      24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
      24  24  24  24  24  24  24  24  24  24  24  24  24  24  24
          24  24  24  24  24  24  24  24  24  24  24  24  24
              24  24  24  24  24  24  24  24  24  24  24
                     24  24  24  24  24  24  24
Planar_reg  2
                     25  25  25  25  25  25  25
              25  25  25 304 214 109 214 304  25  25  25
          25  25 409 364 289 199  94 199 289 364 409  25  25
      25  25 424 394 349 274 184  79 184 274 349 394 424  25  25
      25 409 394 379 334 259 169  64 169 259 334 379 394 409  25
  25  25 364 349 334 319 244 154  49 154 244 319 334 349 364  25  25
  25 304 289 274 259 244 229 139  34 139 229 244 259 274 289 304  25
  25 214 199 184 169 154 139 124  16 124 139 154 169 184 199 214  25
  25 109  94  79  64  49  34  16   1  16  34  49  64  79  94 109  25
  25 214 199 184 169 154 139 124  16 124 139 154 169 184 199 214  25
  25 304 289 274 259 244 229 139  34 139 229 244 259 274 289 304  25
  25  25 364 349 334 319 244 154  49 154 244 319 334 349 364  25  25
      25 409 394 379 334 259 169  64 169 259 334 379 394 409  25
      25  25 424 394 349 274 184  79 184 274 349 394 424  25  25
          25  25 409 364 289 199  94 199 289 364 409  25  25
              25  25  25 304 214 109 214 304  25  25  25
                     25  25  25  25  25  25  25
.
.
.
.
.
.
 Planar_reg  16
                     25  25  25  25  25  25  25
              25  25  25 318 228 123 228 318  25  25  25
          25  25 423 378 303 213 108 213 303 378 423  25  25
      25  25 438 408 363 288 198  93 198 288 363 408 438  25  25
      25 423 408 393 348 273 183  78 183 273 348 393 408 423  25
  25  25 378 363 348 333 258 168  63 168 258 333 348 363 378  25  25
  25 318 303 288 273 258 243 153  48 153 243 258 273 288 303 318  25
  25 228 213 198 183 168 153 138  33 138 153 168 183 198 213 228  25
  25 123 108  93  78  63  48  33  15  33  48  63  78  93 108 123  25
```

```
 25 228 213 198 183 168 153 138  33 138 153 168 183 198 213 228  25
 25 318 303 288 273 258 243 153  48 153 243 258 273 288 303 318  25
 25  25 378 363 348 333 258 168  63 168 258 333 348 363 378  25  25
     25 423 408 393 348 273 183  78 183 273 348 393 408 423  25
     25  25 438 408 363 288 198  93 198 288 363 408 438  25  25
         25  25 423 378 303 213 108 213 303 378 423  25  25
             25  25  25 318 228 123 228 318  25  25  25
                     25  25  25  25  25  25  25
Planar_reg  17
                     26  26  26  26  26  26  26
             26  26  26  26  26  26  26  26  26  26  26
         26  26  26  26  26  26  26  26  26  26  26  26  26
     26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
     26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
 26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
 26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
 26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
 26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
 26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
     26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
     26  26  26  26  26  26  26  26  26  26  26  26  26  26  26
         26  26  26  26  26  26  26  26  26  26  26  26  26
             26  26  26  26  26  26  26  26  26  26  26
                     26  26  26  26  26  26  26
PR_assign 1  2  3  4  5  6  7  4*8  6*9  4*10  11  12  13  14  15  16  17
cr_axinfo 36.2255 0.3531
bank_conf
                     0   0   0   0   0   0   0
             0   0   0   0   0   0   0   0   0   0   0
         0   0   0   0   1   0   6   0   1   0   0   0   0
     0   0   0   0   3   0   5   0   5   0   3   0   0   0   0
     0   0   0   7   0   0   0   7   0   0   0   7   0   0   0
 0   0   0   3   0   5   0   4   0   4   0   5   0   3   0   0   0
 0   0   1   0   0   0   6   0   2   0   6   0   0   0   1   0   0
 0   0   0   5   0   4   0   2   0   2   0   4   0   5   0   0   0
 0   0   6   0   7   0   2   0   7   0   2   0   7   0   6   0   0
 0   0   0   5   0   4   0   2   0   2   0   4   0   5   0   0   0
 0   0   1   0   0   0   6   0   2   0   6   0   0   0   1   0   0
 0   0   0   3   0   5   0   4   0   4   0   5   0   3   0   0   0
     0   0   0   7   0   0   0   7   0   0   0  -8   0   0   0
     0   0   0   0   3   0   5   0   5   0   3   0   0   0   0
         0   0   0   0   1   0   6   0   1   0   0   0   0
             0   0   0   0   0   0   0   0   0   0   0
                     0   0   0   0   0   0   0
pincal_loc
                     0   0   0   0   0   0   0
             0   0   0   0   0   0   0   0   0   0   0
         0   0   0   0   0   0   0   0   0   0   0   0   0
     0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   1   1   3   3   3   3   3   3   0
 0   0   0   0   0   0   0   0   1   1   3   3   3   3   3   0   0
```

```
       0   0   0   0   0   0   0   1   1   3   3   3   3   3   0
       0   0   0   0   0   0   0   1   1   3   3   3   3   0   0
           0   0   0   0   0   0   1   1   3   3   3   0   0
               0   0   0   0   0   1   1   3   0   0   0
                       0   0   0   0   0   0   0
! ------------------------------------------------------------------------------

!*******************************************************************************
PARAM
      conv_ss   1.e-6 5.e-5 1.e-3 0.001 !epseig,epsl2,epslinf,epstf  (eqn 5)
      eps_erf   0.010
      eps_anm   0.000001
      nlupd_ss  5 5 1
      init_guess 0

!*******************************************************************************
TH
     n_pingt    208 17                    !npin,ngt
     fa_powpit  15.661 21.811             !assembly power(Mw) and pitch(cm)
     pin_dim    4.6955 5.4640 0.673 6.731 !pin radii, rs,rw,tw, and rgt in mm
     flow_cond  289.84 90.7448            !tin,cmfrfa(Kg/sec)
     gamma_frac 0.0                       !direc heating fraction
     hgap       11356.                    !hgap(w/M^2-C)
     n_ring     6                         !number of meshes in pellet
     thmesh_x   17*1                      !Number of T/H Nodes per FA in X-dir
     thmesh_y   17*1                      !Number of T/H Nodes per FA in Y-dir
     thmesh_z   1 6 10 14 18 22 27 28     !junction locations
     write_fbv  T

!*******************************************************************************
PFF
!     file ../PFF_TMI
! ------------------------------------------------------------------------------
 npin_side 15
 pff_comp  1 1 -15
 pff_unrodd  1  !group 1 of set 1
  1.0893  1.0796  1.0796  1.0806  1.0817  1.0828  1.0817  1.0806
  1.0796  1.0655  1.0666  1.0698  1.0796  1.0850  1.0785  1.0687
  1.0796  1.0666  1.0785  1.0861  1.0958  0.0000  1.0850  1.0709
  1.0806  1.0698  1.0861  0.0000  1.0980  1.0882  1.0806  1.0709
  1.0817  1.0796  1.0958  1.0980  1.0936  1.0893  1.0817  1.0720
  1.0828  1.0850  0.0000  1.0882  1.0893  0.0000  1.0871  1.0731
  1.0817  1.0785  1.0850  1.0806  1.0817  1.0871  1.0904  1.0850
  1.0806  1.0687  1.0709  1.0709  1.0720  1.0731  1.0850  0.0000
 pff_comp  2 16 -48
 pff_unrodd  1  !group 1 of set 2
  1.0633  1.0569  1.0579  1.0623  1.0666  1.0698  1.0666  1.0644
  1.0569  0.9768  1.0536  1.0623  1.0796  1.0969  1.0742  1.0601
  1.0579  1.0536  1.0752  1.1055  1.1228  0.0000  1.1001  1.0677
  1.0623  1.0623  1.1055  0.0000  1.1326  1.1174  1.0861  1.0687
  1.0666  1.0796  1.1228  1.1326  1.1174  1.1174  1.0882  1.0709
  1.0698  1.0969  0.0000  1.1174  1.1174  0.0000  1.1044  1.0742
  1.0666  1.0742  1.1001  1.0861  1.0882  1.1044  1.0904  1.0806
  1.0644  1.0601  1.0677  1.0687  1.0709  1.0742  1.0806  0.0000
 pff_comp  3 49 -438
 pff_unrodd  1  !group 1 of set 3
  1.0633  1.0569  1.0579  1.0623  1.0666  1.0698  1.0666  1.0644
  1.0569  0.9768  1.0536  1.0623  1.0796  1.0969  1.0742  1.0601
  1.0579  1.0536  1.0752  1.1055  1.1228  0.0000  1.1001  1.0677
```

```
  1.0623  1.0623  1.1055  0.0000  1.1326  1.1174  1.0861  1.0687
  1.0666  1.0796  1.1228  1.1326  1.1174  1.1174  1.0882  1.0709
  1.0698  1.0969  0.0000  1.1174  1.1174  0.0000  1.1044  1.0742
  1.0666  1.0742  1.1001  1.0861  1.0882  1.1044  1.0904  1.0806
  1.0644  1.0601  1.0677  1.0687  1.0709  1.0742  1.0806  0.0000
! ------------------------------------------------------------------------------

!*******************************************************************************
TRAN
     Time_Step  100.0 0.1 100.0  10.0
     Scram      T 114.0 0.4 2.2
     nlupd_tr   5 1 5 10
     conv_tr    0.001
     eps_xsec   0.001
     pin_freq   1000000
!    theta      1.0
PLOT
!    file ../sscoupl.plc
! ------------------------------------------------------------------------------
!  X-Y time plot
!***************************************
! type of x-axis
!    0  -  time = default
!    1  -  sstime
!    2  -  case number
! x_max is needed if type>0
!            type     x_min  x_max
     XTYPE     1        0       1000
!
!           alp     num    Min  Max    Graph Color
!
      XY   tfuel   014121 250.0 750.0     1    1
      XY   tfuel   014176 250.0 750.0     1    2
      XY   tcool   001176 280.0 330.0     2    1
      XY   tcool   014176 280.0 330.0     2    2
      XY   tcool   028176 280.0 330.0     2    3
      XY   dcool   017676 600.0 800.0     3    1
      XY   dcool   014176 600.0 800.0     3    2
      XY   dcool   028176 600.0 800.0     3    3
      XY   relp    014121 0.0   1.5       4    1
      XY   relp    014176 0.0   1.5       4    2
      XY   keff         0 1.004 1.006     5    1

!*****************************************************************
!         alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*****************************************************************
 RECTMAP  crpmap  15  15    800.0  1000.        1          1
          0   0   0   0   0   1   2   3   4   5   0   0   0   0   0
          0   0   0   6   7   8   9  10  11  12  13  14   0   0   0
          0   0  15  16  17  18  19  20  21  22  23  24  25   0   0
          0  26  27  28  29  30  31  32  33  34  35  36  37  38   0
          0  39  40  41  42  43  44  45  46  47  48  49  50  51   0
         52  53  54  55  56  57  58  59  60  61  62  63  64  65  66
         67  68  69  70  71  72  73  74  75  76  77  78  79  80  81
         82  83  84  85  86  87  88  89  90  91  92  93  94  95  96
         97  98  99 100 101 102 103 104 105 106 107 108 109 110 111
        112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
          0 127 128 129 130 131 132 133 134 135 136 137 138 139   0
          0 140 141 142 143 144 145 146 147 148 149 150 151 152   0
```

