WAPD-TM-1266
DEPARTMENT OF ENERGY RESEARCH
AND DEVELOPMENT REPORT

PDQ-8 REFERENCE MANUAL

(LWBR DEVELOPMENT PROGRAM)

C. J. PFEIFER
C. J. SPITZ

MAY 1978

CONTRACT EY-76-C-11-0014

BETTIS ATOMIC POWER LABORATORY
WEST MIFFLIN, PENNSYLVANIA

Operated for the U. S. Department of Energy by
WESTINGHOUSE ELECTRIC CORPORATION

DISCLAIMER

PDQ-8 REFERENCE MANUAL

(LWBR Development Program)

C. J. Pfeifer
C. J. Spitz

May 1978

CONTRACT EY-76-C-11-0014

Printed in the United States of America
Available from the
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

NOTE

This document is an interim memorandum prepared primarily for internal reference and does not represent a final expression of the opinion of Westinghouse. When this memorandum is distributed externally, it is with the express understanding that Westinghouse makes no representation as to completeness, accuracy, or usability of information contained therein.

BETTIS ATOMIC POWER LABORATORY WEST MIFFLIN, PENNSYLVANIA

Operated for the
U. S. Department of Energy
by
Westinghouse Electric Corporation

NOTICE

Copies of this program may be obtained by domestic users from:

Argonne Code Center
Attn: Mrs. Margaret Butler
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60440

FOREWORD

The Shippingport Atomic Power Station located in Shippingport, Pennsylvania was the first large-scale, central-station nuclear power plant in the United States and the first plant of such size in the world operated solely to produce electrical power. This project was started in 1953 to confirm the practical application of nuclear power for large-scale electric power generation. It has provided much of the technology being used for design and operation of the commercial, central-station nuclear power plants now in use.

Subsequent to development and successful operation of the Pressurized Water Reactor in the AEC-owned reactor plant at the Shippingport Atomic Power Station, the Atomic Energy Commission in 1965 undertook a research and development program to design and build a Light Water Breeder Reactor core for operation in the Shippingport Station. In 1976, with fabrication of the Light Water Breeder Reactor (LWBR) nearing completion the Energy Research and Development Administration established the Advanced Water Breeder Applications program (AWBA) to develop and disseminate technical information which would assist U.S. industry in evaluating the LWBR concept. All three of these reactor development projects have been administered by the Division of Naval Reactors with the goal of developing practical improvements in the utilization of nuclear fuel resources for generation of electrical energy using water-cooled nuclear reactors.

The objective of the Light Water Breeder Reactor project has been to develop a technology that would significantly improve the utilization of the nation's nuclear fuel resources employing the well-established water reactor technology. To achieve this objective, work has been directed toward analysis, design, component tests, and fabrication of a water-cooled, thorium oxide fuel cycle breeder reactor to install and operate at the Shippingport Station. Operation of the LWBR core in the Shippingport Station started in the Fall of 1977 and is expected to be completed in about 3 to 4 years. Then the fissionable fuel inventory of the core will be measured. This effort, when completed in about 2 to 3 years after completion of LWBR core operation, is expected to confirm that breeding actually took place.

The Advanced Water Breeder Applications (AWBA) project was initiated to develop and disseminate technical information that will assist U.S. industry in evaluating the LWBR concept for commercial-scale applications. The project will explore some of the problems that would be faced by industry in adapting technology confirmed in the LWBR program. Information to be developed includes concepts for commercial-scale prebreeder cores which will produce uranium-233 for light water breeder cores while producing electric power, improvements for breeder cores based on the technology developed to fabricate and operate the Shippingport LWBR core, and other information and technology to aid in evaluating commercial-scale application of the LWBR concept.

Technical information developed under the Shippingport, LWBR, and AWBA projects has been and will continue to be published in technical memoranda, one of which is this present report.

TABLE OF CONTENTS

ABSTRACT

The PDQ-8 program is designed to solve the neutron diffusion - depletion problem in one, two, or three dimensions on the CDC-6600 and CDC-7600 computers. Very large problems can be accommodated. The three dimensional spatial calculation may be either explicit or discontinuous trial function synthesis. Up to five lethargy groups are permitted. The fast group treatment may be simplified P(3), and the thermal neutrons may be represented by a single group or a pair of overlapping groups. Adjoint, fixed source, one iteration, additive fixed source, eigenvalue, and boundary value calculations may be performed. The HARMONY system is used for cross section variation and generalized depletion chain solutions. The depletion is a combination gross block depletion for all nuclides as well as a fine block depletion for a specified subset of the nuclides. The geometries available include rectangular, cylindrical, spherical, hexagonal, and a very general quadrilateral geometry with diagonal interfaces. All geometries allow variable mesh in all dimensions. Various control searches as well as temperature and xenon feedbacks are provided.

The program can solve two dimensional problems at the rate of about one million group-points per hour and three dimensional problems at the rate of about one-half to three-quarters of a million group-points per hour. These rates are for the CDC-7600; the CDC-6600 is about one-fifth the speed of the CDC-7600. The synthesis spatial solution time is dependent on the number of trial functions used and the number of gross blocks. The actual running times may vary widely due to the convergence rate of the iterations, due to the use of control searches or feedbacks, or due to the complexity of the depletion formulation.

The PDQ-8 program is used at Bettis on a production basis for solving diffusion - depletion problems. This report describes the various features of the program and then separately describes the input required to utilize these features.

1.1. GENERAL PROGRAM DESCRIPTION: INTRODUCTION

The design and analysis of a nuclear reactor requires determination of the characteristics of the reactor throughout its operating history. These characteristics include the distribution of power throughout the reactor, the concentrations of the various nuclides at different locations in the reactor, the control rod position required for criticality, plus many others. A knowledge of these characteristics contributes to a determination of reactor behavior associated with material, thermal, or reactivity considerations.

With a finite - difference diffusion - theory representation of neutron transport theory, depletion programs such as this one are used (in one, two, and three dimensions) to obtain the neutron flux and material distributions in a reactor at various times in life. In practice, the calculations are performed in two steps. First, for an initial geometry and material description of the reactor, the flux distribution of neutrons in several energy groups is obtained at discrete spatial mesh points in the reactor and surrounding reflector regions. In the solution of the spatial problem either an eigenvalue, which is a measure of the closeness of the described reactor to criticality, is found or some parameter (poison, buckling, control rod position) is varied to yield neutron balance. The spatial flux is combined with the material inventory and nuclear cross sections to obtain the power distribution.

Once the spatial flux and power distributions have been obtained, the second step in diffusion - depletion programs is to simulate reactor operation during a specified time interval. Using the power normalized flux from the spatial calculation, the differential equations describing the time behavior of the nuclide concentrations are solved for that time interval. The solution yields a new distribution of nuclide concentrations in the reactor which is used in the generation of few - group macroscopic cross sections for the next spatial calculation. This report describes a program which is capable of performing such a computation of power and material distributions throughout a reactor lifetime.

The PDQ-8 program is designed to solve the neutron diffusion-depletion problem in one, two, and three dimensions on the CDC-6600 and CDC-7600 computers. Up to five groups are allowed, but six equations may be solved when the fast group treatment is simplified P(3). The thermal neutrons may be represented by a single group or a pair of overlapping groups. Adjoint and non-adjoint problems may be solved as well as fixed-source, eigenvalue, and boundary value problems.

The geometries allowed are slab, cylindrical and spherical in one dimension; rectangular, cylindrical, and hexagonal in two dimensions; and rectangular and hexagonal in three dimensions. In addition, a very general quadrilateral geometry with diagonal interfaces is available in two dimensional problems as well as three dimensional synthesis problems. All geometries allow variable mesh in all dimensions. A two dimensional "slice" calculation capability from a three dimensional problem description is available to generate trial functions for synthesis solutions.

Various control rod, poison, and moving fuel searches as well as fuel and moderator temperature feedbacks are allowed in all geometries which exhibit the axial direction explicitly. Xenon feedback is allowed in any geometry.

The cross section, feedbacks, and depletion calculations are performed over gross blocks in all dimensions and utilize the HARMONY system. This system provides a flexible representation of time-dependent cross sections and generalized depletion chain definitions. For efficiency, a dual type of depletion is done. All isotopes are depleted over gross blocks while a selected subset of the isotopes (usually the power producing isotopes) may be depleted over a finer block mesh.

Complete consistency checking of input data is provided as well as extensive editing and printer-plotting of calculated quantities such as pointwise, meshwise, and blockwise data along with integrals and averages of such data over arbitrary combinations of blocks.

There are very few fixed constraints on spatial problem sizes since the entire program is written using dynamic core and disk storage allocation techniques. The program has successfully run two dimensional problems with up

to two million group-points and explicit three dimensional problems with up to six million group-points. Three dimensional synthesis problems with up to seventy million group-points have been executed successfully. The only real constraint on problem size is the disk storage capacity.

The program can solve two dimensional problems at the rate of about one million group-points per hour and three dimensional problems at the rate of about one-half to three-quarters of a million group-points per hour. These rates are for the CDC-7600; the CDC-6600 is about one-fifth the speed of the CDC-7600. The synthesis spatial solution time is dependent on the number of trial functions used and the number of gross blocks. The actual running times may vary widely due to the convergence rate of the iterations, due to the use of control searches or feedbacks, or due to the complexity of the depletion formulation. In general, the user will find that past experience is the best reference for predicting run time requirements.

This manual is designed primarily as a tutorial on how to use the program. Many detailed mathematical specifications are not included but are available in the referenced documents.

The first descriptive chapter, Chapter 2, contains a description of the equations solved by the program in the various geometries and dimensionalities. Detailed descriptions of the various difference equations are included.

In Chapter 3, a tutorial on geometry construction for the various geometries is given. Then in Chapter 10, specific input data required to contruct these geometries is described. This separation of the general description of a subject from the detailed input description for that same subject is typical of most of the chapters in this manual.

In Chapter 4, a general description of the HARMONY cross section and depletion sub-system is given. The general form of the depletion equations is given, the solution to those depletion equations is shown, the treatment of files containing nuclide densities is described, and the possible time behavior of the cross sections is discussed. Then in Chapter 11, specific input data required to specify depletion chains, cross sections, and initial nuclide densities is given.

In Chapter 5, a general description of the types of available edits is given. Chapter 12 then describes the input data required to select these edits.

In Chapter 6, the various control searches and feedbacks are described as well as the strategy employed when multiple searches and feedbacks occur simultaneously. Chapter 15 contains a description of the input data for each of the searches and feedbacks.

Chapter 7 contains a discussion of the use of external or "permanent" File Manager files. In addition, each such file that can optionally be written by the program is described in detail so that other programs can manipulate them if necessary.

Chapter 8 is the beginning chapter on input preparation. Control cards and input deck structure are discussed as well as the "free-form" input, the concept of cases and sub-cases, and finally an input checklist which is a list of all possible cards with a very brief description of each card.

Chapter 9 contains detailed descriptions of control information. This includes all of the data which is used in determining input data consistency as well as the data required to read or write File Manager files. Also included in this chapter is data required to execute "special" paths such as input checks, etc.

Chapter 13 contains detailed descriptions of the data required to execute sub-cases. Each of the optional cards is described and default values are given.

Chapter 14 contains detailed descriptions of the data required to use the three dimensional synthesis capability. The special nature of the spatial solution is discussed with respect to limitations in problem size.

Chapter 16 contains a description of miscellaneous data and simply includes all input data which does not fall into any other particular category.

Chapter 17 discusses in detail the form of the output which can be obtained from the program using the various edit options available.

Three appendices are included on programming details. Appendix A is a program abstract, Appendix B gives programming details, and Appendix C describes the program structure by listing each overlay, each routine in the overlay, and a brief statement on the function of the overlay.

Finally, Appendix D includes three sample problems which are indicative of the type of output obtained from different problem types.

2.1. SPATIAL FLUX SOLUTIONS: DIFFUSION EQUATIONS

There are three forms of the diffusion equation solved by the program. In the basic form of the equation, the first of G (less than or equal to 5) groups is represented by a single equation (P(1) treatment of the fast group) and there is a single thermal group. One variation of the basic form allows for two thermal groups. A second variation represents the first group by two equations (P(3) fast group treatment).

Diffusion coefficients and macroscopic cross sections used in the equations may be input directly or may be calculated by the program using macroscopic cross section tables along with spatially varying nuclide concentrations and input microscopic cross section tables and/or interpolating tables for either of these cross sections. In each of the three forms of the equation, "sigma total" refers to the coefficient of the group flux.

The basic form of the diffusion equation (single thermal group, P(1) fast group) is given by Equations 2.1.1 and 2.1.2. In these equations, (x) represents the spatial variable(s), g is the lethargy group index, and G is the index of the thermal group which may be 1, 2, 3, 4, or 5.

The second form of the diffusion equation allows for two thermal groups. In the case of a two thermal group problem, Equations 2.1.1 are unchanged for fast groups but are replaced for $g = G-1$ and G by Equations 2.1.3 and 2.1.4, respectively. Although these appear to be general equations for the treatment of two thermal groups, the spatial calculation of the program actually ignores the two terms in Equation 2.1.3 involving the group G flux. This is only acceptable if the second diffusion coefficient for group G-1 and the second sigma total coefficient for group G-1 are several orders of magnitude smaller than the first diffusion coefficient for group G-1, the first sigma total coefficient for group G-1, and the epithermal removal coefficient, i.e., Inequality 2.1.5 is satisfied. One model which satisfies this restriction treats the thermal neutrons as two overlapping groups and is described in Reference 13. In this model the group G-1 flux and the group G flux are the magnitudes of the thermal flux components corresponding respectively to a hardened and a Maxwellian thermal spectrum. Two thermal groups cannot be used in a three-dimensional problem.

The third form of the diffusion equation involves a simplified P(3) treatment of the fast group. Since this treatment requires two second-order differential equations for the fast group, the program under this option automatically increases the number of solution groups by one during the spatial calculation. Specifically, in a P(3) calculation Equations 2.1.1 for groups 1 and 2 are replaced by the three Equations 2.1.6, and Equation 2.1.2 is replaced by Equation 2.1.7. At the end of the spatial calculation, the number of groups is automatically reduced by one (to the original number) and the fast flux is defined as in Equation 2.1.8.

The variations for two thermal groups and P(3) treatment of the fast group may be used in the same problem.

EQUATIONS 2.1.1 - 2.1.2

$$\left\{-\nabla\cdot[D_g(x)\nabla\phi_g(x)] + [\Sigma_g^a(x) + \Sigma_g^r(x) + D_g(x)B_g^2(x)]\phi_g(x)\right.$$
$$\left. = \frac{\chi_g}{\lambda}\,\psi(x) + \Sigma_{g-1}^r(x)\phi_{g-1}(x)\right\}_{g=1}^{G} \qquad 2.1.1$$

where

$$\Sigma_0^r(x) = 0$$

and

$$\psi(x) = \sum_{g=1}^{G} \nu\Sigma_g^f(x)\phi_g(x)\ . \qquad 2.1.2$$

The physical interpretations of these symbols are

- D = the diffusion coefficient,
- Σ^a = the macroscopic absorption cross section,
- Σ^r = the macroscopic removal (slowing down) cross section,
- B^2 = the geometric buckling,
- ν = the average number of neutrons emitted per fission,
- Σ^f = the macroscopic fission cross section,
- χ = the fission source fraction,
- ϕ = the neutron flux,
- ψ = the fission source, and
- λ = the eigenvalue.

EQUATIONS 2.1.3 - 2.1.5

$$-\nabla\cdot[D^1_{G-1}(x)\nabla\phi_{G-1}(x)] + [\Sigma^1_{G-1}(x) + D^1_{G-1}(x)B^2_{G-1}(x)]\phi_{G-1}(x)$$

$$= \frac{\chi_{G-1}}{\lambda}\,\psi(x) + R_{G-1}(x)\Sigma^r_{G-2}(x)\phi_{G-2}(x) + \nabla\cdot[D^2_{G-1}(x)\nabla\phi_G(x)]$$

$$- [\Sigma^2_{G-1}(x) + D^2_{G-1}(x)B^2_G(x)]\phi_G(x) \qquad 2.1.3$$

where R_{G-1} = fraction of group G-2 neutrons which downscatter into group G-1.

$$-\nabla\cdot[D^1_G(x)\nabla\phi_G(x)] + [\Sigma^1_G(x) + D^1_G(x)B^2_G(x)]\phi_G(x)$$

$$= \frac{\chi_G}{\lambda}\,\psi(x) + R_G(x)\Sigma^r_{G-2}(x)\phi_{G-2}(x) + \nabla\cdot[D^2_G(x)\nabla\phi_{G-1}(x)]$$

$$- [\Sigma^2_G(x) + D^2_G(x)B^2_{G-1}(x)]\phi_{G-1}(x) \qquad 2.1.4$$

where R_G = fraction of group G-2 neutrons which downscatter into group G.

$$\left\{D^2_{G-1},\ \Sigma^2_{G-1}\right\} << \left\{D^1_{G-1},\ \Sigma^1_{G-1},\ R_{G-1}\right\} \qquad 2.1.5$$

EQUATIONS 2.1.6 - 2.1.8

$$-\nabla\cdot(D_1\nabla\tilde{\phi}_1) + (\Sigma_1^a + \Sigma_1^r + D_1B_1^2)\,\tilde{\phi}_1$$

$$= \frac{\chi_1}{\lambda}\,\psi + 2(\Sigma_1^a + \Sigma_1^r)\,\hat{\phi}_1$$

$$-\nabla\cdot\left(\frac{9}{7}\,D_1\,\nabla\hat{\phi}_1\right) + \left[\frac{4}{3}\,(\Sigma_1^a + \Sigma_1^r) + \frac{5}{9D_1} + \frac{9}{7}\,D_1B_1^2\right]\hat{\phi}_1 \qquad 2.1.6$$

$$= -\frac{2}{3}\,\frac{\chi_1}{\lambda}\,\psi + \frac{2}{3}\,(\Sigma_1^a + \Sigma_1^r)\,\tilde{\phi}_1$$

$$-\nabla\cdot(D_2\nabla\phi_2) + (\Sigma_2^a + \Sigma_2^r + D_2B_2^2)\,\phi_2$$

$$= \frac{\chi_2}{\lambda}\,\psi + \Sigma_1^r\,\tilde{\phi}_1 - 2\Sigma_1^r\hat{\phi}_1$$

$$\psi = \nu\Sigma_1^f\,\tilde{\phi}_1 - 2\nu\Sigma_1^f\,\hat{\phi}_1 + \sum_{g=2}^{G}\nu\Sigma_g^f\phi_g \qquad 2.1.7$$

$$\phi_1 = \tilde{\phi}_1 - 2\hat{\phi}_1 \qquad 2.1.8$$

2.2. SPATIAL FLUX SOLUTIONS: EXPLICIT SOLUTIONS

The program may be used to solve six different types of explicit (non-synthesis) problems: eigenvalue, boundary value, one iteration, fixed source, additive fast source, and simplified P(L). The equations in Section 2.1 are the governing equations in eigenvalue, boundary value, and one iteration problems.

In fixed source problems, Equation 2.1.2 is not used and the fission source term (the product of the groupwise chi and the fission source divided by lambda) in Equations 2.1.1 is replaced by the input source S(x) for each group. Likewise in a P(3) fixed source problem, Equation 2.1.7 is not used and the fission source terms in Equations 2.1.6 are replaced respectively by S1(x), -2/3 S1(x), and S2(x), where S1(x) and S2(x) are the input source values for groups 1 and 2.

In additive fast source and simplified P(L) problems, an "additive" fixed source (additive in the sense that the fission source term is also present) is included. Such an additive source is present only in the first group in an additive fast source calculation. This "source" in the first group is the thermal group removal cross section for both of these problem types. In this case, the thermal group removal cross section does not contribute to the thermal group total cross section. In simplified P(L) problems, there is an additive source in every group g (greater than 1) which is the removal cross section for group g-1.

In a simplified P(L) calculation, the slowing down term (namely, the product of the group removal cross section and the group flux) is replaced by the appropriate group g removal cross section so that EACH solution group contains an additive fixed source. Mathematically, the solution of both the additive fast source and simplified P(L) problems is a boundary value problem and as such converges only if the problem without the additive fast source is subcritical. Incidentally, the ratio of the second mode eigenvalue to the first mode eigenvalue (printed in the iteration output as SIG/I or SIG/O) for these problems is the eigenvalue of the problem without the fixed additive source provided a sufficient number of inner iterations is performed AND a unity eigenvalue guess is input (see Reference 4).

In all problems for which the fission source is represented by Equation 2.1.2 or 2.1.7, the lambda term in the denominator of those equations is the input eigenvalue guess and does not change during outer iterations except in eigenvalue problems.

Zero flux, zero current, and rotational symmetry boundary conditions (see Section 3.7) are permitted for all problem types, with fixed flux boundaries also permitted in boundary value problems.

The difference equations used in the explicit solution for various geometries and dimensionalities are given in Section 2.4. The one-dimensional group equations are solved by Gauss elimination; the two-dimensional equations are solved using a single-line cyclic Chebyshev semi-iterative technique (Reference 10); and single-line successive overrelaxation is used in three dimensions. The outer iterations are accelerated by extrapolating the group fluxes using a procedure based on Chebyshev polynomials. This extrapolation and the inner-outer iteration strategy are described in References 4, 5, 6, and 7.

The convergence criterion used by the program for explicit solutions is given by Inequality 2.2.1. Only points for which the fission source is non-zero are tested for convergence. In eigenvalue and boundary value problems, source iterations are performed until this criterion is satisfied in all groups. A single source iteration is performed in one iteration problems and in both these and fixed source problems, flux iterations are performed in each group until the criterion is satisfied. In slowly convergent problems, Equation 2.2.1 is altered slightly to assure that the maximum relative error of the flux does not exceed the square root of the input convergence criterion (epsilon).

EQUATION 2.2.1

$$\max_{x} \left| \frac{\phi_n(x)}{\phi_{n-1}(x)} - 1 \right| < \epsilon \qquad 2.2.1$$

where

$\phi_n(x)$ is the flux at point x at the end of iteration n

ϵ is the convergence parameter.

2.3. SPATIAL FLUX SOLUTIONS: SYNTHESIS SOLUTIONS

Synthesis solutions (eigenvalue problems only) are available for three-dimensional problems. The synthesis method assumes that the three-dimensional flux has the form shown in Equation 2.3.1, where the two-dimensional trial functions (the H(x,y)) are assumed known while the axial mixing coefficients (the Z(z)) are to be determined. Note that K(g) terms are used to approximate the flux in group g.

The program uses the axially-discontinuous trial function method (Reference 11) which allows the user to switch sets of trial functions used in different axial zones. Thus the H(x,y) in Equation 2.3.1 are also discontinuous functions of z.

The trial function and zone structure are defined by the user. Up to fifteen trial functions in each group are allowed in up to fifteen axial zones. The trial functions are two-dimensional pointwise flux shapes input by the user. These may be conveniently generated by a program option which directs the program to run a two-dimensional problem at a particular axial elevation given a three-dimensional problem input description. The user may also define trial functions by specifying a particular axial elevation of an existing three-dimensional pointwise flux distribution. The program will also create difference trial functions or generate a unity trial function upon request. A difference trial function is created by taking the pointwise difference of two existing trial functions; a unity trial function has a value of 1.0 at all points except on a zero flux boundary where it is 0.0.

Note that the set of input trial functions in a given zone must be linearly independent. Further, near linear dependence of the trial functions results in convergence difficulties.

The program solves for the eigenvalue and axial mixing coefficients for each group, trial function, and axial point. These mixing coefficients are then combined with transverse planar integrals of the flux to form the three-dimensional blockwise integrated fluxes for editing and depletion. The program also computes the fractional flux contribution (normalized mixing coefficient) for each trial function position based on the solution mixing coefficients. Fractional fluxes are defined by Equation 2.3.2, and indicate the contribution of each trial function to the total synthesized flux in each group at each axial point. The program will also optionally create a three-dimensional pointwise flux. Note that, in a synthesis problem, the pointwise flux is usually not generated since very large problem sizes can be accomodated if such flux is not required. The conditions under which a pointwise flux is generated are described in Section 12.3. For very large synthesis problems, generation of a pointwise flux may not be possible due to limitations in disk storage capacity.

The Weilandt iteration method is used by the program to solve for the axial mixing coefficients and eigenvalue. This method converges to the solution associated with the eigenvalue closest to the input guess eigenvalue. Since we desire the solution giving the largest eigenvalue, it is recommended that the input eigenvalue guess be higher than expected. In an attempt to guarantee an overestimation initially and for successive solutions during feedback processes, the program will increase the guess eigenvalue by ten per cent before the iteration begins.

In the calculation of the synthesis trial function integrals from which the iteration matrices are computed, the input trial functions are also used as the weight functions (Galerkin method). The approximations used by the program for the computation of the trial function flux product integrals are given in Section 2.4.

The convergence criterion used by the program for synthesis iterations is given by Inequality 2.3.3. Note that a loose convergence criterion in synthesis problems may produce erratic results. Synthesis problems should generally be converged more tightly than explicit problems.

The user may optionally request that the program perform a residual calculation to provide an estimation of the accuracy of a synthesis solution. A pointwise residual for each group is an indicator of neutron balance, defined to be the difference between the left side and the right side of the diffusion

equation (Equations 2.1.1); i.e., it is the difference between loss rate and production rate for a given flux and eigenvalue solution. The program computes the integrals of these pointwise and groupwise residuals over planar gross blocks based on the eigenvalue and mixing coefficients of the synthesis solution. These integral residuals are then summed in absolute value over all planar gross blocks producing a single residual value (called the absolute residual) for each axial point (plane) and group. A relative residual is also computed by normalizing the absolute residual by the sum (in absolute value) of the loss rates (left side of Equation 2.1.1) integrated over planar gross blocks for each plane and group.

The procedure used by the program for the calculation of residuals is based upon the use of residuals in the satisfaction of the three-dimensional finite difference equations for which the synthesis method constructs an approximate solution. In this framework, the exact solution to the problem is considered to be the explicit solution to these finite difference equations for the specific three-dimensional mesh under consideration. The computed residuals thus are an estimate of the deviation of the synthesis solution from a three-dimensional explicit solution.

EQUATIONS 2.3.1 - 2.3.3

$$\phi^g(x,y,z) = \sum_{k=1}^{K(g)} H_k^g(x,y)\ Z_k^g(z) \qquad 2.3.1$$

where

$H_k^g(x,y)$ are the trial functions

$Z_k^g(z)$ are the axial mixing coefficients

K(g) is the number of trial functions used for group g.

$$F_j^g(z) = \frac{Z_j^g(z) \int H_j^g(x,y)\ dx\ dy}{\sum_{k=1}^{K(g)} Z_k^g(z) \int H_k^g(x,y)\ dx\ dy} \qquad 2.3.2$$

$$\left| \frac{1}{\bar{\lambda}_n + \frac{1}{\lambda_I}} - \frac{1}{\underline{\lambda}_n + \frac{1}{\lambda_I}} \right| < \left| \frac{1}{\lambda_n + \frac{1}{\lambda_I}} \right| \epsilon \qquad 2.3.3$$

where $\bar{\lambda}_n$ and $\underline{\lambda}_n$ are the maximum and minimum measures, respectively, of the estimated eigenvalue λ_n after n iterations, λ_I is the effective eigenvalue guess, and ϵ is the input convergence parameter.

2.4. SPATIAL FLUX SOLUTIONS: DIFFERENCE EQUATIONS

This section contains the difference equations used by the program in both explicit and synthesis solutions.

Explicit Solutions

The difference equations for explicit solutions to the diffusion equation are derived at the mesh points; thus the flux solution of the problem will be obtained at the mesh points. The difference equation coefficients are described here in terms of the contribution of a single mesh element in a particular geometry (and dimensionality) to the coefficients in the difference equations for the points at the vertices of the mesh element. Note that the total coefficient in the difference equation at any mesh point will be the sum of the contributions from all of the mesh elements surrounding the mesh point. The coefficient contributions defined in this section are identified by a two-letter subscript determined as follows. If P and Q are two vertices of a mesh element, then the subscripts PP and PQ are used to designate the contributions of the element to the coefficients of the fluxes at points P and Q respectively, in the equation at point P. A more detailed description of the difference equations may be found in References 4, 5, 8, and 9. Fission and group coupling coefficients are not given explicitly since these are calculated in the same manner as the total cross section coefficient.

The coefficient contributions from a single mesh element in various geometries and dimensionalities are as follows:

1-D: The one-dimensional mesh element is shown in Figure 2.4.1. The coefficient contributions are given by Equations 2.4.1. Here r is the distance from the origin (point 0) to point P, and p is 0, 1, and 2 for rectangular, cylindrical, and spherical geometry respectively.

2-D Rectangular: The two-dimensional rectangular mesh element is shown in Figure 2.4.2. The coefficient contributions are given by Equations 2.4.2.

2-D Cylindrical: The two-dimensional cylindrical mesh element is shown in Figure 2.4.2. The coefficient contributions are given by Equations 2.4.3, where r is the distance from the origin to line PR.

3-D Rectangular: In the three-dimensional rectangular case, if rectangle TUVW is a distance h(3) below rectangle PQRS as in Figure 2.4.3, the coefficient contributions are given by Equations 2.4.4.

2-D Hexagonal: The mesh element for hexagonal geometry is shown in Figure 2.4.4. The coefficient contributions (Reference 9) are given by Equations 2.4.5.

3-D Hexagonal: In the three dimensional hexagonal case, if triangle STU is a distance h(3) below triangle PQR as in Figure 2.4.5, the coefficient contributions are given by Equations 2.4.6.

2-D Quadrilateral: The mesh element for two-dimensional quadrilateral geometry is shown in Figure 2.4.6. The coefficient contributions (Reference 8) are given in Equations 2.4.7.