```
          0   0 153 154 155 156 157 158 159 160 161 162 163   0   0
          0   0   0 164 165 166 167 168 169 170 171 172   0   0   0
          0   0   0   0   0 173 174 175 176 177   0   0   0   0   0
!
 RECTMAP  lp2d   15  15      0.0   450.       1           1
          0   0   0   0   0   1   2   3   4   5   0   0   0   0   0
          0   0   0   6   7   8   9  10  11  12  13  14   0   0   0
          0   0  15  16  17  18  19  20  21  22  23  24  25   0   0
          0  26  27  28  29  30  31  32  33  34  35  36  37  38   0
          0  39  40  41  42  43  44  45  46  47  48  49  50  51   0
         52  53  54  55  56  57  58  59  60  61  62  63  64  65  66
         67  68  69  70  71  72  73  74  75  76  77  78  79  80  81
         82  83  84  85  86  87  88  89  90  91  92  93  94  95  96
         97  98  99 100 101 102 103 104 105 106 107 108 109 110 111
        112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
          0 127 128 129 130 131 132 133 134 135 136 137 138 139   0
          0 140 141 142 143 144 145 146 147 148 149 150 151 152   0
          0   0 153 154 155 156 157 158 159 160 161 162 163   0   0
          0   0   0 164 165 166 167 168 169 170 171 172   0   0   0
          0   0   0   0   0 173 174 175 176 177   0   0   0   0   0

 RECTMAP  relp   15   15     0.5   1.5         1           1
      00000 00000 00000 00000 00000 00011 00012 00013 00014 00015 00000 00000 00000 00000 00000
      00000 00000 00000 00021 00022 00023 00024 00025 00026 00027 00028 00029 00000 00000 00000
      00000 00000 00034 00035 00036 00037 00038 00039 00040 00041 00042 00043 00044 00000 00000
      00000 00048 00049 00050 00051 00052 00053 00054 00055 00056 00057 00058 00059 00060 00000
      00000 00064 00065 00066 00067 00068 00069 00070 00071 00072 00073 00074 00075 00076 00000
      00080 00081 00082 00083 00084 00085 00086 00087 00088 00089 00090 00091 00092 00093 00094
      00097 00098 00099 00100 00101 00102 00103 00104 00105 00106 00107 00108 00109 00110 00111
      00114 00115 00116 00117 00118 00119 00120 00121 00122 00123 00124 00125 00126 00127 00128
      00131 00132 00133 00134 00135 00136 00137 00138 00139 00140 00141 00142 00143 00144 00145
      00148 00149 00150 00151 00152 00153 00154 00155 00156 00157 00158 00159 00160 00161 00162
      00000 00166 00167 00168 00169 00170 00171 00172 00173 00174 00175 00176 00177 00178 00000
      00000 00182 00183 00184 00185 00186 00187 00188 00189 00190 00191 00192 00193 00194 00000
      00000 00000 00198 00199 00200 00201 00202 00203 00204 00205 00206 00207 00208 00000 00000
      00000 00000 00000 00213 00214 00215 00216 00217 00218 00219 00220 00221 00000 00000 00000
      00000 00000 00000 00000 00000 00227 00228 00229 00230 00231 00000 00000 00000 00000 00000
!
 RECTMAP  tcool   17   17   310.0  330.0        1           1
    00000 00000 00000 00000 00000 28001 28002 28003 28004 28005 28006 28007 00000 00000 00000 00000 00000
    00000 00000 00000 28008 28009 28010 28011 28012 28013 28014 28015 28016 28017 28018 00000 00000 00000
    00000 00000 28019 28020 28021 28022 28023 28024 28025 28026 28027 28028 28029 28030 28031 00000 00000
    00000 28032 28033 28034 28035 28036 28037 28038 28039 28040 28041 28042 28043 28044 28045 28046 00000
    00000 28047 28048 28049 28050 28051 28052 28053 28054 28055 28056 28057 28058 28059 28060 28061 00000
    28062 28063 28064 28065 28066 28067 28068 28069 28070 28071 28072 28073 28074 28075 28076 28077 28078
    28079 28080 28081 28082 28083 28084 28085 28086 28087 28088 28089 28090 28091 28092 28093 28094 28095
    28096 28097 28098 28099 28100 28101 28102 28103 28104 28105 28106 28107 28108 28109 28110 28111 28112
    28113 28114 28115 28116 28117 28118 28119 28120 28121 28122 28123 28124 28125 28126 28127 28128 28129
    28130 28131 28132 28133 28134 28135 28136 28137 28138 28139 28140 28141 28142 28143 28144 28145 28146
    28147 28148 28149 28150 28151 28152 28153 28154 28155 28156 28157 28158 28159 28160 28161 28162 28163
    28164 28165 28166 28167 28168 28169 28170 28171 28172 28173 28174 28175 28176 28177 28178 28179 28180
    00000 28181 28182 28183 28184 28185 28186 28187 28188 28189 28190 28191 28192 28193 28194 28195 00000
    00000 28196 28197 28198 28199 28200 28201 28202 28203 28204 28205 28206 28207 28208 28209 28210 00000
    00000 00000 28211 28212 28213 28214 28215 28216 28217 28218 28219 28220 28221 28222 28223 00000 00000
    00000 00000 00000 28224 28225 28226 28227 28228 28229 28230 28231 28232 28233 28234 00000 00000 00000
    00000 00000 00000 00000 00000 28235 28236 28237 28238 28239 28240 28241 00000 00000 00000 00000 00000
!*********************************************************************
!  Axial Distribution Plots
!*********************************************************************
!        alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*********************************************************************
 AXPLOT  relp   28    4    0.0    1.8       1            1
   01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000 12000 13000 14000 15000 16000 17000 18000
19000 20000 21000 22000 23000 24000 25000 26000 27000 28000
   01121 02121 03121 04121 05121 06121 07121 08121 09121 10121 11121 12121 13121 14121 15121 16121 17121 18121
19121 20121 21121 22121 23121 24121 25121 26121 27121 28121
   01176 02176 03176 04176 05176 06176 07176 08176 09176 10176 11176 12176 13176 14176 15176 16176 17176 18176
19176 20176 21176 22176 23176 24176 25176 26176 27176 28176
```

```
   01050 02050 03050 04050 05050 06050 07050 08050 09050 10050 11050 12050 13050 14050 15050 16050 17050 18050
19050 20050 21050 22050 23050 24050 25050 26050 27050 28050
! end of plot control
```

VI.A.2 Transient Input Deck

The transient input deck is formed by adding the following 3 lines to the CNTL block of the steady state parcs input:

```
decay_heat T
transient  T
restart    T ss.rst  20
```

The steady-state PLOT block should be replaced with the following:

```
!  X-Y time plot
!*************************************
! type of x-axis
!    0  -  time = default
!    1  -  burnup
!    2  -  case number
! x_max is needed if type>0
!            type     x_min  x_max
!     XTYPE     2         1       10
!
!           alp     num    Min  Max    Graph Color
!
      XY   tfuel   014121 250.0 750.0     1    1
      XY   tfuel   014176 250.0 750.0     1    2
      XY   tcool   001176 220.0 320.0     2    1
      XY   tcool   014176 220.0 320.0     2    2
      XY   tcool   028176 220.0 320.0     2    3
      XY   dcool   017676 600.0 900.0     3    1
      XY   dcool   014176 600.0 900.0     3    2
      XY   dcool   028176 600.0 900.0     3    3
      XY   relp    014121 0.0   3.0       4    1
      XY   relp    014176 0.0   3.0       4    2
      XY   plevel     0   0.0   1.2       5    1
      XY   rhoadj     0  -8.0   6.0       6    1
      XY   rhodm      0  -8.0   6.0       6    2
      XY   rhotf      0  -8.0   6.0       6    3
      XY   rhocr      0  -8.0   6.0       6    4
      XY   bank(1)    0   0.   1000       9    1
      XY   bank(2)    0   0.   1000       9    2
      XY   bank(3)    0   0.   1000       9    3
      XY   bank(4)    0   0.   1000       9    4
      XY   bank(5)    0   0.   1000       9    5
      XY   bank(6)    0   0.   1000       9    6
      XY   bank(7)    0   0.   1000       9    7
      XY   bank(8)    0   0.   1000       9    8

!*********************************************************************
!         alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*********************************************************************
 RECTMAP  crpmap  15  15     0.0   1000.        1          10
          0   0   0   0   0   1   2   3   4   5   0   0   0   0   0
          0   0   0   6   7   8   9  10  11  12  13  14   0   0   0
          0   0  15  16  17  18  19  20  21  22  23  24  25   0   0
          0  26  27  28  29  30  31  32  33  34  35  36  37  38   0
          0  39  40  41  42  43  44  45  46  47  48  49  50  51   0
```

```
          52  53  54  55  56  57  58  59  60  61  62  63  64  65  66
          67  68  69  70  71  72  73  74  75  76  77  78  79  80  81
          82  83  84  85  86  87  88  89  90  91  92  93  94  95  96
          97  98  99 100 101 102 103 104 105 106 107 108 109 110 111
         112 113 114 115 116 117 118 119 120 121 122 123 124 125 126
           0 127 128 129 130 131 132 133 134 135 136 137 138 139   0
           0 140 141 142 143 144 145 146 147 148 149 150 151 152   0
           0   0 153 154 155 156 157 158 159 160 161 162 163   0   0
           0   0   0 164 165 166 167 168 169 170 171 172   0   0   0
           0   0   0   0   0 173 174 175 176 177   0   0   0   0   0

 RECTMAP  relp   15   15      0.5   3.0         1           10
       00000 00000 00000 00000 00000 00011 00012 00013 00014 00015 00000 00000 00000 00000 00000
       00000 00000 00000 00021 00022 00023 00024 00025 00026 00027 00028 00029 00000 00000 00000
       00000 00000 00034 00035 00036 00037 00038 00039 00040 00041 00042 00043 00044 00000 00000
       00000 00048 00049 00050 00051 00052 00053 00054 00055 00056 00057 00058 00059 00060 00000
       00000 00064 00065 00066 00067 00068 00069 00070 00071 00072 00073 00074 00075 00076 00000
       00080 00081 00082 00083 00084 00085 00086 00087 00088 00089 00090 00091 00092 00093 00094
       00097 00098 00099 00100 00101 00102 00103 00104 00105 00106 00107 00108 00109 00110 00111
       00114 00115 00116 00117 00118 00119 00120 00121 00122 00123 00124 00125 00126 00127 00128
       00131 00132 00133 00134 00135 00136 00137 00138 00139 00140 00141 00142 00143 00144 00145
       00148 00149 00150 00151 00152 00153 00154 00155 00156 00157 00158 00159 00160 00161 00162
       00000 00166 00167 00168 00169 00170 00171 00172 00173 00174 00175 00176 00177 00178 00000
       00000 00182 00183 00184 00185 00186 00187 00188 00189 00190 00191 00192 00193 00194 00000
       00000 00000 00198 00199 00200 00201 00202 00203 00204 00205 00206 00207 00208 00000 00000
       00000 00000 00000 00213 00214 00215 00216 00217 00218 00219 00220 00221 00000 00000 00000
       00000 00000 00000 00000 00000 00227 00228 00229 00230 00231 00000 00000 00000 00000 00000
!
 RECTMAP  tcool   17   17   220.0  300.0         1           1
    00000 00000 00000 00000 00000 01001 01002 01003 01004 01005 01006 01007 00000 00000 00000 00000 00000
    00000 00000 00000 01008 01009 01010 01011 01012 01013 01014 01015 01016 01017 01018 00000 00000 00000
    00000 00000 01019 01020 01021 01022 01023 01024 01025 01026 01027 01028 01029 01030 01031 00000 00000
    00000 01032 01033 01034 01035 01036 01037 01038 01039 01040 01041 01042 01043 01044 01045 01046 00000
    00000 01047 01048 01049 01050 01051 01052 01053 01054 01055 01056 01057 01058 01059 01060 01061 00000
    01062 01063 01064 01065 01066 01067 01068 01069 01070 01071 01072 01073 01074 01075 01076 01077 01078
    01079 01080 01081 01082 01083 01084 01085 01086 01087 01088 01089 01090 01091 01092 01093 01094 01095
    01096 01097 01098 01099 01100 01101 01102 01103 01104 01105 01106 01107 01108 01109 01110 01111 01112
    01113 01114 01115 01116 01117 01118 01119 01120 01121 01122 01123 01124 01125 01126 01127 01128 01129
    01130 01131 01132 01133 01134 01135 01136 01137 01138 01139 01140 01141 01142 01143 01144 01145 01146
    01147 01148 01149 01150 01151 01152 01153 01154 01155 01156 01157 01158 01159 01160 01161 01162 01163
    01164 01165 01166 01167 01168 01169 01170 01171 01172 01173 01174 01175 01176 01177 01178 01179 01180
    00000 01181 01182 01183 01184 01185 01186 01187 01188 01189 01190 01191 01192 01193 01194 01195 00000
    00000 01196 01197 01198 01199 01200 01201 01202 01203 01204 01205 01206 01207 01208 01209 01210 00000
    00000 00000 01211 01212 01213 01214 01215 01216 01217 01218 01219 01220 01221 01222 01223 00000 00000
    00000 00000 00000 01224 01225 01226 01227 01228 01229 01230 01231 01232 01233 01234 00000 00000 00000
    00000 00000 00000 00000 00000 01235 01236 01237 01238 01239 01240 01241 00000 00000 00000 00000 00000
!*********************************************************************
!  Axial Distribution Plots
!*********************************************************************
!        alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*********************************************************************
 AXPLOT  relp   28    4    0.0    5.0       1            1
   01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000 12000 13000 14000 15000 16000 17000 18000
19000 20000 21000 22000 23000 24000 25000 26000 27000 28000
   01121 02121 03121 04121 05121 06121 07121 08121 09121 10121 11121 12121 13121 14121 15121 16121 17121 18121
19121 20121 21121 22121 23121 24121 25121 26121 27121 28121
   01176 02176 03176 04176 05176 06176 07176 08176 09176 10176 11176 12176 13176 14176 15176 16176 17176 18176
19176 20176 21176 22176 23176 24176 25176 26176 27176 28176
   01050 02050 03050 04050 05050 06050 07050 08050 09050 10050 11050 12050 13050 14050 15050 16050 17050 18050
19050 20050 21050 22050 23050 24050 25050 26050 27050 28050
! end of plot control
```

VI.A.3 MAPTAB (rad.map) Input

```
*
* Method of Calculating Doppler Temperature
*
%DOPL
 LINC  0.7
* AVG
*
* Trip Unit Number for T/H Code
*
%TRIP
 112
%VOLRMAP1
 vessel  99
*
* Radial Mapping of T/H Volume Numbers to Neutronic Plane
*
%VOLRMAP2
 0   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17
 1   *  *  *  *  * 20 20 20 20 20 20 20  *  *  *  *  *
 2   *  *  * 21 21 20 14 14 14 14 14 20 19 19  *  *  *
 3   *  * 21 21 15 14 14 14 14 14 14 14 13 19 19  *  *
 4   * 21 21 15 15  9  8  8  8  8  8  7 13 13 19 19  *
 5   * 21 15 15 15  9  8  8  8  8  8  7 13 13 13 19  *
 6  21 21 15  9  9  9  3  2  2  2  1  7  7  7 13 19 19
 7  21 15 15  9  9  3  3  2  2  2  1  1  7  7 13 13 19
 8  21 15 15  9  9  3  3  3  2  1  1  1  7  7 13 13 19
 9  21 15 15  9  9  3  3  3  2  1  1  1  7  7 13 13 19
 9  22 16 16 10 10  4  4  4  5  6  6  6 12 12 18 18 24
10  22 16 16 10 10  4  4  4  5  6  6  6 12 12 18 18 24
11  22 16 16 10 10  4  4  5  5  5  6  6 12 12 18 18 24
12  22 22 16 10 10 10  4  5  5  5  6 12 12 12 18 24 24
13   * 22 16 16 16 10 11 11 11 11 11 12 18 18 18 24  *
14   * 22 22 16 16 10 11 11 11 11 11 12 18 18 24 24  *
15   *  * 22 22 16 17 17 17 17 17 17 17 18 24 24  *  *
16   *  *  * 22 22 23 17 17 17 17 17 23 24 24  *  *  *
17   *  *  *  *  * 23 23 23 23 23 23 23  *  *  *  *  *
*
* Weighting Factors for %VOLRMAP2
*
%VOLRMAP3
 0    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17
 1   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *
 2   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *
 3   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *
 4   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
 5   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
 6  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 7  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 8  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 9  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
 9  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
10  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
11  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
12  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
13   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
14   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
```

```
15   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *
16   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *
17   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *
```

VI.B BWR Peach Bottom Turbine Trip Benchmark

VI.B.1 Steady State Input Deck

```
CASEID ss   PBTT BWR SS 3D
!*****************************************************************************
CNTL !table 5
      core_type  BWR
      core_power 61.5852
      ppm        0.0
      bank_pos   480.0 400.0 360.0 340.0 320.0 260.0  40.0   0.0
      th_fdbk    T
      xe_sm      0
      decay_heat F
      pin_power  F
      ext_th     T    maptab8ch_05_rad   TRAC   50    1
      transient  F
      restart    F    ss3d.rst  1
!                    input  iteration     planar                  adj
!                     edit      table      power        pin       reac
      print_opt          T          T          F          F          F
!                     fdbk       flux     planar
!                      rho    precurs       flux         Xe        T/H
      print_opt          F          F          F          F          T
      print_opt          F          F          F
      oned_kin   F   SA1D
!*****************************************************************************
PARAM !table 6
      n_iters    5      500
      conv_ss    1.0e-6  1.e-5  5.e-4  0.001 !keff,globfs,locfs,tempf
      wielandt   0.04   0.1    1.0
      nodal_kern HYBRID
      nlupd_ss   3 3 1
      eps_anm    0.005
      eps_erf    0.005
      decusp     2
      init_guess 0
!*****************************************************************************
XSEC  !tabl 7
      func_type  13

      dnp_ngrp   6
      kin_comp   1  1 -435

!fix mslb specs

      dnp_beta   0.000153 0.001086 0.000965 0.002019 0.000791 0.000197
      dnp_lambda 0.012818 0.031430 0.125062 0.329776 1.414748 3.822362

!anl data, parcs default

     dhp_beta   2.35402E-02 1.89077E-02 1.39236E-02 6.90315E-03 3.56888E-03 3.31633E-03
      dhp_lambda 1.05345E-01 8.37149E-03 5.20337E-04 4.73479E-05 3.28153E-06 1.17537E-
11
```

```
!*****************************************************************************
GEOM  !table 8
!     file      GEOM_PBTT
! ----------------------------------------------------------------------------
 geo_dim  32  32  26              !nasyx,nasyy,nz
 Rad_Conf
!1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16|17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
 0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0  0  0  0  !1
 0  0  0  0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  0  0  0  !2
 0  0  0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  0  0  !3
 0  0  0  0  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  0  0  0  0  !4
 0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  !5
 0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  !6
 0  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  0  !7
 1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  !8
 1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  !9
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !10
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !11
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !12
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !13
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !14
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !15
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !16
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !17
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !18
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !19
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !20
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !21
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !22
 1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  !23
 1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  !24
 1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  !25
 0  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  0  !26
 0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  !27
 0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  !28
 0  0  0  0  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  0  0  0  0  !29
 0  0  0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  0  0  !30
 0  0  0  0  0  0  1  1  1  2  2  2  2  2  2  2  2  2  2  2  2  2  2  1  1  1  0  0  0  0  0  0  !31
 0  0  0  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0  0  0  0  !32

 grid_x     32*15.494
 neutmesh_x 32*1
 grid_y     32*15.494
 neutmesh_y 32*1
 grid_z     26*15.240
 Boun_Cond  1  1  1  1  1  1      !ibcw,ibce,ibcn,ibcs,ibcb,ibct

 planar_reg 1
                433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
            433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
        433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
      433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
    433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
  433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
  433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
    433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
      433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
        433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
            433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
```