Synthesis Solutions

The difference equation coefficients required for the synthesis solution of the diffusion equation involve terms comprised of the product of a macroscopic cross section and a synthesis trial function integral. Since the macroscopic cross section is constant over gross blocks (see Section 3.8), the trial function integrals are calculated over these same sets of planar meshes and then the product of cross sections and integrals are summed over all radial gross blocks for one axial position to obtain the required coefficients. The definitions of the integrals are given here in terms of the contribution of a single mesh element to the integral over the planar gross block in which it is

contained. The required integrals are of the form given in Equations 2.4.8.

In rectangular geometry, the integration is over the planar mesh element in Figure 2.4.7. The contribution of this mesh element to each of the three types of trial function integrals is given in Equations 2.4.9.

In hexagonal geometry, the integration is over the planar mesh element in Figure 2.4.8. The contribution of this mesh element to each of the three types of trial function integrals is given in Equations 2.4.10.

In quadrilateral geometry, the integration is over the planar mesh element in Figure 2.4.9. The contribution of this mesh element to each of the three types of trial function integrals is given in Equations 2.4.11.

ONE-DIMENSIONAL DIFFERENCE EQUATIONS

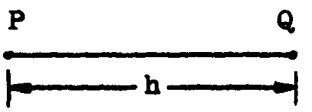


FIGURE 2.4.1 One-Dimensional Mesh Element

$$C_{PQ} = C_{QP} = -\frac{(r + h/2)^p}{h} D$$

$$C_{PP} = \frac{(r + h/2)^{p+1} - r^{p+1}}{p + 1} \Sigma^t - C_{PQ} \qquad 2.4.1$$

$$C_{QQ} = \frac{(r + h)^{p+1} - (r + h/2)^{p+1}}{p + 1} \Sigma^t - C_{QP}$$

where Σ^t = sigma total

TWO-DIMENSIONAL RECTANGULAR AND CYLINDRICAL DIFFERENCE EQUATIONS

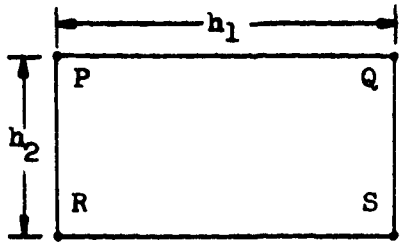


FIGURE 2.4.2

Two-Dimensional Mesh Element for Rectangular and Cylindrical Geometry

Rectangular:

$$C_{PQ} = C_{QP} = C_{RS} = C_{SR} = -\frac{h_2}{2h_1} D$$

$$C_{PR} = C_{RP} = C_{QS} = C_{SQ} = -\frac{h_1}{2h_2} D \qquad 2.4.2$$

$$C_{PP} = C_{QQ} = C_{RR} = C_{SS} = \frac{h_1 h_2}{4} \Sigma^t - C_{PQ} - C_{PR}$$

Cylindrical:

$$C_{PQ} = C_{QP} = C_{RS} = C_{SR} = -\frac{(r + h_1/2)h_2}{2h_1} D$$

$$C_{PR} = C_{RP} = -\frac{(r + h_1/4)h_1}{2h_2} D$$

$$C_{QS} = C_{SQ} = -\frac{(r + 3h_1/4)h_1}{2h_2} D \qquad 2.4.3$$

$$C_{PP} = C_{RR} = \frac{(r + h_1/4)h_1 h_2}{4} \Sigma^t - C_{PQ} - C_{PR}$$

$$C_{QQ} = C_{SS} = \frac{(r + 3h_1/4)h_1 h_2}{4} \Sigma^t - C_{QP} - C_{QS}$$

THREE-DIMENSIONAL RECTANGULAR DIFFERENCE EQUATIONS

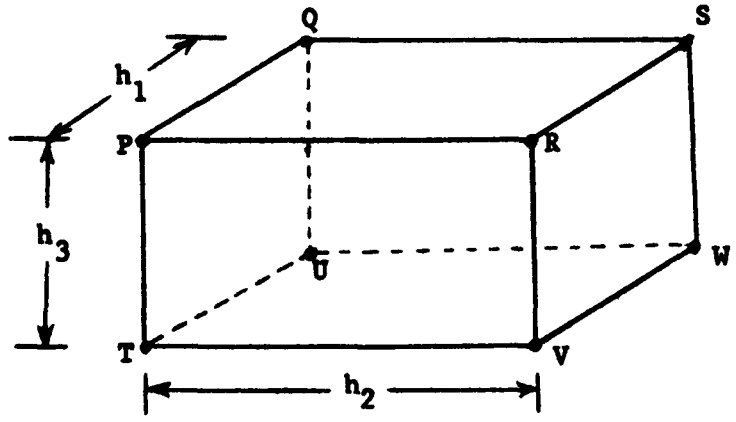


FIGURE 2.4.3

Three-Dimensional Rectangular Mesh Element

$$C_{PQ} = C_{QP} = C_{RS} = C_{SR} = C_{TU} = C_{UT} = C_{VW} = C_{WV}$$

$$= -\frac{h_2 h_3}{4h_1} D$$

$$C_{PR} = C_{RP} = C_{QS} = C_{SQ} = C_{TV} = C_{VT} = C_{UW} = C_{WU}$$

$$= -\frac{h_1 h_3}{4h_2} D$$

2.4.4

$$C_{PT} = C_{TP} = C_{QU} = C_{UQ} = C_{RV} = C_{VR} = C_{SW} = C_{WS}$$

$$= -\frac{h_1 h_2}{4h_3} D$$

$$C_{PP} = C_{QQ} = C_{RR} = C_{SS} = C_{TT} = C_{UU} = C_{VV} = C_{WW}$$

$$= \frac{h_1 h_2 h_3}{8} \Sigma^t - C_{PQ} - C_{PR} - C_{PT}$$

TWO-DIMENSIONAL HEXAGONAL DIFFERENCE EQUATIONS

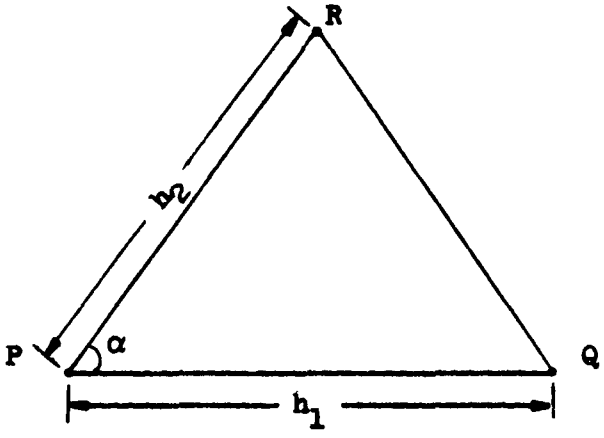


FIGURE 2.4.4

Two-Dimensional
Hexagonal Mesh Element

$$C_{PQ} = C_{QP} = - D \frac{h_2 - h_1 \cos \alpha}{2 h_1 \sin \alpha}$$

$$C_{PR} = C_{RP} = - D \frac{h_1 - h_2 \cos \alpha}{2 h_2 \sin \alpha}$$

$$C_{QR} = C_{RQ} = - D \frac{\cot \alpha}{2}$$

$$C_{PP} = \tfrac{1}{2} D \left[\left(\frac{h_1}{h_2} + \frac{h_2}{h_1} \right) \csc \alpha - 2 \cot \alpha \right] + \frac{\Sigma^t h_1 h_2 \sin \alpha}{6}$$

$$C_{QQ} = D \frac{h_2 \csc \alpha}{2 h_1} + \frac{\Sigma^t h_1 h_2 \sin \alpha}{6}$$

$$C_{RR} = D \frac{h_1 \csc \alpha}{2 h_2} + \frac{\Sigma^t h_1 h_2 \sin \alpha}{6} \qquad 2.4.5$$

THREE-DIMENSIONAL HEXAGONAL DIFFERENCE EQUATIONS

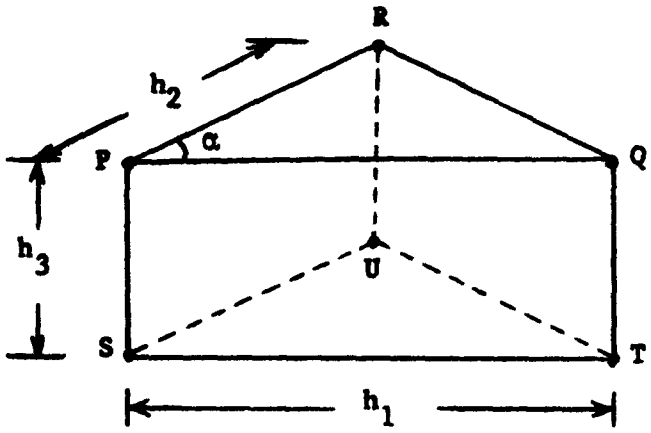


FIGURE 2.4.5

Three-Dimensional
Hexagonal Mesh Element

$$C_{PQ} = C_{QP} = C_{ST} = C_{TS} = - D \frac{h_3 (h_2 - h_1 \cos \alpha)}{4 h_1 \sin \alpha}$$

$$C_{PR} = C_{RP} = C_{SU} = C_{US} = - D \frac{h_3 (h_1 - h_2 \cos \alpha)}{4 h_2 \sin \alpha}$$

$$C_{QR} = C_{RQ} = C_{TU} = C_{UT} = - D \frac{h_3 \cot \alpha}{4}$$

$$C_{PS} = C_{SP} = C_{QT} = C_{TQ} = C_{RU} = C_{UR} = - D \frac{h_1 h_2 \sin \alpha}{6 h_3}$$

$$C_{PP} = C_{SS} = D \frac{h_3}{4} \left[\left(\frac{h_1}{h_2} + \frac{h_2}{h_1} \right) \csc \alpha - 2 \cot \alpha \right] + \frac{\Sigma^t h_1 h_2 h_3 \sin \alpha}{12} - C_{PS}$$

$$C_{QQ} = C_{TT} = D \frac{h_2 h_3 \csc \alpha}{4 h_1} + \frac{\Sigma^t h_1 h_2 h_3 \sin \alpha}{12} - C_{QT}$$

$$C_{RR} = C_{UU} = D \frac{h_1 h_3 \csc \alpha}{4 h_2} + \frac{\Sigma^t h_1 h_2 h_3 \sin \alpha}{12} - C_{RU} \qquad 2.4.6$$

TWO-DIMENSIONAL QUADRILATERAL DIFFERENCE EQUATIONS

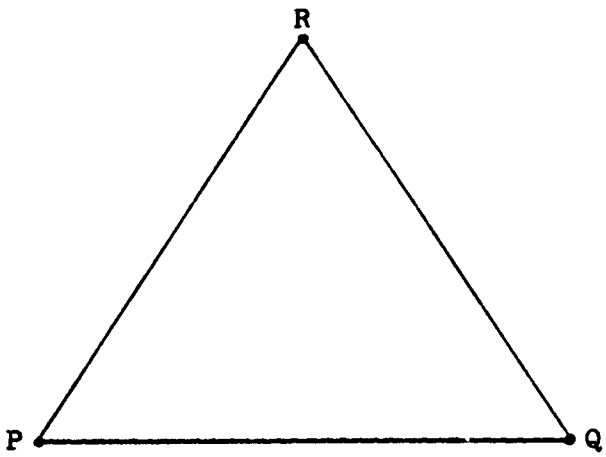


FIGURE 2.4.6

Two-Dimensional
Quadrilateral Mesh Element

Coordinates of points P, Q, and R are
(x_P,y_P), (x_Q,y_Q), and (x_R,y_R) respectively.

The area of the triangle is A.

$$C_{PP} = \frac{D}{4A}\left[\Delta y_2^2 + \Delta x_2^2\right] + \frac{\Sigma^t A}{3}$$

$$C_{QQ} = \frac{D}{4A}\left[\Delta y_3^2 + \Delta x_3^2\right] + \frac{\Sigma^t A}{3}$$

$$C_{RR} = \frac{D}{4A}\left[\Delta y_1^2 + \Delta x_1^2\right] + \frac{\Sigma^t A}{3}$$

2.4.7

$$C_{PQ} = C_{QP} = -\frac{D}{4A}\left[\Delta y_2\,\Delta y_3 + \Delta x_2\,\Delta x_3\right]$$

$$C_{PR} = C_{RP} = +\frac{D}{4A}\left[\Delta y_2\,\Delta y_1 + \Delta x_2\,\Delta x_1\right]$$

$$C_{QR} = C_{RQ} = -\frac{D}{4A}\left[\Delta y_3\,\Delta y_1 + \Delta x_3\,\Delta x_1\right]$$

where $\Delta x_1 = x_Q - x_P$ $\quad \Delta y_1 = y_Q - y_P$
$\Delta x_2 = x_R - x_Q$ $\quad \Delta y_2 = y_R - y_Q$
$\Delta x_3 = x_R - x_P$ $\quad \Delta y_3 = y_R - y_P$

RECTANGULAR SYNTHESIS TRIAL FUNCTION INTEGRALS

$$Z_1 = \iint \phi(x,y)\,dxdy$$

$$Z_2 = \iint \phi(x,y)\,\psi(x,y)\,dxdy \qquad 2.4.8$$

$$Z_3 = \iint \nabla\phi(x,y)\cdot\nabla\psi(x,y)\,dxdy$$

where $\phi(x,y)$ and $\psi(x,y)$ are planar trial functions and the integrals are computed over planar gross blocks.