```
                             433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433 433
 planar_reg 2
                             435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435
                         435 435 435 241  97 121  97 121 121 121 121 121 121 121  97  97 241 435 435 435
                     435 435 435 121 121   1  97   1 121   1   1   1   1  97   1 121   1 121 121 435 435 435
                 435 435 145 289 289   1 217   1 217   1 217 265 313 217   1 193   1 217   1 337 289 169 435 435
             435 435 435 121 145   1 313 265 313 337 361 337 337 361 385 337 361 337 217 337   1 145 121 435 435 435
         435 435 435 289 217   1 361   1 337  49 337   1 337  25  25 385   1 337  49 337   1 337   1 217 289 435 435 435
     435 435 169 121 193   1 337 217 337 313 337 313 385 313 385 385 409 385 313 337 313 385 217 337   1 217 121 169 435 435
 435 435 435 265 145   1 337  73 337  49 385  49 337  25 337 337 313 385  25 337  49 385  49 361  73 337   1 145 289 435 435 435
 435 435 121 289   1 361 217 385 337 385 385 337 337 385 313 385 385 337 337 313 385 289 385 313 361 217 337   1 289 145 435 435
 435 241 121   1 361   1 337  49 385  25 337  25 337  25 337  25  25 385  25 337  25 385  25 337  49 385   1 337   1 121 241 435
 435  97   1 217 217 337 265 385 361 337 313 385 337 337 313 385 385 289 385 337 337 337 385 313 337 313 337 217 217   1  97 435
 435 121 121   1 361  49 385  49 337  25 337  25 385  25 385 385 337 385  25 385  25 337  25 337  49 385  49 337   1 121  97 435
 435 121   1 193 361 385 313 361 337 337 313 361 337 385 385 385 385 337 385 313 385 337 337 313 337 313 361 361 193   1 121 435
 435 145  97   1 385  49 337  25 337  25 337  25 385  25 385  25  25 385  25 385  25 337  25 337  25 385   1 337   1  97 121 435
 435 121   1 217 337 361 337 337 337 385 337 385 385 385 337 337 385 337 385 337 385 289 337 385 337 313 337 361 217   1 121 435
 435 121   1 265 361  25 361 289 361  25 385 337 385  25 337 337 337 337  25 385 337 337  25 385 289 385  25 337 313   1 121 435
 435 145   1 265 337  25 385 337 337  25 337 337 337  25 361 385 337 337  25 385 337 385  25 385 289 361  25 385 265   1 121 435
 435 121   1 217 361 385 337 337 337 385 313 385 337 385 337 361 337 385 385 337 385 289 337 337 361 289 337 337 217   1 121 435
 435 121 121   1 337   1 385  25 337  25 337  25 385  25 385  25  25 385  25 385  25 385  25 337  25 385   1 337   1  97 121 435
 435 121   1 193 361 385 265 361 337 337 313 385 313 385 313 385 385 337 385 361 385 313 337 337 337 313 361 385 193   1 121 435
 435 121 121   1 361  49 385  49 337  25 337  25 385  25 385 361 337 385  25 385  25 337  25 337  49 337  49 337   1 121 121 435
 435  97   1 217 217 385 313 337 313 385 337 337 337 385 313 337 385 337 385 313 337 313 337 313 337 313 337 217 217   1  97 435
 435 241  97   1 361   1 385  49 337  25 385  25 337  25 385  25  25 337  25 385  25 337  25 337  49 385   1 313   1  97 217 435
 435 435 145 289   1 361 217 337 313 337 337 337 337 385 361 385 409 313 385 337 337 337 385 313 385 217 361   1 313 121 435 435
 435 435 435 289 145   1 337  73 337  49 337  49 337  25 385 313 313 385  25 385  49 385  49 385  73 337   1 145 289 435 435 435
     435 435 169 121 217   1 385 217 385 265 337 313 385 289 385 385 289 361 313 337 265 337 217 337   1 217 121 169 435 435
         435 435 435 289 217   1 361   1 385  49 385   1 385  25  25 385  49 337  49 361   1 361   1 193 289 435 435 435
             435 435 435 121 145   1 361 217 361 361 409 409 337 361 385 409 361 361 217 361   1 145 121 435 435 435
                 435 435 145 241 337   1 217   1 193   1 217 217 217 217   1 217   1 217   1 337 289 145 435 435
                     435 435 435 121 121   1 121   1 121   1   1   1   1 121   1  97   1 121 121 435 435 435
                         435 435 435 241  97 121 121 145 121 121 121 121 145 121 121  97 241 435 435 435
                             435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435
.
.
.
.
.
.
 planar_reg 25
                             435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435
                         435 435 435 264 120 144 120 144 144 144 144 144 144 144 120 120 264 435 435 435
                     435 435 435 144 144  24 120  24 144  24  24  24  24 120  24 144  24 144 144 435 435 435
                 435 435 168 312 312  24 240  24 240  24 240 288 336 240  24 216  24 240  24 360 312 192 435 435
             435 435 435 144 168  24 336 288 336 360 384 360 360 384 408 360 384 360 240 360  24 168 144 435 435 435
         435 435 435 312 240  24 384  24 360  72 360  24 360  48  48 408  24 360  72 360  24 360  24 240 312 435 435 435
     435 435 192 144 216  24 360 240 360 336 360 336 408 336 408 408 432 408 336 360 336 408 240 360  24 240 144 192 435 435
 435 435 435 288 168  24 360  96 360  72 408  72 360  48 360 360 336 408  48 360  72 408  72 384  96 360  24 168 312 435 435 435
 435 435 144 312  24 384 240 408 360 408 408 360 360 408 336 408 408 360 360 336 408 312 408 336 384 240 360  24 312 168 435 435
 435 264 144  24 384  24 360  72 408  48 360  48 360  48 360  48  48 408  48 360  48 408  48 360  72 408  24 360  24 144 264 435
 435 120  24 240 240 360 288 408 384 360 336 408 360 360 336 408 408 312 408 360 360 360 408 336 360 336 360 240 240  24 120 435
 435 144 144  24 384  72 408  72 360  48 360  48 408  48 408 408 360 408  48 408  48 360  48 360  72 408  72 360  24 144 120 435
 435 144  24 216 384 408 336 384 360 360 336 384 360 408 408 408 408 360 408 336 408 360 360 336 360 336 384 384 216  24 144 435
 435 168 120  24 408  72 360  48 360  48 360  48 408  48 408  48  48 408  48 408  48 360  48 360  48 408  24 360  24 120 144 435
 435 144  24 240 360 384 360 360 360 408 360 408 408 408 360 360 408 360 408 360 408 312 360 408 360 336 360 384 240  24 144 435
 435 144  24 288 384  48 384 312 384  48 408 360 408  48 360 360 360 360  48 408 360 360  48 408 312 408  48 360 336  24 144 435
 435 168  24 288 360  48 408 360 360  48 360 360 360  48 384 408 360 360  48 408 360 408  48 408 312 384  48 408 288  24 144 435
 435 144  24 240 384 408 360 360 360 408 336 408 360 408 360 384 360 408 408 360 408 312 360 360 384 312 360 360 240  24 144 435
 435 144 144  24 360  24 408  48 360  48 360  48 408  48 408  48  48 408  48 408  48 408  48 360  48 408  24 360  24 120 144 435
 435 144  24 216 384 408 288 384 360 360 336 408 336 408 336 408 408 360 408 384 408 336 360 360 360 336 384 408 216  24 144 435
 435 144 144  24 384  72 408  72 360  48 360  48 408  48 408 384 360 408  48 408  48 360  48 360  72 360  72 360  24 144 144 435
 435 120  24 240 240 408 336 360 336 408 360 360 360 408 336 360 408 360 408 336 360 336 360 336 360 336 360 240 240  24 120 435
 435 264 120  24 384  24 408  72 360  48 408  48 360  48 408  48  48 360  48 408  48 360  48 360  72 408  24 336  24 120 240 435
 435 435 168 312  24 384 240 360 336 360 360 360 360 408 384 408 432 336 408 360 360 360 408 336 408 240 384  24 336 144 435 435
 435 435 435 312 168  24 360  96 360  72 360  72 360  48 408 336 336 408  48 408  72 408  72 408  96 360  24 168 312 435 435 435
     435 435 192 144 240  24 408 240 408 288 360 336 408 312 408 408 312 384 336 360 288 360 240 360  24 240 144 192 435 435
         435 435 435 312 240  24 384  24 408  72 408  24 408  48  48 408  72 360  72 384  24 384  24 216 312 435 435 435
             435 435 435 144 168  24 384 240 384 384 432 432 360 384 408 432 384 384 240 384  24 168 144 435 435 435
                 435 435 168 264 360  24 240  24 216  24 240 240 240 240  24 240  24 240  24 360 312 168 435 435
                     435 435 435 144 144  24 144  24 144  24  24  24  24 144  24 120  24 144 144 435 435 435
                         435 435 435 264 120 144 144 168 144 144 144 144 168 144 144 120 264 435 435 435
                             435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435 435
 planar_reg 26
                             434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                         434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                     434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
             434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
         434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
     434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
```

```
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
     434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
         434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
             434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                     434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                         434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
                             434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434 434
 PR_Assign  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
 CR_axinfo  15.24  0.762    !fully inserted position and step size
 bank_conf
                         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                      0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
                   0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
                0  0  0  1  1  1  1  4  4  1  1  3  3  1  1  4  4  1  1  1  1  0  0  0
             0  0  0  0  1  1  1  1  4  4  1  1  3  3  1  1  4  4  1  1  1  1  0  0  0  0
          0  0  0  1  1  1  1  8  8  1  1  6  6  1  1  6  6  1  1  8  8  1  1  1  1  0  0  0
       0  0  0  0  1  1  1  1  8  8  1  1  6  6  1  1  6  6  1  1  8  8  1  1  1  1  0  0  0  0
    0  0  0  1  1  1  1  2  2  1  1  3  3  1  1  5  5  1  1  3  3  1  1  2  2  1  1  1  1  0  0  0
    0  0  0  1  1  1  1  2  2  1  1  3  3  1  1  5  5  1  1  3  3  1  1  2  2  1  1  1  1  0  0  0
    0  1  1  1  1  8  8  1  1  6  6  1  1  7  7  1  1  7  7  1  1  6  6  1  1  8  8  1  1  1  1  0
    0  1  1  1  1  8  8  1  1  6  6  1  1  7  7  1  1  7  7  1  1  6  6  1  1  8  8  1  1  1  1  0
    0  1  1  4  4  1  1  3  3  1  1  1  1  1  1  1  1  1  1  1  1  1  1  3  3  1  1  4  4  1  1  0
    0  1  1  4  4  1  1  3  3  1  1  1  1  1  1  1  1  1  1  1  1  1  1  3  3  1  1  4  4  1  1  0
    0  1  1  1  1  6  6  1  1  7  7  1  1  5  5  1  1  5  5  1  1  7  7  1  1  6  6  1  1  1  1  0
    0  1  1  1  1  6  6  1  1  7  7  1  1  5  5  1  1  5  5  1  1  7  7  1  1  6  6  1  1  1  1  0
    0  1  1  3  3  1  1  5  5  1  1  1  1  1  1  1  1  1  1  1  1  1  1  5  5  1  1  3  3  1  1  0
    0  1  1  3  3  1  1  5  5  1  1  1  1  1  1  1  1  1  1  1  1  1  1  5  5  1  1  3  3  1  1  0
    0  1  1  1  1  6  6  1  1  7  7  1  1  5  5  1  1  5  5  1  1  7  7  1  1  6  6  1  1  1  1  0
    0  1  1  1  1  6  6  1  1  7  7  1  1  5  5  1  1  5  5  1  1  7  7  1  1  6  6  1  1  1  1  0
    0  1  1  4  4  1  1  3  3  1  1  1  1  1  1  1  1  1  1  1  1  1  1  3  3  1  1  4  4  1  1  0
    0  1  1  4  4  1  1  3  3  1  1  1  1  1  1  1  1  1  1  1  1  1  1  3  3  1  1  4  4  1  1  0
    0  1  1  1  1  8  8  1  1  6  6  1  1  7  7  1  1  7  7  1  1  6  6  1  1  8  8  1  1  1  1  0
    0  1  1  1  1  8  8  1  1  6  6  1  1  7  7  1  1  7  7  1  1  6  6  1  1  8  8  1  1  1  1  0
    0  0  0  1  1  1  1  2  2  1  1  3  3  1  1  5  5  1  1  3  3  1  1  2  2  1  1  1  1  0  0  0
    0  0  0  1  1  1  1  2  2  1  1  3  3  1  1  5  5  1  1  3  3  1  1  2  2  1  1  1  1  0  0  0
       0  0  0  0  1  1  1  1  8  8  1  1  6  6  1  1  6  6  1  1  8  8  1  1  1  1  0  0  0  0
          0  0  0  1  1  1  1  8  8  1  1  6  6  1  1  6  6  1  1  8  8  1  1  1  1  0  0  0
             0  0  0  0  1  1  1  1  4  4  1  1  3  3  1  1  4  4  1  1  1  1  0  0  0  0
                0  0  0  1  1  1  1  4  4  1  1  3  3  1  1  4  4  1  1  1  1  0  0  0
                   0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0  0
                      0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
                         0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

! -----------------------------------------------------------------------------

!*****************************************************************************
TH    !table 9

      n_pingt    49 0                        !npin,ngt
      FA_POWPIT  4.31021 15.494              !assembly power(Mw) and pitch(cm)
      pin_dim    5.0000 6.0000 0.900 6.0000  !pin radii, rs,rw,tw, and rgt in mm
      flow_cond  282.0 12.548                !tin,cmfrfa(Kg/sec)

      gamma_frac 0.0                         !direct heating fraction
      hgap       10000.                      !hgap(w/M^2-C)
      n_ring     6                           !number of meshes in pellet
      thmesh_x   32*1                        !Number of T/H Nodes per FA in X-dir
      thmesh_y   32*1                        !Number of T/H Nodes per FA in Y-dir
      thmesh_z   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
!junction locations
      freeze_tf  F    800.0
      freeze_dm  F    300.0
```

```
      write_fbv  T  ss3d.fbv

      read_dopl  F  ss3d.fbv
      read_tmdm  F  ss3d.fbv
!*******************************************************************************
!PFF  table 10, power form function
!*******************************************************************************
PLOT
!     file sscoupl.plc
! ------------------------------------------------------------------------------
!  X-Y time plot
!**************************************
! type of x-axis
!    0  -  time = default
!    1  -  sstime
!    2  -  case number
! x_max is needed if type>0
!            type     x_min  x_max
     XTYPE     1        0       80
!
!           alp     num    Min  Max    Graph Color
!
      XY   tfuel   013460 250.0 750.0     1    1
      XY   tfuel   013472 250.0 750.0     1    2
      XY   tcool   001472 280.0 300.0     2    1
      XY   tcool   013472 280.0 300.0     2    2
      XY   tcool   026472 280.0 300.0     2    3
      XY   relp    013460 0.0   1.9       4    1
      XY   relp    013472 0.0   1.9       4    2
      XY   keff         0 1.000 1.010     5    1
      XY   vcool   001472  0.0  1.0       6    1
      XY   vcool   013472  0.0  1.0       6    2
      XY   vcool   026472  0.0  1.0       6    3

!*********************************************************************
!         alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*********************************************************************
 RECTMAP  lp2d   30 30    0.0  500.         1           10
  0   0   0   0   0   0   0   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   0   0   0   0   0   0   0
  0   0   0   0   0  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50   0   0   0   0   0
  0   0   0   0   0  51  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68  69  70   0   0   0   0   0
  0   0   0   0  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91  92   0   0   0   0
  0   0  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118   0   0
  0   0 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144   0   0
  0 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172   0
173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202
203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232
233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262
263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292
293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322
323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352
353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382
383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412
413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442
443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472
473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502
503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532
533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562
563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592
  0 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620   0
  0   0 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646   0   0
  0   0 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672   0   0
  0   0   0   0 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694   0   0   0   0
  0   0   0   0   0 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714   0   0   0   0   0
  0   0   0   0   0 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734   0   0   0   0   0
  0   0   0   0   0   0   0 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0 751 752 753 754 755 756 757 758 759 760 761 762 763 764   0   0   0   0   0   0   0   0
!
 RECTMAP  relp   30   30     0.3   1.9        1          1
```

```
  0   0   0   0   0   0   0   0  22  23  24  25  26  27  28  29  30  31  32  33  34  35   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57   0   0   0   0   0   0   0
  0   0   0   0   0  63  64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82   0   0   0   0   0
  0   0   0   0   0  88  89  90  91  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107   0   0   0   0   0
  0   0   0   0 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135   0   0   0   0
  0   0 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166   0   0
  0   0 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197   0   0
  0 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230   0
234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263
266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295
298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327
330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359
362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391
394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423
426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455
458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487
490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519
522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551
554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583
586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615
618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647
650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679
  0 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710   0
  0   0 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741   0   0
  0   0 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772   0   0
  0   0   0   0 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799   0   0   0   0
  0   0   0   0   0 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825   0   0   0   0   0
  0   0   0   0   0 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850   0   0   0   0   0
  0   0   0   0   0   0   0 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0 878 879 880 881 882 883 884 885 886 887 888 889 890 891   0   0   0   0   0   0   0   0
!
 RECTMAP  tcool   32  32 280.  285.0         1           1
  0   0   0   0   0   0   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18   0   0   0   0   0   0   0
  0   0   0   0   0   0  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38   0   0   0   0   0   0
  0   0   0   0   0  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60   0   0   0   0   0
  0   0   0   0  61  62  63  64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84   0   0   0   0
  0   0   0  85  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109 110   0   0   0
  0   0 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138   0   0
  0 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168   0
169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200
201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232
233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264
265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296
297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328
329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360
361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392
393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424
425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456
457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488
489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520
521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552
553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584
585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616
617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648
649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680
681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712
713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744
  0 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774   0
  0   0 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802   0   0
  0   0   0 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828   0   0   0
  0   0   0   0 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852   0   0   0   0
  0   0   0   0   0 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874   0   0   0   0   0
  0   0   0   0   0   0 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894   0   0   0   0   0   0
  0   0   0   0   0   0   0 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912   0   0   0   0   0   0   0
!*********************************************************************
!  Axial Distribution Plots
!*********************************************************************
!        alp    nx   ny    zmin   zmax  color_skip  1/frequency
!*********************************************************************
 AXPLOT  relp   26    3    0.0    2.2       1     1
   01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000 12000 13000 14000
15000 16000 17000 18000 19000 20000 21000 22000 23000 24000 25000 26000
   01460 02460 03460 04460 05460 06460 07460 08460 09460 10460 11460 12460 13460 14460
15460 16460 17460 18460 19460 20460 21460 22460 23460 24460 25460 26460
   01472 02472 03472 04472 05472 06472 07472 08472 09472 10472 11472 12472 13472 14472
15472 16472 17472 18472 19472 20472 21472 22472 23472 24472 25472 26472
 AXPLOT  tcool   26    3   270.0   290.      1     1
   01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000 12000 13000 14000
15000 16000 17000 18000 19000 20000 21000 22000 23000 24000 25000 26000
   01460 02460 03460 04460 05460 06460 07460 08460 09460 10460 11460 12460 13460 14460
15460 16460 17460 18460 19460 20460 21460 22460 23460 24460 25460 26460
```

```
   01472 02472 03472 04472 05472 06472 07472 08472 09472 10472 11472 12472 13472 14472
15472 16472 17472 18472 19472 20472 21472 22472 23472 24472 25472 26472
 AXPLOT  vcool   26    3    0.0    0.7      1     1
   01000 02000 03000 04000 05000 06000 07000 08000 09000 10000 11000 12000 13000 14000
15000 16000 17000 18000 19000 20000 21000 22000 23000 24000 25000 26000
   01460 02460 03460 04460 05460 06460 07460 08460 09460 10460 11460 12460 13460 14460
15460 16460 17460 18460 19460 20460 21460 22460 23460 24460 25460 26460
   01472 02472 03472 04472 05472 06472 07472 08472 09472 10472 11472 12472 13472 14472
15472 16472 17472 18472 19472 20472 21472 22472 23472 24472 25472 26472
! end of plot control
! ------------------------------------------------------------------------------
!******************************************************************************
TRAN  !table 11
     time_step  5.0 0.001
     expo_opt   F     T
     Scram      T 65.0 0.1 2.3
! The above values need checking
     theta      0.5   0.5   0.5
     conv_tr    0.001
     nlupd_tr   5 1 5 10
     eps_xsec   0.01
```

VI.B.2 MAPTAB (maptab8ch_05_rad) Input

```
*
%DOPL
 LINC  0.7
*
%TRIP
 4
*
%VOLRMAP1
 chan
*
* Radial Mapping of T/H Volume Numbers to Neutronic Plane
*
%VOLRMAP2
 0   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
 1   *  *  *  *  *  *  * 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57  *  *  *  *  *  *  *
 2   *  *  *  *  *  * 57 57 57 55 56 56 56 56 56 56 56 56 56 56 56 56 56 55 57 57 57  *  *  *  *  *  *
 3   *  *  *  *  * 57 57 57 56 54 51 54 51 54 51 51 51 51 54 51 54 51 54 56 57 57 57  *  *  *  *  *  *
 4   *  *  *  * 57 57 56 55 53 51 54 51 54 51 54 54 54 54 51 54 51 54 51 53 55 56 57 57  *  *  *  *  *
 5   *  *  * 57 57 57 56 54 51 54 54 54 53 54 53 53 54 53 53 54 53 54 53 51 54 56 57 57 57  *  *  *  *
 6   *  * 57 57 57 55 54 51 54 51 53 51 53 51 53 52 52 53 51 53 51 53 51 53 51 54 55 57 57 57  *  *  *
 7   * 57 57 56 56 54 51 53 54 53 54 53 54 53 54 53 53 54 53 54 53 54 53 54 53 51 54 56 56 57 57  *  *
 8  57 57 57 56 54 51 53 50 53 51 53 51 53 52 53 53 54 53 52 53 51 53 51 54 50 53 51 54 55 57 57 57
 9  57 57 56 53 51 54 54 53 53 53 53 53 53 53 54 53 53 53 53 54 53 53 53 54 54 54 53 51 53 56 57 57
10  57 55 54 51 54 51 53 51 53 52 53 52 53 52 53 52 52 53 52 53 52 53 52 53 51 53 51 53 51 54 55 57
11  57 56 51 54 54 53 54 53 54 53 54 53 53 53 54 53 53 53 53 53 53 53 53 54 53 54 53 54 54 51 56 57
12  57 56 54 51 54 51 53 51 53 52 53 52 53 52 53 53 53 53 52 53 52 53 52 53 51 53 51 53 51 54 56 57
13  57 56 51 54 54 53 54 54 53 53 54 54 53 53 53 53 53 53 54 53 53 53 54 53 54 54 54 54 51 56 57
14  57 56 54 51 54 51 53 52 53 52 53 52 53 52 53 52 52 53 52 53 52 53 52 53 52 53 51 53 51 54 56 57
15  57 56 51 54 53 54 53 53 53 53 53 53 53 53 53 53 53 53 53 53 53 53 53 53 53 54 53 54 54 51 56 57
16  57 56 51 54 54 52 54 53 54 52 53 53 53 52 53 53 53 53 52 53 53 53 52 53 53 53 52 53 54 51 56 57
17  57 56 51 54 53 52 53 53 53 52 53 53 53 52 54 53 53 53 52 53 53 53 52 53 53 54 52 53 54 51 56 57
18  57 56 51 54 54 53 53 53 53 53 54 53 53 53 53 54 53 53 53 53 53 53 53 53 54 53 53 53 54 51 56 57
19  57 56 54 51 53 51 53 52 53 52 53 52 53 52 53 52 52 53 52 53 52 53 52 53 52 53 51 53 51 54 56 57
20  57 56 51 54 54 53 54 54 53 53 54 53 54 53 54 53 53 53 53 54 53 54 53 53 53 54 54 53 54 51 56 57
21  57 56 54 51 54 51 53 51 53 52 53 52 53 54 53 53 53 52 53 52 53 52 53 51 53 51 53 51 54 56 57
22  57 56 51 54 54 53 54 53 54 53 53 53 53 53 54 53 53 53 53 54 53 54 53 54 53 54 53 54 54 51 56 57
23  57 55 54 51 54 51 53 51 53 52 53 52 53 52 53 52 52 53 52 53 52 53 52 53 51 53 51 54 51 54 56 57
24  57 57 56 53 51 54 54 53 54 53 53 53 53 53 54 53 54 54 53 53 53 53 53 54 53 54 54 51 54 56 57 57
25  57 57 57 55 54 51 53 50 53 51 53 51 53 52 53 54 54 53 52 53 51 53 51 53 50 53 51 54 55 57 57 57
26   * 57 57 56 56 54 51 53 54 53 54 53 54 53 53 53 53 53 54 54 53 54 53 54 53 51 54 56 56 57 57  *
27   *  * 57 57 57 55 54 51 54 51 53 51 53 51 53 52 52 53 51 53 51 54 51 54 51 54 55 57 57 57  *  *
28   *  *  * 57 57 57 56 54 51 54 54 54 54 54 53 54 53 54 54 54 53 53 54 54 54 54 51 54 56 57 57 57  *  *  *
29   *  *   * * 57 57 56 55 53 51 54 51 54 51 54 54 54 54 51 54 51 54 51 53 55 56 57 57  *  *  *  *
30   *  *   *  * * 57 57 57 56 54 51 54 51 54 51 51 51 51 54 51 54 51 54 56 57 57 57  *  *  *  *  *
31   *  *   *  *  * * 57 57 57 55 56 56 56 56 56 56 56 56 56 56 56 56 56 55 57 57 57  *  *  *  *  *  *
32   *  *   *  *  *  * * 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57 57  *  *  *  *  *  *  *
*
* Weighting Factors for %VOLRMAP2
*
%VOLRMAP3
 0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32
 1   *   *   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *   *   *
 2   *   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *   *
 3   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *
 4   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *
 5   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *
 6   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *
 7   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
 8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
 9 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
10 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
11 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
12 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
13 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
14 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
15 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
16 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
17 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
18 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
19 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
20 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
21 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
22 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
23 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
```

```
24  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
25  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
26   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *
27   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *
28   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *
29   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *
30   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *
31   *   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *   *
32   *   *   *   *   *   *   *  1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  *   *   *   *   *   *   *
```

VI.C VVER1000 Rod Ejection Benchmark

```
!******************************************************************************
CASEID vv1kre   VVER1K Rod Ejection Benchmark - Refernce Calc. Options
!******************************************************************************
CNTL
      core_power   10.0  !in %
      bank_pos     282.4 353.0 353.0 353.0 353.0 353.0 353.0    0.    0.
      ppm          1000.
      search       ppm
      transient    T
!                    input  iteration     planar                   adj
!                     edit      table      power        pin       reac
      print_opt          T          F          F          F          T
!                     fdbk       flux     planar
!                      rho    precurs       flux         Xe        T/H
      print_opt          F          F          F          F          F

!******************************************************************************
PARAM
! no parameters are specified, all defaults
     conv_ss   1.e-6 1.e-5 1.e-3

!******************************************************************************
XSEC
   func_type 12  ! special xsec for VVER1K

!Delayed Neutron Precurosor Data
!------------------------------------------------------------------------------
 dnp_ngrp   6
 kin_comp   1  1 -4    !Compostions that this set applies
 dnp_lambda 0.0128     0.0315   0.125     0.325     1.55      4.5 !decay constants
 dnp_beta   1.566e-4  1.028e-3  9.442e-4  1.995e-3  6.538e-4  2.224e-4 !beta
 neut_velo  1.98e7    6.15e5  ! Neutron Velocities (cm/sec)