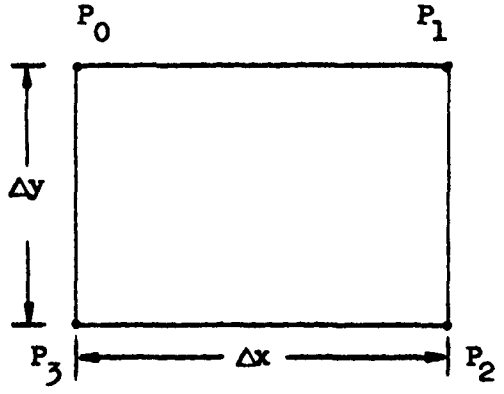


FIGURE 2.4.7

Planar Rectangular Mesh Element

$$Z_1 = \frac{\Delta x \Delta y}{4}(\phi_0 + \phi_1 + \phi_2 + \phi_3)$$

$$Z_2 = \frac{\Delta x \Delta y}{4}(\phi_0\psi_0 + \phi_1\psi_1 + \phi_2\psi_2 + \phi_3\psi_3)$$

$$Z_3 = \frac{1}{2}\left\{\frac{\Delta y}{\Delta x}\left[(\phi_1-\phi_0)(\psi_1-\psi_0) + (\phi_2-\phi_3)(\psi_2-\psi_3)\right]\right. \qquad 2.4.9$$

$$\left. + \frac{\Delta x}{\Delta y}\left[(\phi_3-\phi_0)(\psi_3-\psi_0) + (\phi_2-\phi_1)(\psi_2-\psi_1)\right]\right\}$$

HEXAGONAL SYNTHESIS TRIAL FUNCTION INTEGRALS

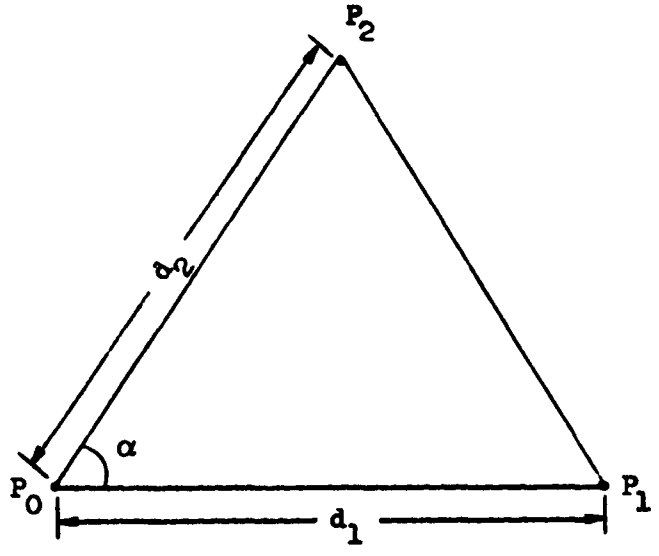


FIGURE 2.4.8

Planar Hexagonal Mesh Element

$$z_1 = \frac{ac}{6}(\phi_0 + \phi_1 + \phi_2)$$

$$z_2 = \frac{ac}{24}\left[\phi_0(2\psi_0 + \psi_1 + \psi_2) + \phi_1(2\psi_1 + \psi_2 + \psi_0) + \phi_2(2\psi_2 + \psi_0 + \psi_1)\right]$$

$$z_3 = \left(\frac{c}{2a} + \frac{b^2}{2ac}\right)(\phi_1-\phi_0)(\psi_1-\psi_0) + \frac{a}{2c}(\phi_2-\phi_0)(\psi_2-\psi_0) - \frac{b}{2c}\left[(\phi_2-\phi_0)(\psi_1-\psi_0) + (\phi_1-\phi_0)(\psi_2-\psi_0)\right] \qquad 2.4.10$$

where $a = d_1$, $b = d_2 \cos\alpha$, and $c = d_2 \sin\alpha$

QUADRILATERAL SYNTHESIS TRIAL FUNCTION INTEGRALS

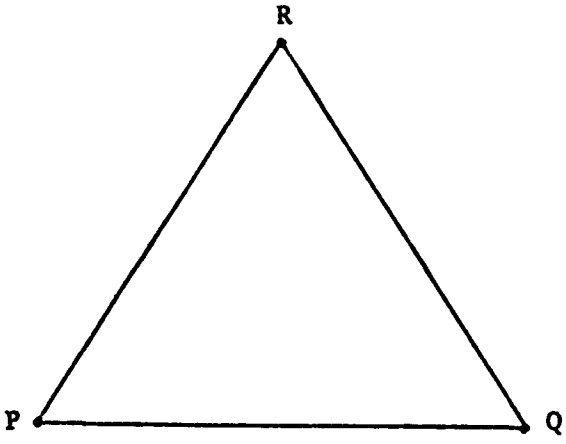


FIGURE 2.4.9

Planar Quadrilateral
Mesh Element

Coordinates of points P, Q, and R are

(x_P, y_P), (x_Q, y_Q), and (x_R, y_R), respectively.

The area of the triangle is A.

$$Z_1 = \frac{A}{3} (\phi_P + \phi_Q + \phi_R)$$

$$Z_2 = \frac{A}{24} \Big[\phi_P \ (2\psi_P + \psi_Q + \psi_R) + \phi_Q \ (2\psi_Q + \psi_P + \psi_R) + \phi_R \ (2\psi_R + \psi_P + \psi_Q) \Big] \qquad 2.4.11$$

$$Z_3 = \frac{1}{4A} \Big\{ (\phi_Q - \phi_P)(\psi_Q - \psi_P)(\Delta x_3^2 + \Delta y_3^2) + (\phi_R - \phi_P)(\psi_R - \psi_P)(\Delta x_1^2 + \Delta y_1^2) - \Big[(\phi_R - \phi_P)(\psi_Q - \psi_P) + (\phi_Q - \phi_P)(\psi_R - \psi_P) \Big] \Big[\Delta x_1 \Delta x_3 + \Delta y_1 \Delta y_3 \Big] \Big\}$$

where $\Delta x_1 = x_Q - x_P$ $\quad \Delta y_1 = y_Q - y_P$

$\Delta x_2 = x_R - x_Q$ $\quad \Delta y_2 = y_R - y_Q$

$\Delta x_3 = x_R - x_P$ $\quad \Delta y_3 = y_R - y_P$

3.1. GEOMETRY DESCRIPTION: INTRODUCTION

The region of solution of the problem is in one of the following available geometries:

1-D: rectangular, cylindrical, spherical
2-D: rectangular, cylindrical, hexagonal, quadrilateral
3-D: rectangular, hexagonal, quadrilateral
(quadrilateral available in 3-D for synthesis solutions only)

These solution geometries are constructed using one of the basic descriptive geometries: rectangular, hexagonal, and quadrilateral. Construction of two-dimensional regions of solution will be discussed first, as the one-dimensional and three-dimensional cases are derived from this.

Two-Dimensional

The two-dimensional geometry description in all geometries is a grid with column boundary C and row boundary R. The row and column intersections are the MESH POINTS at which the flux solution is obtained. Columns are numbered from 0 to C and rows are numbered from 0 to R so that the resulting lattice contains (C+1) columns and (R+1) rows. The number of mesh points in each row is constant, as is the number of mesh points in each column. The segmented lines connecting mesh points along a given row or column of the lattice are called MESH LINES. Each row mesh line intersects each column mesh line at a mesh point. In all geometries, row mesh lines may not intersect other row mesh lines and column mesh lines may not intersect other column mesh lines.

The lattice specified also determines an array of MESH ELEMENTS. The mesh elements in rectangular geometry are themselves rectangular. In hexagonal geometry, the points form an array of mesh quadrilaterals which are cut along a specific diagonal to form triangular mesh elements. In quadrilateral geometry the elements are general quadrilaterals, which are cut along either diagonal to form triangular mesh elements. Identifiers are assigned to these mesh elements which are used to identify material properties. In a problem with column boundary C and row boundary R there will be (C+1)(R+1) mesh points in a plane in all geometries. However, in rectangular geometry there will be CR rectangular mesh elements while in hexagonal and quadrilateral there will be 2CR mesh triangles. The purpose of the mesh description is to specify the location of all mesh points and also the location of all internal boundaries or interfaces. These interfaces are composed of line segments which are the boundaries of mesh rectangles or mesh triangles.

The region of solution for rectangular geometry is a rectangle in the x-y plane, and for cylindrical it is a rectangle in the r-z plane. The axes of the coordinate system coincide with the boundary lines of the rectangle. Both the rectangular and cylindrical solution regions are described using rectangular geometry building capability. The rectangle is oriented in the fourth quadrant (as shown in Figure 3.1.1), the origin being in the upper left corner. Column numbers increase to the right along the x-axis (r-axis in cylindrical) from 0 to the column boundary, and row numbers increase downward along the y-axis (z-axis in cylindrical) from 0 to row boundary.

The hexagonal region of solution is a 120-degree chevron in the x-y plane. The chevron is oriented as in Figure 3.1.2, with column numbers increasing to the right and row numbers increasing downward. The rows bend through a 60-degree angle at the specified diagonal column of the chevron. The first and last rows are considered the top and bottom boundaries, and the first and last columns are the left and right boundaries.

The region of solution for quadrilateral geometry is a general polygon. This can range from a grid of parallel rows and columns with an arbitrary angle of intersection between the rows and columns, to a completely general placement of points in a (C+1) by (R+1) lattice. The grid is oriented in the fourth quadrant as in Figure 3.1.3, with column numbers increasing from left to right and row numbers increasing from top to bottom.

One-Dimensional

For purposes of describing geometry, a one-dimensional region of solution is constructed as a two-dimensional grid with only two rows, 0 and 1, described in rectangular geomtery. The solution space is a single row of points numbered left to right, point 0 on the left.

Three-Dimensional

In 3-D problems, the two-dimensional geometry description is effectively repeated at each axial point producing a parallel array of the 2-D descriptions. Each of these planes of mesh points is called a MESH PLANE. Thus in a 3-D problem all interfaces which will appear in any plane axially must be projected onto a single plane which is then described as specified above.

In a problem with plane boundary P, the lattice will be an array of (P+1) planes; the top plane is plane 0 and the bottom plane is plane P. Since each plane contains the same mesh description, there will be (C+1)(R+1)(P+1) mesh points in the problem, where C is the column boundary and R is the row boundary. Similar to the transverse planar mesh lines, axial mesh lines are segmented lines connecting corresponding points (i.e., points with the same planar (column,row) coordinates) from plane to plane.

Axial detail is further described by varying the materials which are assigned to the mesh elements in various planes of the grid.

FIGURES 3.1.1 - 3.1.2

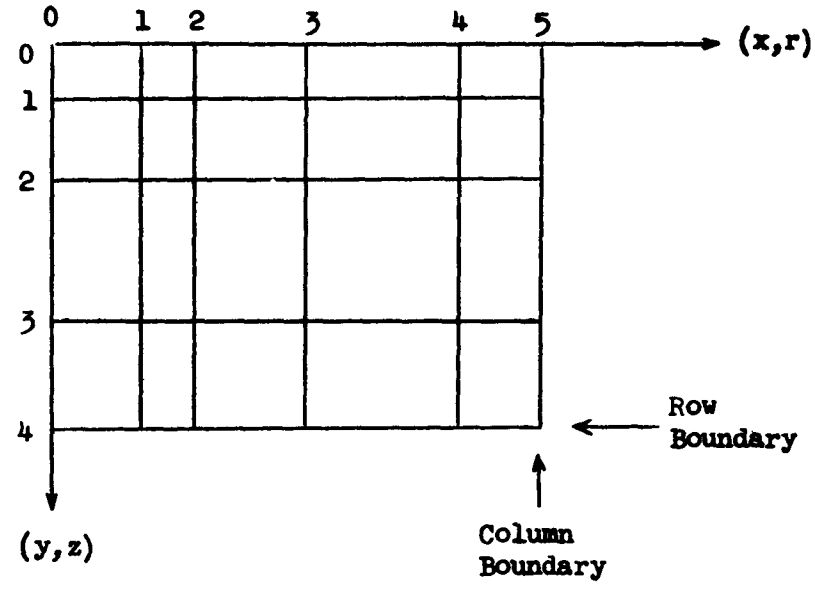


Figure 3.1.1 Rectangular Region of Solution

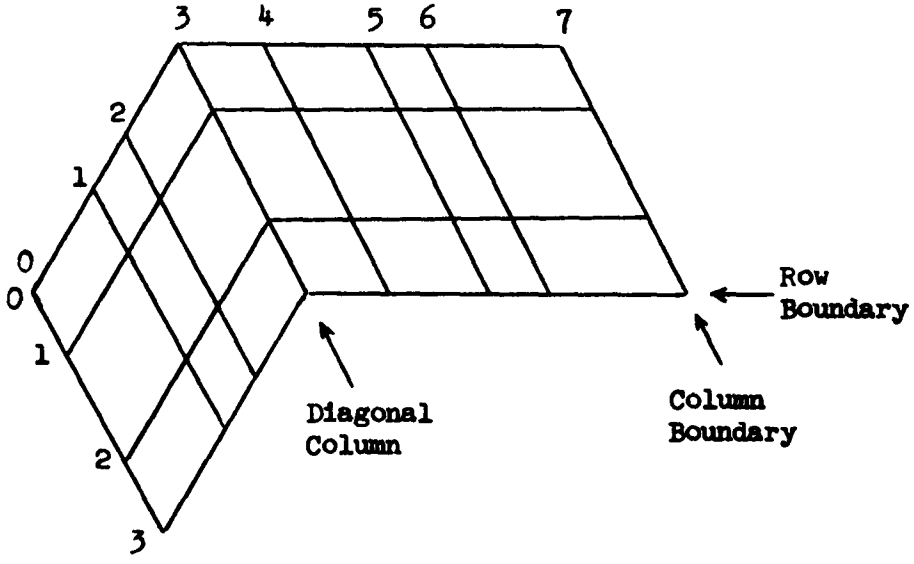
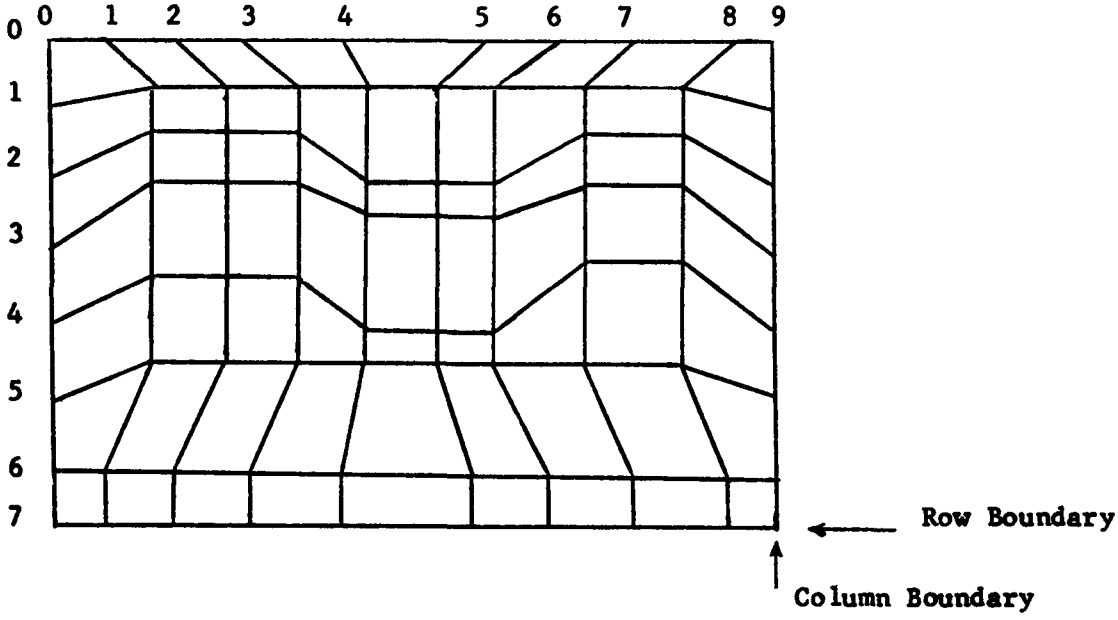


Figure 3.1.2 Hexagonal Region of Solution

FIGURE 3.1.3



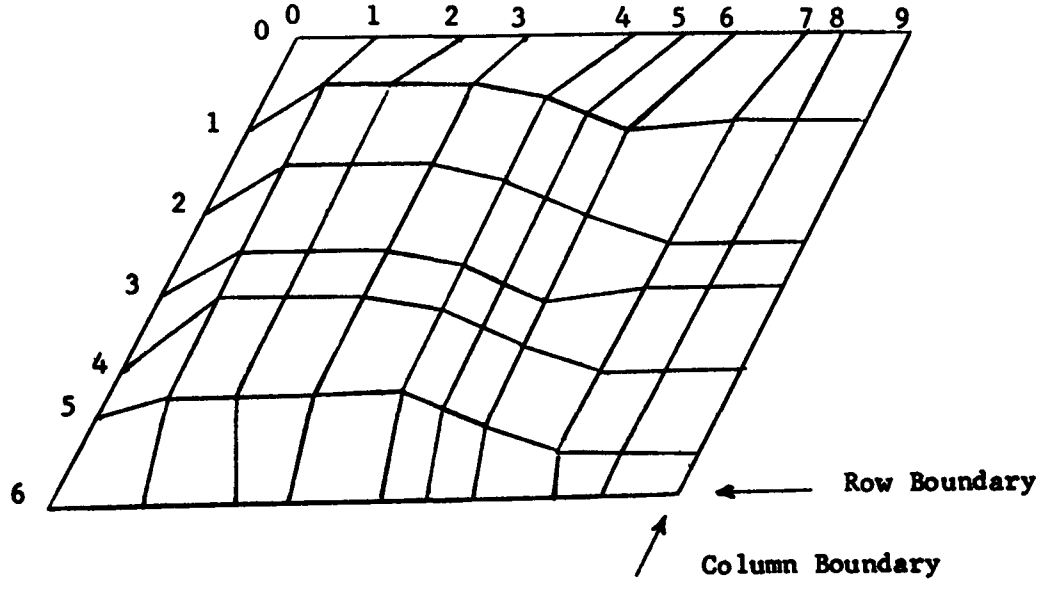


Figure 3.1.3 Possible Quadrilateral Regions of Solution

3.2. GEOMETRY DESCRIPTION: TERMINOLOGY

This section defines some of the more important names and structures used in geometry descriptions. Unless otherwise specified, the definitions apply to all three of the descriptive geometry types (rectangular, hexagonal, and quadrilateral).