!******************************************************************************
GEOMHEX
   geo_dim  7  15       !nring, nz
   rad_conf  360        !full rotation symmetry
           3 3 3 3 3 3
        3 4 2 1 2 1 2 4 3
       3 2 1 2 1 1 2 1 2 3
      3 1 2 1 1 1 1 1 2 1 3
     3 2 1 1 2 1 1 2 1 1 2 3
    3 1 1 1 1 1 2 1 1 1 1 1 3
   3 2 2 1 1 2 1 1 2 1 1 2 2 3
    4 1 1 2 1 1 1 1 1 2 1 1 4
   3 2 2 1 1 2 1 1 2 1 1 2 2 3
    3 1 1 1 1 1 2 1 1 1 1 1 3
     3 2 1 1 2 1 1 2 1 1 2 3
      3 1 2 1 1 1 1 1 2 1 3
       3 2 1 2 1 1 2 1 2 3
        3 4 2 1 2 1 2 4 3
           3 3 3 3 3 3

   grid_hex   23.6     !flat-to-flat distance (cm)
```

```
   grid_z     15*23.533333
   assy_type  1  15*1
   assy_type  2  15*2
   assy_type  3  15*3
   assy_type  4  15*4
   albedo_r   0.1468 0.0831
   albedo_zb  0.1699 0.0061
   albedo_zt  0.1670 0.0802

   cr_axinfo 0.0 1.0 ! step size is 1cm
   bank_conf
           0 0 0 0 0 0
        0 0 0 0 9 0 0 0 0
       0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0 0
     0 9 0 0 1 0 0 1 0 0 8 0
    0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 1 0 0 0 0 0 1 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0
    0 0 0 0 0 0 0 0 0 0 0 0 0
     0 8 0 0 1 0 0 1 0 0 8 0
      0 0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0
        0 0 0 0 9 0 0 0 0
           0 0 0 0 0 0

!*****************************************************************************
TH
      n_pingt      312 19                    !npin,ngt
      fa_powpit    18.4049   21.962275       !assembly power(Mw) and pitch(cm)
      pin_dim      3.765  4.55   0.69  6.3   !pin radii, rs,rw,tw, and rgt in mm
      flow_cond    288.0   112.426           !tin,cmfrfa(Kg/sec)
      gamma_frac   0.0                       !direc heating fraction
      hgap         3157.9                    !hgap(w/M^2-C)
      n_ring       6                         !number of meshes in pellet

!*****************************************************************************
TRAN
      time_step    5.00 0.01 1.0  10.0 !tend,delt0,tswitch,texpand
      move_bank    9  0.0 0.0   0.1 353.0
      conv_tr      0.00001             !eps_r2
      eps_xsec     0.0001
.
```

VI.D PARCS model for PBMR-268 steady-state neutronics benchmark problem.

```
 CASEID PBMR                                CASE N-1     (Cylindrical Coordinate)
!*****************************************************************************
*
CNTL
      th_fdbk    F
!                     input  iteration     planar                   adj
!                      edit      table      power        pin       reac
      print_opt          T          T          T          F          F
!                      fdbk       flux     planar
```

```
!                      rho    precurs       flux         Xe        T/H
      print_opt          F          T          T          F          F
!                                          radial     radial
!                                           power       flux
      print_opt          F          F          T          T          F

!*************************************************************************
*
PARAM
      n_iters    20    500
      nlupd_ss   5    5    1
      nodal_kern fmfd

      conv_ss    1.0e-6    1.e-6      1.e-6   0.001 !keff,globfs,locfs,tempf
      wielandt   1.0e+30   1.0e+30    1.0           !turnoff wielandt

      eps_erf     0.00001  !default 0.005 try to change this value
      eps_anm     1e+50  !

!*************************************************************************
*
XSEC
      file XSEC_PBMR
      DDDC 7   0.1   0.5
!*************************************************************************
*
FMFD
     ref_cond   0.0  296.85  0.7295 626.85  !ppm, Tm in C, rho in gm/cc, Tf in
C ! for TH / , transient
      dnp_ngrp   6
      geninf    2   1    1       1      1    1      !pinx#/FA piny#/FA   #/pin
...
!              mmx mmy  nrefine  mmz  mmxth  mmyth
      method     1       3                   !order(1:diff,3:sp3)
naccel(1:cmr,2:cmfd)

      file  FMFD_PBMR20x20
!*************************************************************************
*
GEOM
 geo_dim   11  1  22           !nasyx,nasyy,nz
 coordinate  2                 !2=cylinder,  default=.not. cylinder
 rad_conf
  1  2  2  2  2  1  1  1  1  1  1
 grid_r     78.6 32.3 24.8  20.9  18.4  6.0 13.0 21.0 20.0 15.0 25.0 ! grid_r
in cylinder(cm)
 neutmesh_r  1    1    1     1      1    1   1    1    1    1    1
 grid_theta     1*3.0                       ! grid_theta in cylinder (degree)
```

```
neutmesh_theta 1*1
grid_z     2*50.0 25.0 17*50.0 2*50.0

boun_cond  0 2 0 0 2 2       !ibcw,ibce,ibcn,ibcs,ibcb,ibct
Planar_Reg 1
 8  8  8  8  8  9  9  9 16  9 17
Planar_Reg 2
 8  8  8  8  8  9  9  9 16  9 17
.
.
.
Planar_Reg 22
 13 13 13 13 13  9  9  9 16  9 17

PR_Assign  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
cr_axinfo 100.0 38.1    !fully inserted position and step size
```

VII. SAMPLE OUTPUTS

VII.A OECD MSLB Benchmark

VII.A.1 Steady State Output

```
  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS


      PPPPPPP           A         RRRRRRR          CCCCC       SSSSS
      PPPPPPPPP        AAA        RRRRRRRRR      CCCCCCCCC   SSSSSSSSS
      PPP    PPPP     AA AA       RRR    RRRR   CCC     CC SSS     SSS
      PPP     PPPP   AA AA        RRR     RRRR CCC        C SSS      SS
      PPP    PPPP   AA   AA      RRR    RRRR  CCC          SSS
      PPPPPPPPP     AA   AA      RRRRRRRRR    CCC          SSSS
      PPPPPPP      AA     AA     RRRRRR       CCC           SSSSSSS
      PPP          AA     AA     RRR RR       CCC             SSSSSSS
      PPP         AAAAAAAAAAA    RRR  RR      CCC                SSSS
      PPP         AA       AA    RRR   RR     CCC                 SSS
      PPP        AA         AA   RRR    RR    CCC        C SS      SSS
      PPP        AA         AA   RRR     RR    CCC    CCC SSS     SSS
      PPP       AA           AA RRR      RR   CCCCCCCCC   SSSSSSSSS
      PPP       AA           AA RRR       RR    CCCCC       SSSSS


                  (Purdue Advanced Reactor Core Simulator)

                       NRC -  V1.17 Mod0


  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS
.
.
.
.
.
.
 ================================================
   Steady State Eigenvalue Calculation Results
 ================================================

  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
--------------------------------------------------------------------------------
   1   1   1.0085264 F   1.9895E-01 F   1.1835E+00 F 10.0000      5.00
   2   1   1.0107931 F   9.7897E-02 F   4.5330E-01 F  0.4988      5.00
   3   1   1.0133206 F   1.0210E-01 F   1.8412E-01 F  1.1086      5.00
   4   1   1.0148231 F   9.1280E-02 F   1.4893E-01 F  0.9401      5.00
   5   1   1.0154511 F   6.6549E-02 F   1.3770E-01 F  0.7483      5.00
 00:08.91   Nodal update...   1, NEM=    0, ANM=21437
 00:08.95   @0.00E+00 s,  k-eff= 1.015451 , Tout= 312.85 C, Tfmax=  648.73 C
Restart advancement:    0 written at time:      0.00000100 s
```

```
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
   6   1   1.0080465 F   1.2552E-01 F   3.7788E-01 F  1.8203      5.00
 00:09.42   @1.00E-06 s,  k-eff= 1.008046 , Tout= 312.85 C, Tfmax=  648.73 C
.
.
.
.
.
.
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
 120   1   1.0048973 F   2.2386E-05 T   3.5597E-05 T  0.7584      5.00
 00:35.59   @ 959.989 s,  k-eff= 1.004897 , Tout= 320.47 C, Tfmax=  631.23 C

 PDMR:  Cleaning up PDMR Memory...
 All done.  Leaving PDMR...
Restart advancement:   20 written at time:   1001.98928193 s
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
 121   1   1.0048935 F   5.0072E-05 F   6.6925E-05 T  2.2367      5.00
 00:36.11   @1001.989 s,  k-eff= 1.004893 , Tout= 320.48 C, Tfmax=  631.24 C

   Time:  0.000
   K-Effective:     1.004893
   Boron Conc:       5.00
   Core Power Level: 1.000000E+00
.
.
.
.
.
.
 Number of CMFD/Nodal/TH Updates and Inners:   3593     18      0    121

 Time for Init.            8.125
          CMFD            17.641
          Nodal            4.422
          T/H             10.422
          Xsec             3.719
          Decusping        0.000
          Precond.         0.000
          Pin Power        0.000
                           -----
          Total           36.203
```

VII.A.2 Transient Output

```
  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS


      PPPPPPP           A         RRRRRRR          CCCCC       SSSSS
      PPPPPPPPP        AAA        RRRRRRRR      CCCCCCCCC    SSSSSSSSS
      PPP    PPPP     AA AA      RRR    RRRR   CCC     CC SSS     SSS
      PPP     PPPP   AA AA       RRR     RRRR CCC        C SSS      SS
      PPP    PPPP   AA   AA      RRR    RRRR  CCC          SSS
      PPPPPPPPP     AA   AA      RRRRRRRRR    CCC          SSSS
      PPPPPPP      AA     AA     RRRRRRR      CCC           SSSSSSS
      PPP          AA     AA     RRR RR       CCC             SSSSSSS
      PPP         AAAAAAAAAAA    RRR  RR      CCC                SSSS
      PPP         AA       AA    RRR   RR     CCC                 SSS
      PPP        AA         AA   RRR    RR    CCC        C SS      SSS
      PPP        AA         AA   RRR     RR    CCC    CCC SSS     SSS
      PPP       AA           AA RRR      RR   CCCCCCCCC   SSSSSSSSS
      PPP       AA           AA RRR       RR    CCCCC       SSSSS


                (Purdue Advanced Reactor Core Simulator)

                     NRC -  V1.17 Mod0


  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS
.
.
.
.
.
.
================================================================
 Performing Transient Calculation...
================================================================
 00:13.45   @   0.000 s, P= 1.000E+02 %, Tout= 320.5 Tf=  631.2 C rho=    0.0 c
Restart advancement:   21 written at time:      0.01000000 s

 Core condition changes which initiate transient

   Time:  0.010
     Boron :   not changed

 00:14.73   @   0.010 s, P= 1.000E+02 %, Tout= 320.5 Tf=  631.2 C rho=    0.0 c

   Time:  0.010
   Reactivity($):     0.000046
   Core beta    :     0.005211
   Boron Conc:       5.00
   Core Power Level: 1.000008E+00

Enthalpy Rise     0.01000   149    23    289.84     0.000     0.000    1.4319    1.4319
1.0000
 Assembly Power Distribution
```