1. Solution Mesh

   a. MESH POINTS - intersections of the rows and columns of the region of solution at which the pointwise solution flux is obtained. In 3-D problems, the same array of mesh points is repeated in each axial plane.

   b. MESH LINES - segmented lines lying along rows or columns of the solution lattice. Each row mesh line intersects each column mesh line at a mesh point. Row mesh lines cannot cross other row mesh lines and column mesh lines cannot cross other column mesh lines. In 3-D problems, axial mesh lines also connect corresponding mesh points from plane to plane.

   c. MESH PLANES - the two-dimensional set of mesh points which is repeated at every axial plane in a 3-D problem. The 3-D geometry description is a parallel array of these mesh planes with all point locations the same for corresponding mesh points from plane to plane, and all mesh element identifiers except composition number the same for corresponding mesh elements from plane to plane.

   d. MESH ELEMENTS - the smallest area of the region of solution over which the geometric identifiers must be constant. In rectangular geometry, each mesh element is a rectangle bounded by two adjacent row mesh lines and two adjacent column mesh lines. In hexagonal and quadrilateral geometry, a mesh element is a triangle formed by a diagonal and two sides of the mesh quadrilateral bounded by two adjacent row mesh lines and two adjacent column mesh lines. In 3-D problems, a mesh element is a rectangular or triangular prism with the base a planar mesh element and bounded by two adjacent mesh planes.

2. Mesh Element Labels

   a. FINAL FIGURE NUMBER - geometric identifier assigned to each mesh element either during the final figure overlay process (if rectangular or hexagonal) or during compound figure generation (if quadrilateral); used in conjunction with the planar region number for gross block determination in all but 1-D problems.

   b. PLANAR REGION NUMBER - geometric identifier assigned to each non-transparent mesh element on the basic figure level by the planar region overlay process; used in conjunction with the final figure number for gross block determination in all but 1-D problems.

   c. CHANNEL NUMBER - geometric identifier assigned on the basic figure level to each mesh element in planar regions specified as fine blocked regions and modified during the final figure overlay process (in rectangular and hexagonal) or during compound figure generation (in quadrilateral); used together with the track number for fine block determination.

   d. TRACK NUMBER - geometric identifier assigned on the basic figure level to each mesh element in planar regions designated as fine blocked regions and used together with the channel number in fine block determination.

3. Geometric Structures

   a. BASIC FIGURE - the fundamental building block used in constructing a geometric description, usually corresponding to some substructure of the solution grid. Its lattice is made up of parallel rows and columns, being a rectangle in rectangular geometry, a 60-degree parallelogram in hexagonal geometry (except transition figures), and a general n-degree parallelogram in quadrilateral geometry.

b. AUXILIARY FIGURE - a fundamental geometry building block containing the same mesh description as a parent basic figure but having different planar region and/or channel-track numbers assigned to its mesh elements.

c. TRANSITION FIGURE - (hexagonal only) a special type of basic figure used in hexagonal geometry to facilitate bending of mesh lines. A transition figure is a basic figure with a column boundary of 1 whose outer boundary is a 60-degree parallelogram and whose interior rows are not necessarily parallel.

d. SUPER FIGURE - (rectangular and hexagonal only) a structure used in building a rectangular or hexagonal geometry. Super figures are lattices constructed by superimposing basic and auxiliary figures, and usually correspond to some substructure of the solution grid.

e. AUXILIARY SUPER FIGURE - (rectangular and hexagonal only) a structure used in building a rectagular or hexagonal lattice based on a parent super figure but having some additional initial figures overlaid on it.

f. FILE FIGURE - (quadrilateral only) a building element in quadrilateral geometry whose constructed description is input from a File Manager figure file.

g. INITIAL FIGURE - collective term for all structures which may be used as building blocks during the geometry generation process.

(rectangular and hexagonal only) - during super figure generation in rectangular and hexagonal geometry, initial figures include all basic figures and auxiliary figures. During the final figure overlay process in rectangular and hexagonal geometry, initial figures include all basic figures, auxiliary figures, super figures, and auxiliary super figures (super figures are referred to as initial super figures).

(quadrilateral only) - at any stage of the compound figure generation in quadrilateral geometry, initial figures include all basic figures, auxiliary figures, file figures, and previously generated compound figures.

h. COMPOUND FIGURE - (quadrilateral only) a structure used in building a quadrilateral geometry. A compound figure is a lattice description constructed by buildup and overlay using initial figures in quadrilateral geometry.

i. SOLUTION FIGURE - (quadrilateral only) the single compound figure in quadrilateral geometry which is designated to be the solution space for the problem.

4. Geometry Generation Processes

a. FINAL FIGURE OVERLAY - (rectangular and hexagonal only) the process by which substructures are assembled to construct the solution mesh in hexagonal and rectangular geometry. Initial figures are superimposed on the solution region defining the spatial positions of all mesh points and assigning the geometric identifiers to each mesh element.

b. COMPOUND FIGURE GENERATION - (quadrilateral only) the central process in quadrilateral geometry generation. Compound figures are generated sequentially and may themselves be used as building blocks for succeeding compound figures. Some or all of the compound figure building descriptions may optionally be input from a File Manager figure file. Successive compound figures generally represent progressively more complex lattice descriptions. One of the compound figures, namely the solution figure, is designated to be the region of solution for the problem.

5. Inventory Blocks

a. GROSS BLOCK - a collection of mesh elements over which material inventories for all nuclides are assumed uniform at any given time in life. These need not be contiguous collections of mesh elements.

b. FINE BLOCK - in a fine blocked problem, the collection of mesh elements over which material inventories for a subset of the nuclides are assumed uniform at any given time in life. These need not be contiguous collections of mesh elements. Fine blocks are always wholly contained in gross blocks.

c. GROSS PLANE - a collection of contiguous axial planes which delimit the extent of gross blocks in the axial direction.

d. FINE PLANE - a collection of contiguous axial planes which delimit the extent of fine blocks in the axial direction. Fine planes are always wholly contained in gross planes.

6. Material Compositions

a. COMPOSITION NUMBER - an identifier assigned to each mesh element through which the material characteristics of the mesh are designated.

b. COMPOSITION CORRESPONDENCE - the method by which composition numbers are assigned to the mesh elements. Compositions may be chosen to correspond to either final figure numbers or planar region numbers. In 3-D problems, composition correspondences may change at each gross plane.

c. CONFIGURATION - a particular set of composition to planar region (or final figure) correspondences. Each configuration identifies some material arrangement.

3.3. GEOMETRY DESCRIPTION: GEOMETRY TYPES

The three geometries available for constructing a planar geometric description are: rectangular, hexagonal, and quadrilateral. The various geometries differ both in the types of mesh descriptions which may be created, and also in the manner in which these structures are defined by the user. Detailed descriptions of these geometry types are given in Sections 3.4, 3.5, and 3.6 respectively. This section is intended to give a brief summary of each geometry type and contrast their capabilities and methods of construction.

In all geometries, the construction of a planar mesh is concerned with specifying the position of each mesh point and specifying the internal boundaries or interfaces by attaching identifiers to each mesh element. The method of attaching identifiers to mesh elements differs only slightly among the three geometries. However, there are important differences as to the directions in which interfaces may exist. In regard to the positioning of mesh points, the geometries may be contrasted by the extent to which mesh lines may deviate from being straight lines (i.e., how mesh lines may be "bent"). Additionally, given that some geometries permit mesh line bending, their methods differ as to whether this redirection of lines must be specifically defined by the user or is automatically accomplished by the geometry generator.

Rectangular geometry limits the definition of mesh points to the intersections of parallel rows and parallel columns in a 90-degree lattice. Interfaces must coincide with column or row mesh lines; diagonal interfaces (i.e., interfaces along the diagonal of a mesh rectangle) are not permitted. Since mesh lines may never be bent, to specifically represent an interface which does not lie along an existing mesh line the user must add an entire row or column to the problem. In creating a rectangular description, the substructures must be assembled such that parallel rows and columns are preserved in the region of solution. The program will check that the user has described a consistent rectangular lattice, having defined the positions of all mesh points and all mesh lines.

Hexagonal geometry is constructed in a 120-degree chevron, and the resulting grid is essentially made up of 60-degree triangular mesh elements. In addition to interfaces which coincide with mesh lines, diagonal interfaces are permitted in one given direction only. Columns are not necessarily parallel or straight (nor are rows) as the additional working direction in hexagonal geometry permits a limited capability for bending rows and columns. There is also an additional capability to bend mesh lines, permitting more exact description and conserving the total number of mesh points which must be used. The bending of the mesh lines in this case must be specifically defined by the user in the process of geometry construction by using special building elements which describe the transitions of the mesh lines. These transition figures must explicitly define the redirection of the mesh lines to insure that mesh lines in adjoining substructures meet at common points. The program will check that the user has defined a legal hexagonal lattice, having consistently defined the positions of all mesh points and mesh lines.

Quadrilateral geometry may be used to define a general quadrilateral lattice. Interfaces may coincide with row or column mesh lines, or one of two possible diagonals of a mesh quadrilateral. The fundamental requirement of quadrilateral geometry is only that a legal (C+1) by (R+1) lattice be described, so each row may not intersect other rows, each column may not intersect other columns, and each row intersects each column at a mesh point. The placement of mesh points within such a lattice may be completely general. In constructing a quadrilateral geometry, the user specifies the exact spatial location and orientation of each substructure. The program will adjust the mesh lines which connect the points on the boundary of the substructure to the adjacent mesh points in the lattice to accommodate this designated position. Thus the user need only describe the mesh in the regions of substance and the geometry generator will automatically define the necessary transitions of the surrounding mesh lines. The program will check the grid constructed to insure that a legal lattice has been described.

Grids which are basically rectangular or hexagonal may frequently be more advantageously represented using quadrilateral geometry. The automatic mesh line bending and generalized diagonalization (interfaces allowed on either diagonal of a mesh quadrilateral) in quadrilateral geometry could result in reducing the total number of mesh lines necessary to describe interfaces.

Additionally, dissimilar substructures (e.g., 90-degree structures in an inherently hexagonal grid) are easily represented.

In all geometries the entire geometry description may be input to the program via card input. Quadrilateral geometry only may also accept data from an input File Manager figure file. Such a file may supply both complete definitions of geometric substructures and also building descriptions for substructures to be used in the geometry generation process. This File Manager figure file can be used to communicate with an external geometry generator.

The program may be requested to write an output File Manager geometry file in all geometries. This file contains the constructed description of the solution space, and may be input to succeeding cases using the same geometry to save the time used for geometry generation. Quadrilateral geometry only may also output a File Manager figure file which contains both constructed descriptions and building information for the geometric substructures used in the problem. This file may then be input to succeeding problems using similar geometry descriptions to save part of the time of geometry generation.

3.4. GEOMETRY DESCRIPTION: RECTANGULAR GEOMETRY

In the description of a rectangular geometry, the elementary building blocks are called basic figures. These may optionally be grouped in a spatial arrangement called a super figure to form a larger building unit. Both of these building blocks are then used to describe the region of solution through a process of both buildup and overlay called the final figure overlay. The purpose of the description is to define the spatial position of all mesh points in the solution space and to attach a set of identifiers to all mesh elements. The region of solution to be constructed is a rectangle. A detailed description of this process follows.

BASIC FIGURES

The fundamental entities of a mesh description are basic figures. These building blocks usually correspond to some substructure of the solution grid. Basic figures in rectangular geometry are rectangles oriented in the fourth quadrant as in Figure 3.4.1. A basic figure is described by giving:

(1) A mesh description.
(2) A planar region overlay.
(3) Channel and track indentifiers (if fine blocking).

The mesh description consists of giving the size (number of rows and columns) of the basic figure, and the mesh spacings along both row 0 and column 0. This completely defines the number and spatial orientation of all points in the rectangle.

The PLANAR REGION OVERLAY consists of a series of overlay sets which assign planar region numbers (identifiers) to each of the rectangular mesh elements in the basic figure. Each overlay set superimposes a particular planar region identifier on a rectangular subset of the basic figure. The sets are processed sequentially, and any set may overlay areas of the mesh specified in previous sets. Every mesh rectangle must be included in at least one of the overlay sets, and, for each mesh rectangle, the last overlay set in which it is included determines its planar region identification number. Planar region numbers may vary from 1 to 999 and need not be sequential. Each planar region number may be used more than once and in more than one basic figure.

As an example, Figure 3.4.1 may be described by overlaying planar region 1 on the entire mesh; region 4 between columns 1 and 3, rows 2 and 4; region 2 between columns 2 and 4, rows 0 and 3; and region 4 between columns 3 and 4, rows 0 and 1.

When the fine blocking option (see Section 3.8) has been selected, CHANNEL and TRACK identifiers are also assigned to the mesh elements in the basic figure. Channel and tracks are bounded by the straight line rows or columns of the basic figure. Normally channels are bounded by columns and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in a basic figure would have the same channel number and all mesh elements between two consecutive rows would have the same track number. This correspondence may optionally be reversed for any basic figure. The effect of this definition is to assign a channel and track identifier to each mesh rectangle in the basic figure. Channel numbers may assume values from 1 to 999,999,999, and track numbers may vary from 1 to 127. Neither need be sequential.