```
    #.####   box power

       1      2      3      4      5      6      7      8      9     10     11     12     13     14     15     16
  2                                          0.3998 0.4573 0.3982 0.4574 0.399
  3                                 0.4628 0.6982 1.1046 1.2074 0.8332 1.2076 1.1049 0.6985 0.4631
  4                          0.6073 1.0977 0.9472 1.3039 1.0849 1.3005 1.0852 1.3044 0.9476 1.0984 0.6078
  5                   0.4614 1.0962 1.0601 1.3004 1.0447 1.3203 1.0399 1.3207 1.0452 1.3012 1.0611 1.0975 0.4621
  6                   0.6924 0.9446 1.2994 1.0566 1.3086 1.0573 1.2975 1.0577 1.3096 1.0577 1.3012 0.9462 0.6938
  7          0.3946 1.0925 1.3007 1.0450 1.3079 1.0360 1.2713 1.0439 1.2721 1.0372 1.3101 1.0472 1.3039 1.0956 0.3959
  8          0.4509 1.1930 1.0815 1.3198 1.0550 1.2689 0.9961 1.2320 0.9970 1.2712 1.0579 1.3240 1.0853 1.1975 0.4527
  9          0.3922 0.8226 1.2948 1.0380 1.2925 1.0401 1.2291 0.8747 1.2309 1.0432 1.2978 1.0427 1.3013 0.8271 0.3944
 10          0.4497 1.1895 1.0786 1.3164 1.0523 1.2659 0.9942 1.2304 0.9966 1.2719 1.0597 1.3264 1.0872 1.1988 0.4532
 11          0.3932 1.0879 1.2951 1.0406 1.3026 1.0322 1.2677 1.0425 1.2727 1.0404 1.3175 1.0551 1.3119 1.1005 0.3974
 12                   0.6889 0.9395 1.2925 1.0514 1.3028 1.0539 1.2958 1.0597 1.3173 1.0713 1.3249 0.9614 0.7020
 13                   0.4587 1.0894 1.0537 1.2931 1.0397 1.3157 1.0387 1.3241 1.0544 1.3256 1.1125 1.1267 0.4714
 14                          0.6034 1.0907 0.9417 1.2972 1.0811 1.2991 1.0884 1.3147 0.9639 1.1281 0.6253
 15                                 0.4600 0.6941 1.0987 1.2028 0.8326 1.2107 1.1122 0.7080 0.4728
 16                                          0.3978 0.4557 0.3980 0.4586 0.4022

       Maximum Pos.    Maximum Value
        ( 13, 10 )    1.3264

 Axial Power Distribution

   Height(cm)    Power      Plane     Mesh
  from bottom              Number    (cm)
      7.44        0.745        2     14.88
     17.23        0.873        3      4.71
     24.68        0.961        4     10.17
     37.20        1.017        5     14.88
     52.08        1.042        6     14.88
     66.96        1.045        7     14.88
     81.84        1.045        8     14.88
     96.72        1.040        9     14.88
    111.60        1.035       10     14.88
    126.48        1.031       11     14.88
    141.36        1.037       12     14.88
    156.24        1.032       13     14.88
    171.12        1.024       14     14.88
    186.00        1.015       15     14.88
    200.88        1.008       16     14.88
    215.76        1.008       17     14.88
    230.64        1.020       18     14.88
    245.52        1.024       19     14.88
    260.40        1.028       20     14.88
    275.28        1.035       21     14.88
    290.16        1.053       22     14.88
    305.04        1.058       23     14.88
    319.92        1.031       24     14.88
    333.49        0.946       25     12.27
    340.93        0.846       26      2.61
    349.68        0.766       27     14.88

  Maximum Pos.     Maximum Value
      23               1.0576


  Fq (Pin)   1.4319
.
.
.
.
.
.
Restart advancement:   34 written at time:    100.15899185 s
```

```
 Number of CMFD/Nodal/TH Updates and Inners:   3987    176      0   3987

 Time for Init.            9.156
          CMFD           993.297
          Nodal           44.406
          T/H             75.156
          Xsec           315.062
          Decusping        0.000
          Precond.         0.000
          Pin Power        0.000
                           -----
          Total         1427.922
```

VII.B BWR Peach Bottom Turbine Trip Benchmark

VII.B.1 Steady State Output

```
  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS


      PPPPPPP           A        RRRRRRR          CCCCC       SSSSS
      PPPPPPPPP        AAA       RRRRRRRRR      CCCCCCCCC   SSSSSSSSS
      PPP    PPPP    AA AA      RRR    RRRR   CCC     CC SSS     SSS
      PPP     PPPP   AA AA      RRR     RRRR CCC       C SSS      SS
      PPP    PPPP   AA   AA     RRR    RRRR  CCC         SSS
      PPPPPPPPP     AA   AA     RRRRRRRRR    CCC         SSSS
      PPPPPPP      AA     AA    RRRRRR       CCC          SSSSSSS
      PPP          AA     AA    RRR RR       CCC            SSSSSSS
      PPP         AAAAAAAAAAA   RRR  RR      CCC               SSSS
      PPP         AA       AA   RRR   RR     CCC                 SSS
      PPP        AA         AA  RRR    RR    CCC       C SS      SSS
      PPP        AA         AA  RRR     RR    CCC    CCC SSS     SSS
      PPP       AA           AA RRR      RR   CCCCCCCCC   SSSSSSSSS
      PPP       AA           AA RRR       RR    CCCCC       SSSSS


                  (Purdue Advanced Reactor Core Simulator)

                       NRC -  V1.17 Mod0


  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS
.
.
.
.
.
.
 ================================================
   Steady State Eigenvalue Calculation Results
 ================================================

 PDMR:  Receiving Time-Dependent TRACE Buffer...
 PDMR:  Receiving Permuted TRACE Vector...

  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
   1   2   1.0100249 F   3.4064E-01 F   3.1788E+00 F 10.0000      0.00
   2   5   1.0201937 F   3.4349E-01 F   8.1428E-01 F  1.2646      0.00
   3   4   1.0207202 F   7.0602E-02 F   4.6712E-01 F  0.2403      0.00
 03:50.38   Nodal update...   1, NEM=12504, ANM=61208
 03:50.70   @0.00E+00 s,  k-eff= 1.020720 , Tout= 286.85 C, Tfmax=  291.85 C

 PDMR:  Sending Time-Depedendent PARCS Buffer...
 PDMR:  Sending Unpermuted PARCS Vector...

 PDMR:  Receiving Time-Dependent TRACE Buffer...
```

```
 PDMR:  Receiving Permuted TRACE Vector...

Restart advancement:    0 written at time:      0.00000100 s
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
   4   3   1.0153525 F   1.3621E-01 F   7.1890E-01 F  1.8357      0.00
 03:55.22   @1.00E-06 s,  k-eff= 1.015353 , Tout= 286.85 C, Tfmax=  291.93 C

 PDMR:  Sending Time-Depedendent PARCS Buffer...
 PDMR:  Sending Unpermuted PARCS Vector...

 PDMR:  Receiving Time-Dependent TRACE Buffer...
 PDMR:  Receiving Permuted TRACE Vector...
 .
 .
 .
 .
 .
 .
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
 120   3   1.0017572 T   2.6570E-05 F   8.7476E-05 T  1.2100      0.00
 10:09.52   @  45.678 s,  k-eff= 1.001757 , Tout= 283.77 C, Tfmax=  628.22 C

 PDMR:  Sending Time-Depedendent PARCS Buffer...
 PDMR:  Sending Unpermuted PARCS Vector...

 PDMR:  Receiving Time-Dependent TRACE Buffer...
 PDMR:  Receiving Permuted TRACE Vector...


 PDMR:  Cleaning up PDMR Memory...
 All done.  Leaving PDMR...
Restart advancement:    1 written at time:     46.00049692 s
  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
-------------------------------------------------------------------------------
 121   3   1.0017571 T   1.0509E-05 F   2.7272E-05 T  0.3955      0.00
 10:13.50   @  46.000 s,  k-eff= 1.001757 , Tout= 283.77 C, Tfmax=  628.22 C

   Time:  0.000
   K-Effective:     1.001757
   Boron Conc:       0.00
   Core Power Level: 6.158520E-01
.
.
.
.
 Number of CMFD/Nodal/TH Updates and Inners:   3824     33      0    430

 Time for Init.          221.641
          CMFD           268.469
          Nodal           74.922
          T/H            238.000
          Xsec            32.453
          Decusping        0.000
          Precond.         0.000
          Pin Power        0.000
                           -----
          Total          613.844
```

VII.C VVER1000 Rod Ejection Benchmark

```
  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS


      PPPPPPP           A         RRRRRRR          CCCCC       SSSSS
      PPPPPPPPP        AAA        RRRRRRRRR      CCCCCCCCC   SSSSSSSSS
      PPP    PPPP     AA AA      RRR    RRRR   CCC     CC SSS     SSS
      PPP     PPPP   AA AA       RRR     RRRR CCC       C SSS      SS
      PPP    PPPP   AA   AA      RRR    RRRR  CCC         SSS
      PPPPPPPPP     AA   AA      RRRRRRRRR    CCC         SSSS
      PPPPPPP      AA     AA     RRRRRRR      CCC          SSSSSSS
      PPP          AA     AA     RRR RR       CCC             SSSSSSS
      PPP         AAAAAAAAAAA    RRR  RR      CCC                SSSS
      PPP         AA       AA    RRR   RR     CCC                 SSS
      PPP        AA         AA   RRR    RR    CCC       C SS      SSS
      PPP        AA         AA   RRR     RR    CCC    CCC SSS     SSS
      PPP       AA           AA RRR      RR   CCCCCCCCC   SSSSSSSSS
      PPP       AA           AA RRR       RR    CCCCC       SSSSS


            (Purdue Advanced Reactor Core Simulator)

                        NRC - V2.5


  PARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCSPARCS


  Executing Case vv1kre
  by countm on helios.ecn.purdue.edu at 17:26:16, Aug. 29, 2003...

  Allocated Memory:    7.03 MBytes
.
.
.
.
.
.
 ================================================
   Steady State Eigenvalue Calculation Results
 ================================================

  Itr Nin    k-eff        Global F.S.    Local F.S.   Dom. R     PPM
--------------------------------------------------------------------------------
   1   1   1.0398084 F   5.0213E-01 F   1.5381E+00 F 10.0000   1000.00
   2   1   1.0449673 F   1.2883E-01 F   5.9592E-01 F  0.3305   1000.00
   3   1   1.0470998 F   7.4311E-02 F   3.2210E-01 F  0.6108   1000.00
 00:01.79  TPEN Nodal update...    1    4
 Max. Tf=  393.2C,  Avg. Outlet Temp.=291.18C, Max. Doppler Change= 2.69E-02 F
   4   1   1.0293568 F   1.6494E-01 F   9.7845E-01 F  2.1406   1100.00
   5   2   1.0308927 F   8.6285E-02 F   2.8901E-01 F  0.5087   1100.00
   6   2   1.0311756 F   4.0814E-02 F   1.7083E-01 F  0.4841   1100.00
.
```

```
.
.
.
.
.
 00:13.27  TPEN Nodal update...    9   31
  27   2   1.0000000 T   5.6900E-06 T   1.6898E-05 T  0.7420   1375.20
 Max. Tf=  425.2C,  Avg. Outlet Temp.=291.18C, Max. Doppler Change= 3.13E-04 T
 00:13.59  k-eff= 1.000000 , Tout= 291.18 , ppm= 1375.20

   K-Effective:     1.000000
   Boron Conc:    1375.20
   Core Power Level: 1.000000E-01

Enthalpy Rise     0.00000   131     8    389.86    27.833    27.833    2.4553    2.4553
1.0000
 Assembly Power Distribution
.
.
.
.
.
.
 Axial Power Distribution

 Distance(cm)  Power       Plane     Mesh
 from Bottom               Number    (cm)
     11.77     0.303          1      23.53
     35.30     0.628          2      23.53
     58.83     0.921          3      23.53
     82.37     1.168          4      23.53
    105.90     1.360          5      23.53
    129.43     1.489          6      23.53
    152.97     1.553          7      23.53
    176.50     1.548          8      23.53
    200.03     1.477          9      23.53
    223.57     1.340         10      23.53
    247.10     1.144         11      23.53
    270.63     0.896         12      23.53
    294.17     0.621         13      23.53
    317.70     0.382         14      23.53
    341.23     0.169         15      23.53

  Maximum Pos.    Maximum Value
       7              1.5527


  Fq (Pin)   2.4653
.
.
.
.
.
.
================================================================================
 00:14.47  Performing Transient Calculation...
 00:14.47  @ 0.00E+00s, P= 1.000E+01%, Tout= 291.2C, Tf=  425.2C, rho=  0.00c
 Max. Doppler Change  4.15E-09 T
```

```
 At Simulation Time =  1.00E-02 ( Time Step     1 )

   Core Condition Change Summary
   -----------------------------
     Boron     :   not changed
      Bank   9 :      35.300
     Boron     :    1375.195
      Bank   1 :     282.400
      Bank   2 :     353.000
      Bank   3 :     353.000
      Bank   4 :     353.000
      Bank   5 :     353.000
      Bank   6 :     353.000
      Bank   7 :     353.000
      Bank   8 :       0.000
      Bank   9 :      35.300