Basic figures are numbered sequentially from 1 to 999.

Auxiliary figures

An auxiliary figure is produced by modifying the planar region overlay and/or the channel and track identifiers (if fine blocking) of a basic figure. If two or more basic figures have the same mesh description (same size and mesh spacings) but some different planar region, channel, or track identifiers, the use of auxiliary figures makes it unnecessary to repeat the mesh interval specification. For changing planar regions, only modifications to the planar

region overlay need be specified in the form of additional overlay sets. If the channel or track identifiers of some of the mesh columns or rows are different, only the changes need be described. The auxiliary figures for a particular basic figure are numbered sequentially from 0 to 9, with the basic figure itself being assigned auxiliary figure number 0. The additional planar region overlay sets or changes in channel and track identifiers for an auxiliary figure modify only the basic figure data (auxiliary figure 0).

Initial figures

A basic figure number followed by an auxiliary figure number identifies an initial figure. Thus initial figure numbers range from 10 to 9999. An initial figure number of 246 would identify auxiliary figure 6 of basic figure 24.

FINAL FIGURE OVERLAY

The rectangular region of solution is defined by the final figure overlay. This consists of a series of overlay sets each of which superimposes a particular initial figure or initial super figure (which will be described later) on some portion of the region of solution. Initially the region of solution may be considered to be a completely flexible lattice of points defined by its row boundary and column boundary. The point positions and mesh identifiers will be defined by positioning the initial figures on it.

An initial figure is positioned by giving the column and row of the solution region at which the origin of the initial figure is to be placed, and the angle through which it is to be clockwise rotated. The angle must be a multiple of 90 degrees. The initial figure may also be reflected, implying an interchange of rows and columns. The rotational orientations of a rectangular initial figure are shown in Figure 3.4.2, and the reflections in Figure 3.4.3. The origins of the initial figures are at the center in both cases.

As in the planar region overlay, the final figure overlay is sequential and may overlay areas of the solution region which have been specified previously. Initial figures may extend beyond the boundaries of the region of solution in any direction; any portion of the initial figure extending outside the solution space boundaries is ignored. The origins of initial figures may actually be positioned outside the region of solution.

A FINAL FIGURE number is associated with each initial figure overlay of the region of solution. This identifier is assigned to each mesh element which is overlaid by the initial figure. This permits different overlays using the same initial figures to be distinguishable, which is important for gross inventory block determination (see Section 3.8) and for editing (see Section 5.2). Final figure numbers range from 1 to 999, and need not be sequential or distinct.

In problems in which the fine blocking option has been selected each mesh element in the initial figure has also been given a channel and a track identification number. If the planar region number of a mesh element has been previously designated as a region to be fine blocked, these identifiers are also assigned to the mesh element in the solution region which it superimposes (otherwise, channel and track numbers of 0 are assigned). Further, a CHANNEL BIAS may be assigned to each initial figure overlaid on the region of solution. The channel identifier assigned to the solution mesh is the sum of the channel number in the initial figure and the channel bias, permitting different overlays using the same initial figure to produce different channel identifiers. This is important for determination of a unique set of fine blocks (see Section 3.8).

Each final figure OVERLAY SET thus consists of the following information: initial figure used, final figure number assigned, column and row at which to position origin of the initial figure, rotation indicator, reflection indicator, and, optionally, channel bias.

Final figure overlay sets are processed sequentially. All of the mesh elements (and consequently all of the mesh points) in the region of solution must have been overlaid by at least one initial figure. The fundamental restriction in the final figure overlay is that the mesh in the initial figures must be chosen such that the rows and columns in adjoining initial figures meet at common boundary points, so parallel rows and columns must be preserved in the final mesh. This need not be true at every stage of the overlay, but only when the overlay is complete.

Upon completion of the overlay process each mesh element of the solution space will be assigned two identifiers in all problems, namely a final figure and a planar region. Further, in fine blocked problems those planar regions defined as fine block regions will also be assigned a channel and a track identifier.

SUPER FIGURES

When the same or a similar pattern of initial figures is repeated in several sections of the region of solution, the overlay procedure may be facilitated through use of super figures. A super figure is a grouping of initial figures in a lattice of fixed size, which may be considered a subset of the region of solution. A super figure is described by giving:

(1) A size description (row boundary and column boundary).
(2) A super figure overlay.

The size description defines the rectangular lattice (number of columns and rows) on which initial figures are overlaid. The SUPER FIGURE OVERLAY consists of overlay sets, each of which superimposes a particular initial figure on the super figure. The initial figure is positioned by giving the row and column of the super figure at which the initial figure origin is to be placed. The initial figure may be rotated and/or reflected in the frame of reference of the super figure. The super figure overlay is sequential and may overlay areas of the super figure which have been previously specified. Initial figures may extend beyond super figure boundaries. Any portion of an initial figure which is outside the super figure boundaries is ignored, and initial figure origins may be located outside these boundaries.

Super figures are numbered sequentially from 1 to 999.

Auxiliary Super Figures

An auxiliary super figure is obtained by modifying the super figure overlay of a super figure. If two or more rectangles have the same column boundary and row boundary but differ somewhat in overlay sets, the use of auxiliary super figures makes it unnecessary to repeat the size specification and any redundant super figure overlay sets. As with basic figures, the auxiliary figures for a particular super figure are numbered sequentially from 1 to 9, and the super figure itself is assigned auxiliary figure number 0. Additional super figure overlay sets for other auxiliary super figures modify only the overlay sets for auxiliary super figure number 0.

Initial Super Figures

An initial super figure is identified by a super figure number followed by an auxiliary super figure number, and thus initial super numbers range from 10 to 9999. An initial super figure is superimposed on the region of solution via the final figure overlay. A single final figure number is assigned to the initial super figure when it is laid down. As in the case of a normal initial figure, the initial super figure is positioned by giving the row and column of the solution region at which the origin is to be placed. Super figures may also be rotated and/or reflected. In laying down an initial super figure on the region of solution, the super figure may overlay previously specified sections; it may be later overlaid by an initial figure or another initial super figure;

it may extend outside the region of solution; and it may have its origin outside the region of solution.

Portions of a super figure may remain unspecified when the super figure overlay is complete. Such sections are called TRANSPARENCIES. When a super figure with such areas is laid on the region of solution, the transparency produces no change in that section of the solution grid over which it is superimposed. The use of transparencies in super figures thus allows figures with an outer boundary of other than a rectangle to be superimposed on the region of solution. Any figure whose boundary is in all places parallel to one of the coordinate axes may be constructed via a super figure.

RECTANGULAR GEOMETRY EXAMPLE

Suppose the geometry shown in Figure 3.4.4 is to be constructed. This structure may represent one-fourth of a symmetric array of similar structures, with the solution to the larger problem actually being obtained by applying appropriate boundary conditions. Mesh points have been added in Figure 3.4.5, and the initial figures to be used in constructing the geometry are shown in Figure 3.4.6. Note that initial figure 0021 is an auxiliary figure of 0020. The rows and columns in adjoining figures all meet at common boundary points. As a result, some figures contain more rows and columns than are required to describe their interfaces.

The geometry may be constructed in steps by the following overlay:

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0010	0,0	0	No
0010	4,4	90	No
0010	4,4	270	No
0020	4,8	90	No
0020	8,4	270	Yes
0010	8,8	180	No
0021	8,8	90	No
0021	8,4	0	No
0030	8,8	0	No
0040	0,11	0	Yes
0040	11,0	0	No

As a further example, an alternate method of laying down this same mesh is shown below. First, super figure 001 shown in Figure 3.4.7 is constructed by the following process:

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0010	4,0	90	No
0010	8,4	180	No
0020	4,4	90	No
0021	8,4	90	No

and then the following final figure overlay (where negative initial figure numbers refer to initial super figures):

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0010	0,0	0	No
-0010	0,4	0	No
-0010	4,0	0	Yes
0030	8,8	0	No
0040	0,11	0	Yes
0040	11,0	0	No

FIGURES 3.4.1 - 3.4.3

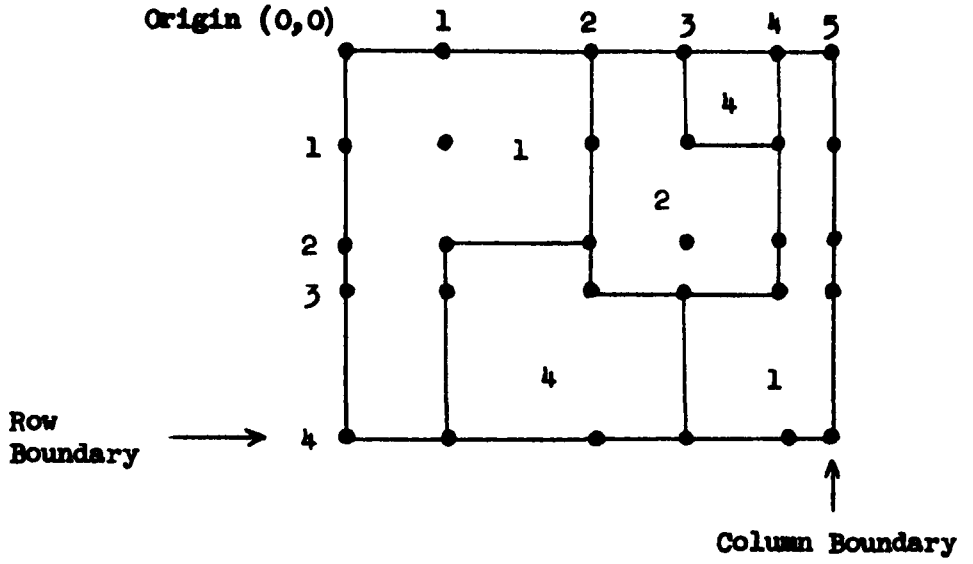


Figure 3.4.1 Rectangular Basic Figure

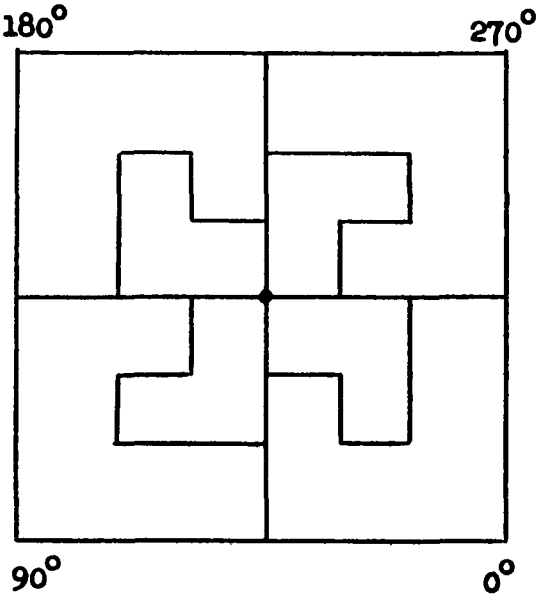


Figure 3.4.2

Initial Figure Rotations

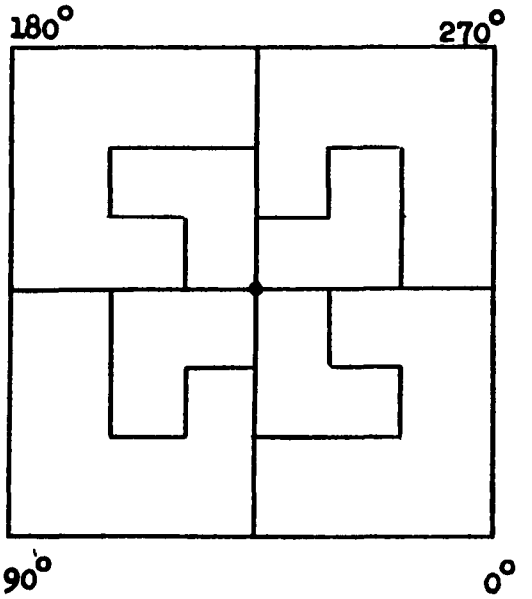


Figure 3.4.3

Initial Figure Rotations
with Reflection

FIGURES 3.4.4 - 3.4.5

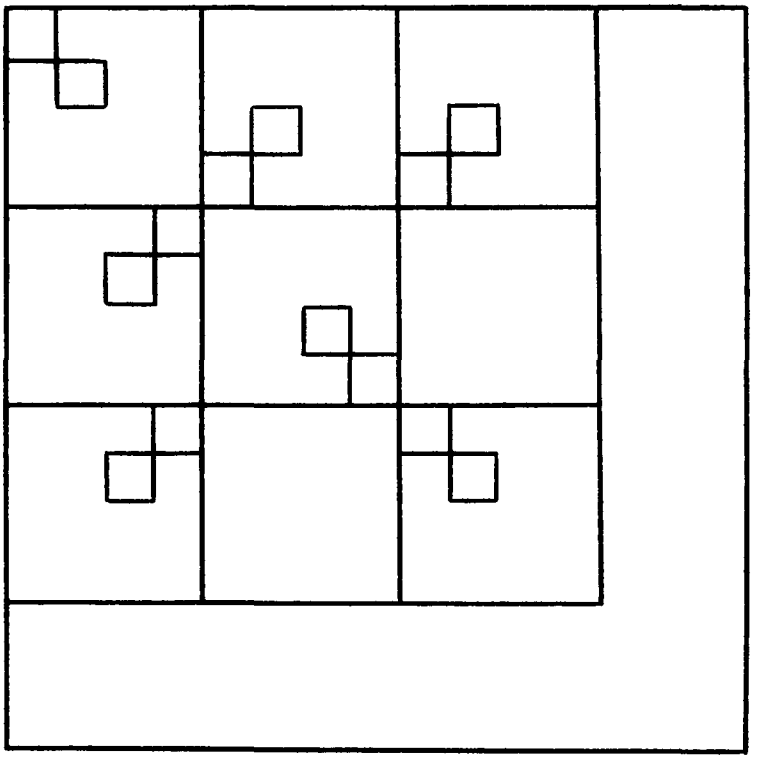


Figure 3.4.4

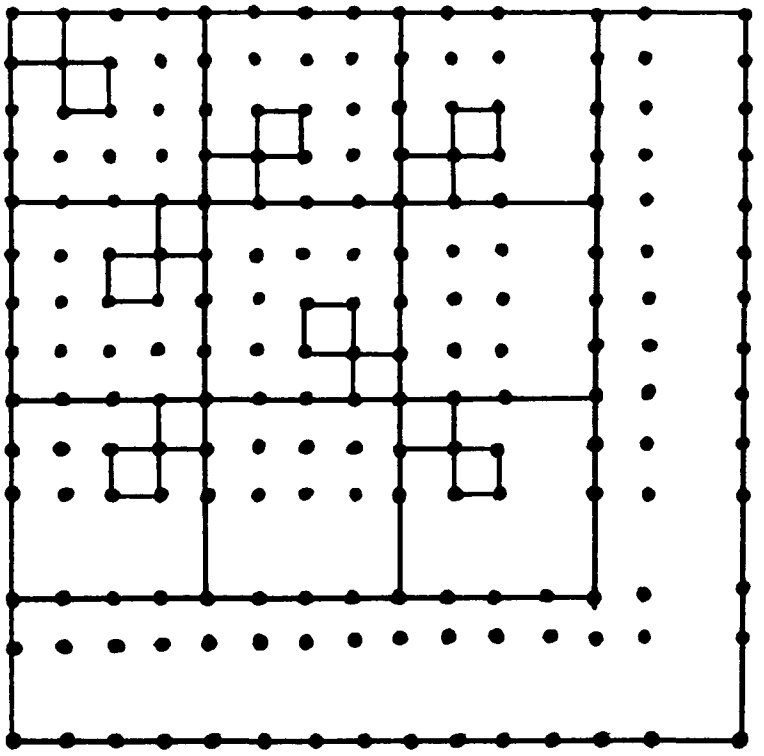


Figure 3.4.5

FIGURES 3.4.6 - 3.4.7

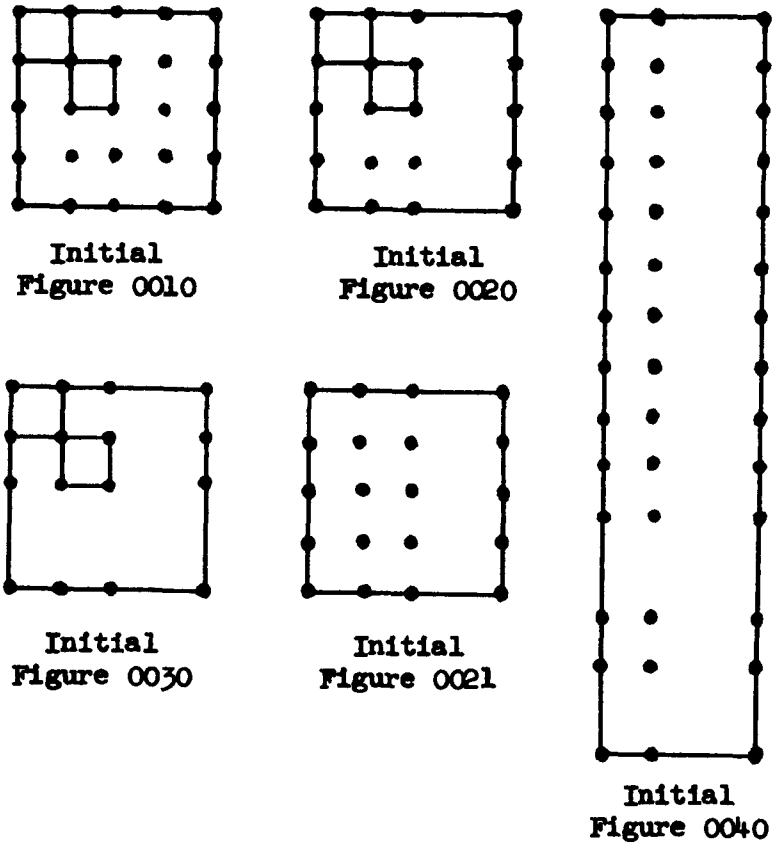
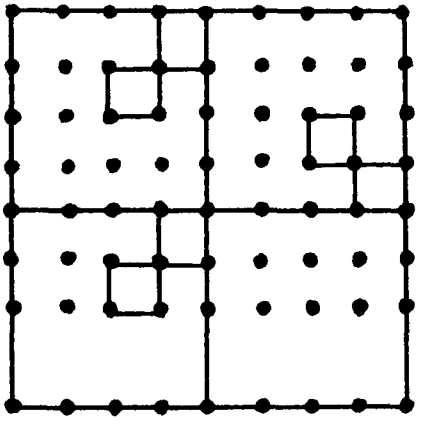


Figure 3.4.6



Initial Super Figure 0010

Figure 3.4.7

3.5. GEOMETRY DESCRIPTION: HEXAGONAL GEOMETRY

In the description of a hexagonal geometry, the elementary building blocks are called basic figures. Special basic figures which allow a more general mesh bending are called transition figures. Basic figures and transition figures may optionally be grouped in a spatial arrangement called a super figure to form a larger building unit. All of these substructures are then used to describe the region of solution through a process of both buildup and overlay called the final figure overlay. The purpose of the description is to define the spatial position of all mesh points in the solution space and to attach a set of identifiers to all mesh elements. The region of solution to be constructed is a 120-degree chevron. A detailed description of this process follows.

BASIC FIGURES

The fundamental entities of a mesh description are basic figures. These building blocks usually correspond to some substructures in the solution grid. Basic figures in hexagonal geometry are 60-degree parallelograms oriented in the fourth quadrant as in Figure 3.5.1. A basic figure is descibed by giving:

(1) A mesh description.
(2) A planar region overlay.
(3) Channel and track identifiers (if fine blocking).

The mesh description consists of giving the size (number of rows and columns) of the basic figure, and the mesh spacings along both row 0 and column 0. This completely defines the number and spatial orientation of all points in the parallelogram.

The PLANAR REGION OVERLAY consists of a series of overlay sets which assign planar region numbers (identifiers) to each of the mesh elements in the basic figure. Each overlay set superimposes a particular planar region identifier on a subset of the basic figure bounded by a parallelogram. The sets are processed sequentially, and any set may overlay areas of the mesh specified in previous sets. Every mesh element (parallelogram) must be included in at least one of the overlay sets, and, for each mesh parallelogram the last overlay set in which it is included determines its planar region identification number. Planar region numbers may vary from 1 to 999 and need not be sequential.

As an example, Figure 3.5.1 may be described by overlaying planar region 1 on the entire mesh; region 4 between columns 1 and 3, rows 2 and 4; region 2 between columns 2 and 4, rows 0 and 3; and region 4 between columns 3 and 4, rows 0 and 1.

When the fine blocking option (see Section 3.9) has been selected, CHANNEL and TRACK identifiers are also assigned to the mesh elements in the basic figure. Channels and tracks are bounded by the straight line rows or columns of the basic figure. Normally channels are bounded by columns and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in a basic figure would have the same channel number, and all mesh elements between two consecutive rows would have the same track number. This correspondence may optionally be reversed for any basic figure. The effect of this definition is to assign a channel and track identifier to each mesh parallelogram in the basic figure. Channel numbers may assume values from 1 to 999,999,999, and track numbers may vary from 1 to 127. Neither need be sequential.

Basic figures are numbered sequentially from 1 to 999.

Auxiliary figures

An auxiliary figure is produced by modifying the planar region overlay and/or the channel and track identifiers (if fine blocking) of a basic figure. If two or more basic figures have the same mesh description (same size and mesh spacings) but some different planar region, channel, or track identifiers, the use of auxiliary figures makes it unnecessary to repeat the mesh interval specification. For changing planar regions, only changes to the planar region overlay must be specified in the form of additional overlay sets. If the

channel or track identifiers of some of the mesh columns or rows are different, only the changes need be described. The auxiliary figures for a particular basic figure are numbered sequentially from 0 to 9, with the basic figure itself being assigned auxiliary figure number 0. The additional planar region overlay sets or changes in channel and track identifiers for an auxiliary figure modify only the basic figure data (auxiliary figure 0).

Initial figures

A basic figure number followed by an auxiliary figure number identifies an initial figure. Thus initial figure numbers range from 10 to 9999. An initial figure number of 246 would identify auxiliary figure 6 of basic figure 24.

Transition figures

A special type of basic figure in hexagonal geometry is called a transition figure. Although there is a limited capability for bending mesh lines in regular hexagonal geometry using regular basic figures, transition figures introduce an extended capability for bending mesh lines. There are two differences between a normal basic figure as described above and a transition figure. First, the column boundary of a transition figure must be equal to 1. Secondly, although its columns are parallel and its outside boundary is a 60-degree parallelogram, its internal rows need not be parallel. That is, mesh lines passing through a transition figure may be bent. A typical transition figure is shown in figure 3.5.2. The mesh description consists of specifying the column mesh spacing, and the row spacings for both column 0 and column 1. As in the case of a normal basic figure, the mesh elements of a transition figure are labelled via a planar region overlay. A transition figure may have auxiliary figures, and an initial figure number consists of the transition figure number followed by the auxiliary figure number. Transition figures are numbered in the sequence with normal basic figures.

FINAL FIGURE OVERLAY

The hexagonal region of solution (chevron) is defined by the final figure overlay. This consists of a series of overlay sets each of which superimposes a particular initial figure or initial super figure (which will be described later) on some portion of the region of solution. Initially the region of solution may be considered to be a completely flexible lattice of points defined by its row boundary and column boundary. The point positions and mesh identifiers will be defined by positioning the initial figures on it.

An initial figure is positioned by giving the column and row of the solution region at which the origin of the initial figure is to be placed, and the angle through which it is to be clockwise rotated. The angle must be a multiple of 60 degrees. The initial figure may also be reflected, implying an interchange of rows and columns. The rotational orientations of a hexagonal initial figure are shown in Figure 3.5.3, and the reflections in Figure 3.5.4. The origins are at the center.

As in the planar region overlay, the final figure overlay is sequential and may overlay areas of the solution region which have been specified previously. One exception to this is that transition figures may not be overlaid, although they may overlay normal initial figures. Normal initial figures (non-transition figures) may extend beyond the boundaries of the region of solution in any direction. Transition figures may extend beyond the boundaries of the region of solution only across the top or bottom row of the chevron and not across column 0 or column boundary. Any portion of the initial figure extending outside the solution space boundaries is ignored. The origins of initial figures may actually be positioned outside the region of solution, providing the conditions concerning transition figures are observed.

A FINAL FIGURE number is associated with each initial figure overlay of the region of solution. This identifier is assigned to each mesh element which is overlaid by the initial figure. This permits different overlays using the same initial figures to be distinguishable, which is important for gross inventory block determination (see Section 3.9) and for editing (see Section 5.2). Final figure numbers range from 1 to 999, and need not be sequential or distinct.

In problems in which the fine blocking option has been selected each mesh element in the initial figure has also been given a channel and a track identification number. If the planar region number of a mesh element has been previously designated as a region to be fine blocked, these identifiers are also assigned to the mesh element in the solution region which it superimposes (otherwise, channel and track numbers of 0 are assigned). Further, a CHANNEL BIAS may be assigned to each initial figure overlaid on the region of solution. The channel identifier assigned to the solution mesh is the sum of the channel number in the initial figure and the channel bias, permitting different overlays using the same initial figure to produce different channel identifiers. This is important for determination of a unique set of fine blocks (see Section 3.9).

Each final figure OVERLAY SET thus consists of the following information: initial figure used, final figure number assigned, column and row at which to position origin of the initial figure, rotation indicator, reflection indicator, and, optionally, channel bias.

Final figure overlay sets are processed sequentially. All of the mesh elements (and consequently all of the mesh points) in the region of solution must have been overlaid by at least one initial figure. The fundamental restriction in the final figure overlay is that the mesh in the initial figures must be chosen such that the rows and columns in adjoining initial figures meet at common boundary points. This need not be true at every stage of the overlay, but only when the overlay is complete.

There are two mechanisms for bending mesh lines in hexagonal geometry. Because of the ability to lay down an initial figure across the diagonal of a mesh parallelogram, a limited line bending may be obtained using normal initial figures (non-transition figures). This is in general produced when a non-constant mesh initial figure is overlaid on the chevron with a 60-degree rotation relative to the half of the chevron on which it is superimposed. An expanded capablity for mesh line bending is provided by transition figures. Although only the rows of a transition figure may bend, laying down a properly rotated transition figure will produce bending of the columns in the region of solution. This provides a method of adjusting mesh lines in any direction to achieve finer detail in any given area of the mesh. Transition figures also make possible exact representations of localized rectangular sections within a hexagonal region of solution. Internal interfaces which are inherently non-hexagonal may also be represented using transition figures.

Upon completion of the overlay process each mesh element of the solution space will be assigned two identifiers in all problems, namely a final figure and a planar region. Further, in fine blocked problems those planar regions defined as fine block regions will also be assigned a channel and a track identifier.

SUPER FIGURES

When the same or a similar pattern of initial figures is repeated in several sections of the region of solution, the overlay procedure may be facilitated through use of super figures. A super figure is a grouping of initial figures in a lattice of fixed size, which may be considered a subset of the region of solution. A super figure is described by giving:

(1) A size description (row boundary and column boundary).
(2) A super figure overlay.

The size description (number of columns and rows) defines a lattice on which initial figures are overlaid. The SUPER FIGURE OVERLAY consists of overlay sets, each of which superimposes a particular initial figure on the super figure. The initial figure is positioned by giving the row and column of

the super figure at which the initial figure origin is to be placed. The initial figure may be rotated and/or reflected in the frame of reference of the super figure. The super figure overlay is sequential and may overlay areas of the super figure which have been previously specified (recall, however, transition figures may not be overlaid). Normal initial figures (non-transition figures) may extend beyond super figure boundaries; transition figure may not. Any portion of an initial figure which is outside the super figure boundaries is ignored, and initial figure origins may be located outside these boundaries.

Super figures are numbered sequentially from 1 to 999.

Auxiliary Super Figures

An auxiliary super figure is obtained by modifying the super figure overlay of a super figure. If two or more such substructures have the same column boundary and row boundary but differ somewhat in overlay sets, the use of auxiliary super figures makes it unnecessary to repeat the size specification and any redundant super figure overlay sets. As with basic figures, the auxiliary figures for a particular super figure are numbered sequentially from 1 to 9, and the super figure itself is assigned auxiliary figure number 0. Additional super figure overlay sets for other auxiliary super figures modify only the overlay sets for auxiliary super figure number 0.

Initial Super Figures

An initial super figure is identified by a super figure number followed by an auxiliary super figure number, and thus initial super figure numbers range from 10 to 9999. An initial super figure is superimposed on the region of solution via the final figure overlay. A single final figure number is assigned to the initial super figure when it is laid down. As in the case of a normal initial figure, the initial super figure is positioned by giving the row and column of the solution region at which the origin is to be placed. Super figures may also be rotated and/or reflected. In laying down an initial super figure on the region of solution, the super figure may overlay previously specified sections; it may be later overlaid by an initial figure or another initial super figure; it may extend outside the region of solution (provided previously stated rules concerning transition figures in this regard are not violated); and it may have its origin outside the region of solution.

Portions of a super figure may remain unspecified when the super figure overlay is complete. Such sections are called TRANSPARENT REGIONS. When a super figure with such areas is laid on the region of solution, the transparency produces no change in that section of the solution grid over which it is superimposed. The use of transparent regions in super figures thus allows figures with an outer boundary of other than a parallelogram to be superimposed on the region of solution. Any figure whose boundaries lie along the three hexagonal coordinate directions may be constructed via a super figure.