 Max.   Xsec  Change  1.78E-01 T
   itr      r2/r0          r2/b2           l2            linf
    1   2.7715E-02 F   7.8561E-03 F   1.8301E-03 F   2.7238E-02 F 1.002939E+01
 00:15.99  TPEN Nodal update...   10   35
    2   1.1387E-02 F   3.2246E-03 F   1.6779E-03 F   7.1861E-03 F 1.004655E+01
    3   4.5527E-03 T   1.2893E-03 F   1.2056E-03 F   2.2226E-03 F 1.005843E+01
 00:17.43  TPEN Nodal update...   11   39
    4   8.3820E-02 F   8.2360E-04 F   2.2972E-04 F   2.9148E-04 T 1.006190E+01
    5   7.4877E-03 F   7.3572E-05 F   1.5501E-04 F   2.7739E-04 T 1.006778E+01
    6   2.2616E-03 T   2.2222E-05 F   2.8689E-05 F   5.9222E-05 T 1.006808E+01
 00:18.62  TPEN Nodal update...   12   42
    7   3.1776E-02 F   4.5396E-05 F   1.1940E-05 F   2.5222E-05 T 1.006829E+01
    8   4.0502E-03 T   5.7862E-06 T   6.1361E-06 T   1.4650E-05 T 1.006863E+01
 00:18.90  @ 1.00E-02s, P= 1.007E+01%, Tout= 291.2C, Tf=  425.2C, rho=  0.83c

   Reactivity($):     0.008269
   Core beta    :       500.00
   Boron Conc:    1375.20
   Core Power Level: 1.006864E-01

Enthalpy Rise     0.01000   131     8    389.86    27.833    27.833    2.4474    2.4474
1.0000
 Assembly Power Distribution

     #.####   box power

   -26 -24 -22 -20 -18 -16 -14 -12 -10  -8  -6  -4  -2   0   2   4   6   8  10  12  14  16  18  20  22  24  26

 -14                           0.6462  0.7219  0.5299  0.5294  0.7204  0.6444
 -12                     0.6462  1.1125  1.2724  0.7918  0.5732  0.7905  1.2691  1.1084  0.6429
 -10                   0.7219  1.2725  1.1671  1.3759  0.8309  0.8301  1.3728  1.1630  1.2655  0.7160
 -8              0.5300  0.7919  1.3759  1.1446  1.0494  0.9430  1.0478  1.1412  1.3685  0.7828  0.5202
 -6           0.5296  0.5733  0.8310  1.0495  1.4320  1.1241  1.1234  1.4291  1.0453  0.8225  0.5527  0.5197
 -4      0.7206  0.7907  0.8303  0.9431  1.1243  1.2274  1.5696  1.2261  1.1216  0.9386  0.8217  0.7815  0.7145
 -2 0.6447  1.2695  1.3733  1.0482  1.1237  1.5698  1.2222  1.2217  1.5677  1.1209  1.0437  1.3654  1.2622  0.6411
  0   1.1089  1.1635  1.1417  1.4298  1.2266  1.2220  1.1512  1.2211  1.2248  1.4262  1.1377  1.1588  1.1043
  2 0.6432  1.2662  1.3693  1.0460  1.1224  1.5687  1.2217  1.2213  1.5674  1.1208  1.0436  1.3654  1.2621  0.6411
  4     0.7164  0.7834  0.8232  0.9396  1.1222  1.2261  1.5685  1.2256  1.1213  0.9384  0.8216  0.7814  0.7145
  6           0.5207  0.5534  0.8231  1.0457  1.4291  1.1228  1.1226  1.4284  1.0449  0.8223  0.5526  0.5196
  8               0.5206  0.7832  1.3688  1.1411  1.0474  0.9419  1.0471  1.1406  1.3680  0.7826  0.5201
 10                   0.7162  1.2657  1.1630  1.3724  0.8294  0.8293  1.3720  1.1624  1.2650  0.7157
 12                     0.6429  1.1084  1.2688  0.7901  0.5723  0.7899  1.2684  1.1079  0.6426
 14                               0.6443  0.7201  0.5289  0.5289  0.7199  0.6441

        Maximum Pos. Maximum Value
         ( -6, -2 )   1.5698
```

```
 Axial Power Distribution

 Distance(cm)  Power       Plane     Mesh
 from Bottom               Number    (cm)
     11.77     0.315          1      23.53
     35.30     0.642          2      23.53
     58.83     0.930          3      23.53
     82.37     1.172          4      23.53
    105.90     1.360          5      23.53
    129.43     1.487          6      23.53
    152.97     1.549          7      23.53
    176.50     1.543          8      23.53
    200.03     1.471          9      23.53
    223.57     1.334         10      23.53
    247.10     1.139         11      23.53
    270.63     0.892         12      23.53
    294.17     0.617         13      23.53
    317.70     0.380         14      23.53
    341.23     0.168         15      23.53

  Maximum Pos.    Maximum Value
       7              1.5486


  Fq (Pin)   2.4593
.
.
.
.
.
.
  TPEN Nodal Update Time Statistics (% of Total)
          Point Flux      55.970      14.98 %
      One-Node Solve     112.570      30.13 %
  Total Nodal Update     236.010      63.17 %



 Number of CMFD/Nodal/TH Updates/Inners and Sweeps: 886    239     345    906    741

  Time for Init.          0.300
           CMFD         100.070
           Nodal        236.010
           T/H           21.580
           Xsec          15.970
           Pin Power      0.000
                         -----
           Total        373.630


 06:13.65  Job Finished at 17:32:34.
```

VII.D Some parts of the output file of the PBMR-268 benchmark problem

```
  .
  .
 148   1   1.3921787 T   1.0943E-06 F   2.1450E-05 F  0.9286      0.00
 149   1   1.3921787 T   1.0158E-06 F   1.9961E-05 F  0.9283      0.00
 150   1   1.3921787 T   9.4326E-07 T   1.8493E-05 F  0.9286      0.00
 00:00.77  k-eff= 1.392179 , Tout=   0.00 , ppm=    0.00

   K-Effective:     1.392179
 .
 .
R-Z Power Distribution

   Plane  Distance(cm) Mesh    Power
   Number from Bottom  (cm)
     5     25.00     50.00     0.000    2.533    2.803    1.739    1.039    0.000
..
     6     75.00     50.00     0.000    3.252    3.485    2.108    1.254    0.000
..
     7    125.00     50.00     0.000    3.128    3.390    2.108    1.301    0.000
..
     8    175.00     50.00     0.000    2.142    2.540    1.925    1.873    0.000
..
     9    225.00     50.00     0.000    1.534    1.916    1.581    1.676    0.000
..
    10    275.00     50.00     0.000    1.135    1.458    1.244    1.356    0.000
..
    11    325.00     50.00     0.000    0.853    1.111    0.962    1.060    0.000
..
    12    375.00     50.00     0.000    0.646    0.847    0.738    0.817    0.000
..
    13    425.00     50.00     0.000    0.490    0.645    0.564    0.625    0.000
..
    14    475.00     50.00     0.000    0.372    0.490    0.429    0.477    0.000
..
    15    525.00     50.00     0.000    0.282    0.372    0.326    0.362    0.000
..
    16    575.00     50.00     0.000    0.212    0.280    0.246    0.273    0.000
..
    17    625.00     50.00     0.000    0.159    0.210    0.184    0.204    0.000
..
    18    675.00     50.00     0.000    0.117    0.154    0.135    0.150    0.000
..
    19    725.00     50.00     0.000    0.084    0.111    0.097    0.107    0.000
..
```

```
    20    775.00     50.00     0.000    0.059    0.078    0.068    0.073    0.000
..
.
.
Axial Flux Distribution

 Distance(cm) Fast     Thermal        Plane   Mesh
 from Bottom  Flux      Flux          Number  (cm)
    25.000 6.814E-02 2.083E+01          1     50.000
    75.000 1.131E+00 7.116E+01          2     50.000
   112.500 9.703E+00 1.032E+02          3     25.000
   150.000 1.753E+01 1.517E+02          4     50.000
   200.000 1.503E+02 2.094E+02          5     50.000
   250.000 2.011E+02 2.673E+02          6     50.000
   300.000 1.962E+02 2.681E+02          7     50.000
   350.000 1.396E+02 2.778E+02          8     50.000
   400.000 1.066E+02 2.313E+02          9     50.000
   450.000 8.199E+01 1.821E+02         10     50.000
   500.000 6.287E+01 1.407E+02         11     50.000
   550.000 4.807E+01 1.078E+02         12     50.000
   600.000 3.665E+01 8.228E+01         13     50.000
   650.000 2.788E+01 6.261E+01         14     50.000
   700.000 2.114E+01 4.748E+01         15     50.000
   750.000 1.595E+01 3.582E+01         16     50.000
   800.000 1.193E+01 2.679E+01         17     50.000
   850.000 8.782E+00 1.972E+01         18     50.000
   900.000 6.269E+00 1.409E+01         19     50.000
   950.000 4.100E+00 9.564E+00         20     50.000
  1000.000 3.057E-01 6.659E+00         21     50.000
  1050.000 1.844E-02 1.972E+00         22     50.000
```

VIII. REFERENCES

[1] Downar, T. J. et al, “PARCS, A Multi-Dimensional Two-Group Reactor Kinetics Code Based on the Nonlinear Analytic Nodal Method,” PU/NE-98-26, Sept. 1998.

[2] Joo, H. G., and Downar, T. J., “Completion Report for Pin Power Reconstruction Routine,” PU/NE-99-05, Purdue University, Jan. 1999.

[3] Barber, D. and Downar, T., “Completion Report for the Coupled RELAP5/PARCS Code,” PU/NE-98-31, Purdue University, Nov. 1998.

[4] Miller, R. and Downar, T., “Completion Report for the Coupled TRACE/PARCS Code,” PU/NE-99-9, Purdue University, June 1998.

[5] Joo, H. G., Lee, K, Zee, S. Q. and Downar, T. J. “Software Requirements Specification for the One-Dimensional Kinetics Module for TRAC-M/PARCS,” PU/NE-99-16, July 1999.

[6] Barber, D. “Automatic Mapping Function Generation for the Coupling of TRAC-M and PARCS”, to appear November 2000.

[7] Joo, H. G., Jiang, G., and Downar, T. J., “Stabilization Techniques for the Nonlinear Analytic Nodal Method,” *Nucl. Sci. Eng.*, **130**, 1-13 (1998).

[8] Joo, H. G., and Downar, T. J., "An Incomplete Domain Decomposition Preconditioning Method for Nonlinear Nodal Kinetics Calculation," *Nucl. Sci. Eng*., 123, 403-414 (1996).

[9] Joo, H. G., and Downar, T. J., “Software Requirements Specification for Pin Power Reconstruction Routine,” PU/NE-98-32, Purdue University, Jan. 1998.

[10] Dunn, F., “Decay Heat Calculations for Transient Analysis,” *Trans. Am. Nucl. Soc.*, **60**, 633 (1989).

[11] Rowlands, G., “Resonance Absorption and Non-Uniform Temperature Distributions,” Theoretical Physics Division, Atomic Energy Research Establishment, Report AERE -M717, 1961.

[12] Jones,K., et al., “Symbolic Nuclear Analysis Package (SNAP),” U.S. NRC, NUREG/CR-6974, Vol. 1, June, 2009.

[13] Y. Xu, B. Collins, T. Downar, “GENPMAXS v.9: Program for Generating the PARCS Cross Section Interface File PMAXS,” UM-NERS-09-004, October, 2009.

[14] M. DeHart, et al., SCALE: A Modular Code System for Performing Standardized Computer Analysis, ORNL/TM-2005/39, Rev 5.1,, Vols 1-111.

[15] V. Seker, Y. Xu, T. Downar, “PARCSv3.0 Programmers Manual,” UM-NERS-09-003, August, 2009.

[16] T. Downar, Y. Xu, V. Seker, “PARCSv3.0 Theory Manual,” UM-NERS-09-001, October, 2009.