HEXAGONAL GEOMETRY EXAMPLE

Suppose the geometry shown in Figure 3.5.5 is to be constructed. This structure may represent one-third of a symmetric array of similar structures, with the solution to the larger problem actually being obtained by applying appropriate boundary conditions. Mesh points and dotted lines to facilitate the overlay procedure have been added in Figure 3.5.6, and the initial figures to be used in constructing the geometry are shown in Figure 3.5.7. Note that initial figure 0021 is an auxiliary figure of 0020. The rows and columns in adjoining figures all meet at common boundary points. As a result, some figures contain more rows and columns than are required to describe their interfaces. In order to locate the initial figure origins, it is convenient to construct a unitized mesh as is Figure 3.5.9 in which all mesh intervals have been set to unity. This figure clearly displays the rows and columns of the chevron which are obscured in Figure 3.5.6 because of variable mesh.

The geometry may be constructed in steps by the following overlay:

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0010	6,0	60	Yes
0010	10,0	0	No
0020	12,0	120	No
0040	4,3	180	No
0040	15,-3	60	No
0030	4,0	0	Yes
0030	12,0	60	No
0040	4,6	180	No
0040	15,0	60	No
0031	4,3	0	Yes
0031	12,3	60	No

As a further example, an alternate method of laying down this same mesh is shown below. First, super figure 001 shown in Figure 3.5.8 is constructed by the following process:

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0040	0,0	0	No
0040	6,3	180	Yes
0030	0,3	0	No
0031	3,3	0	No

and then the following final figure overlay (where negative initial figure numbers refer to initial super figures):

Initial Figure	Origin (column,row)	Rotated (degrees)	Reflected
0010	6,0	60	Yes
0010	10,0	0	No
0020	12,0	120	No
-0010	15,-3	60	No
-0010	1,-3	0	Yes

FIGURES 3.5.1 - 3.5.2

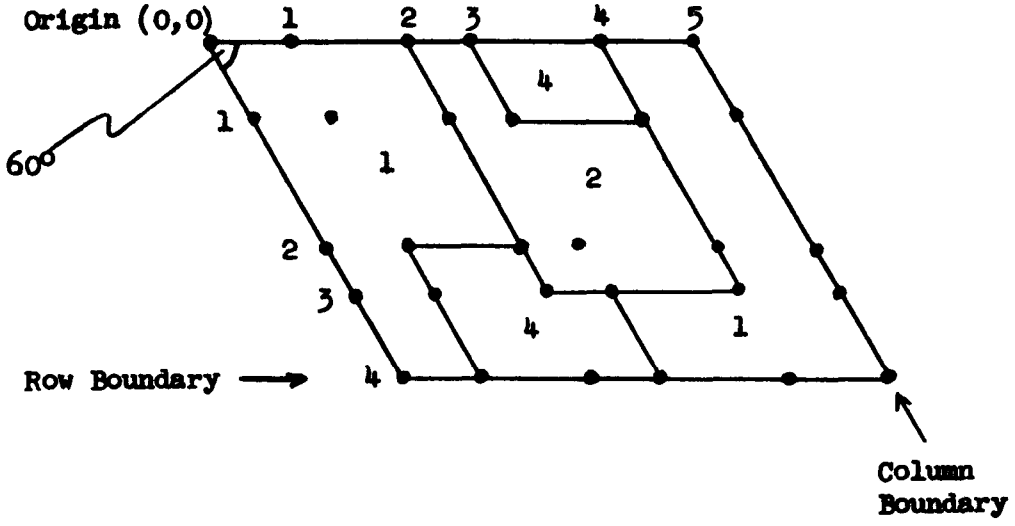


Figure 3.5.1 Hexagonal Basic Figure

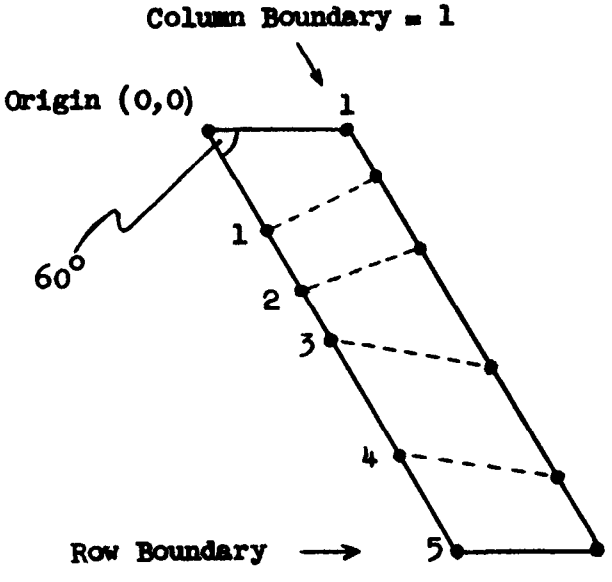


Figure 3.5.2 Transition Figure

FIGURES 3.5.3 - 3.5.4

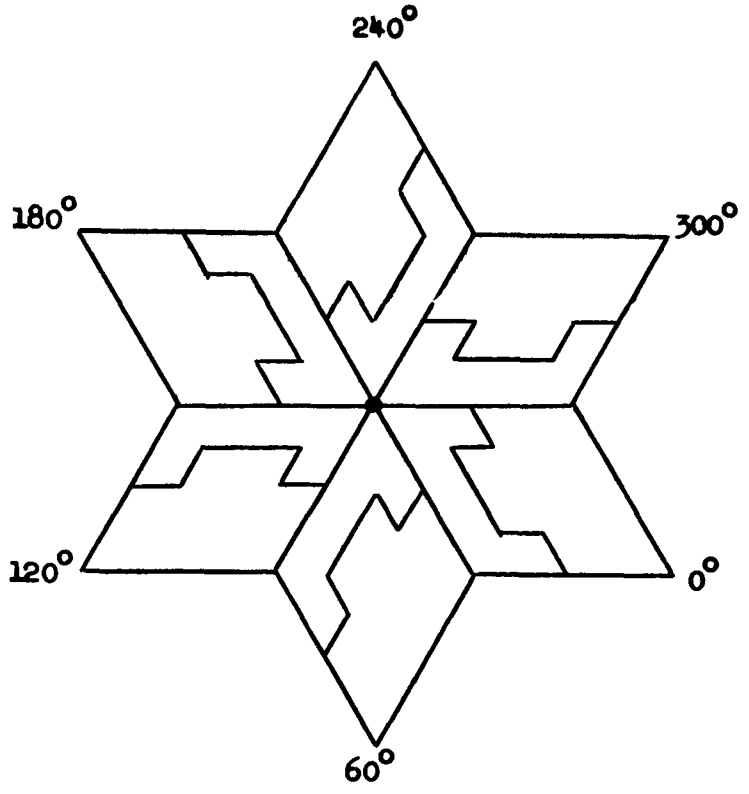


Figure 3.5.3 Initial Figure Rotations

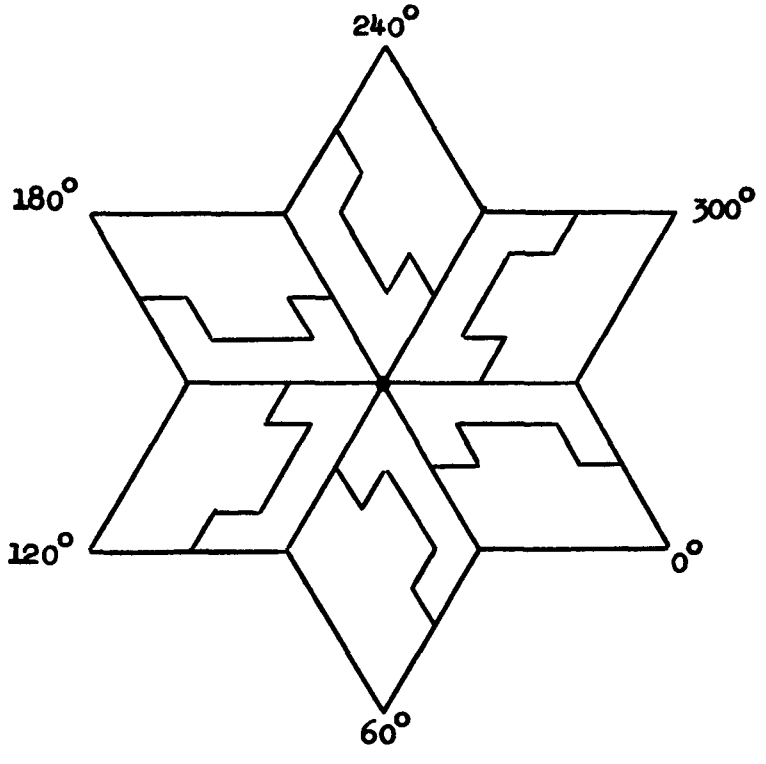


Figure 3.5.4 Initial Figure Rotations with Reflection

FIGURES 3.5.5 - 3.5.6

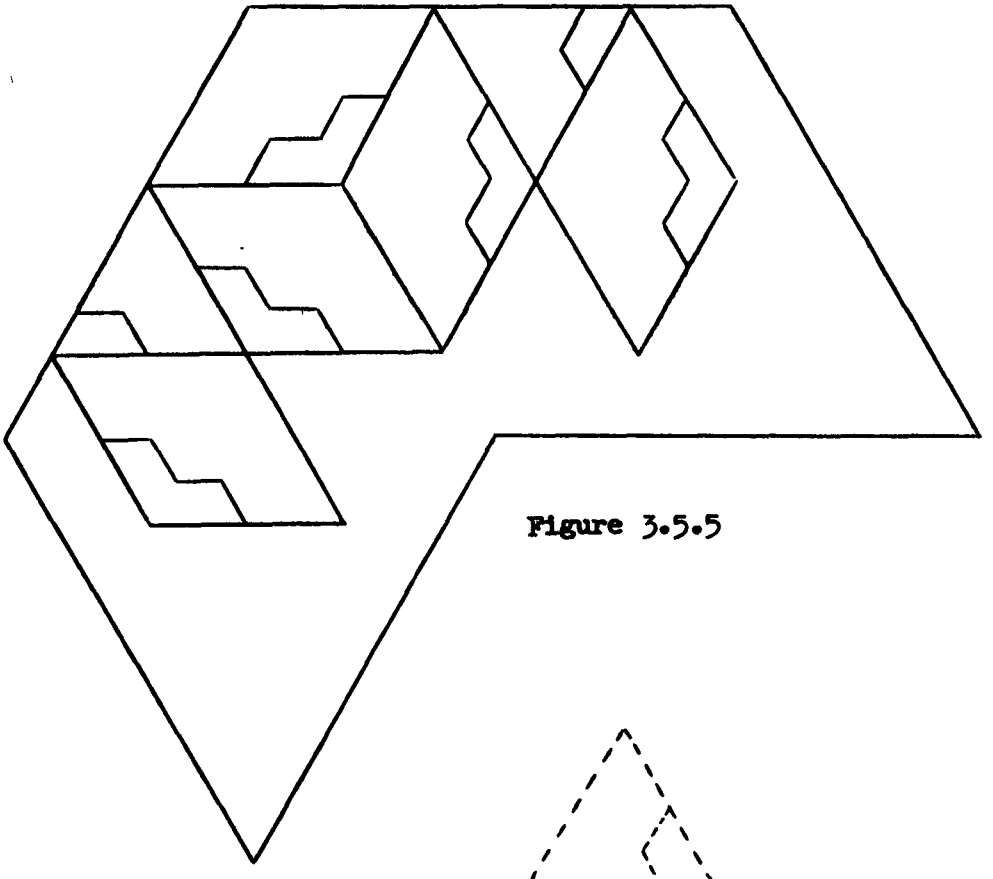


Figure 3.5.5

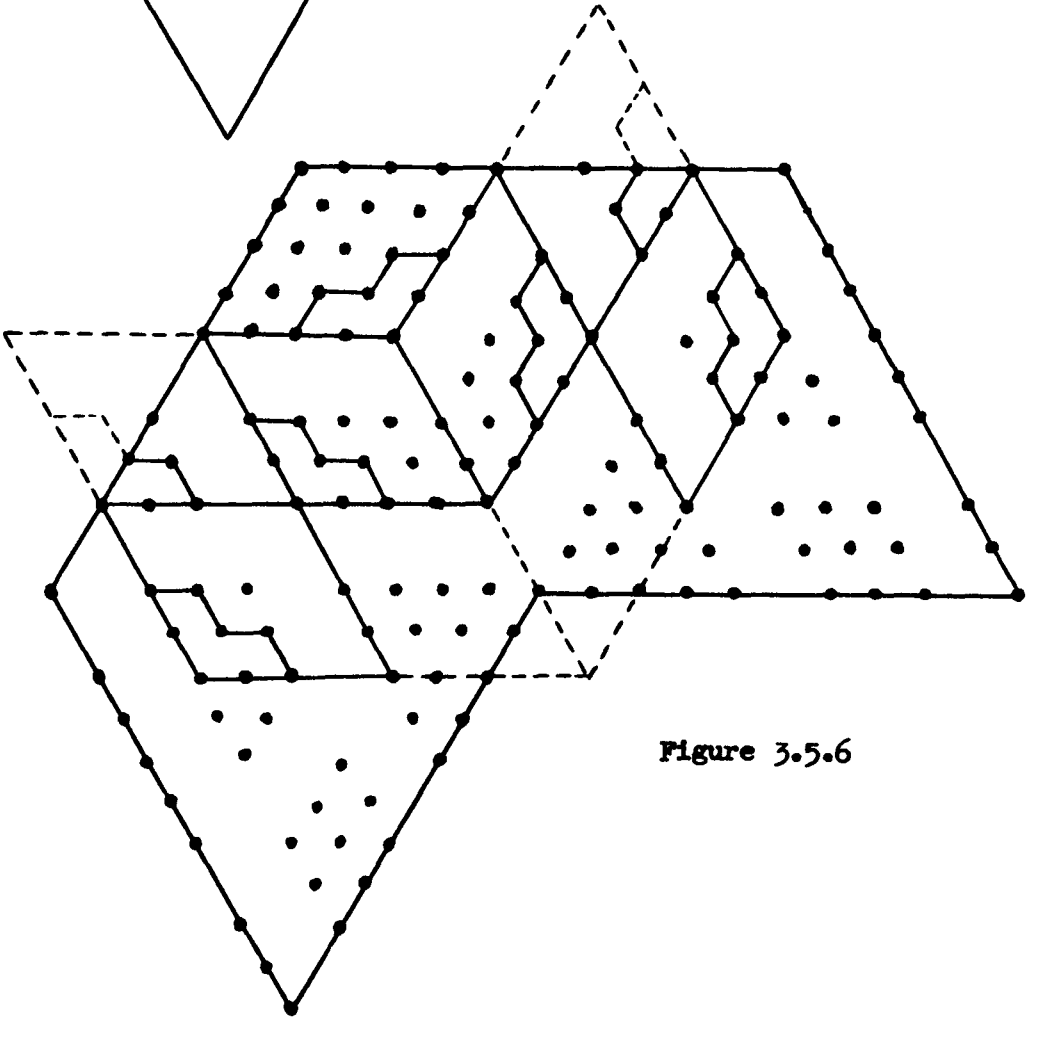


Figure 3.5.6

FIGURES 3.5.7 - 3.5.8

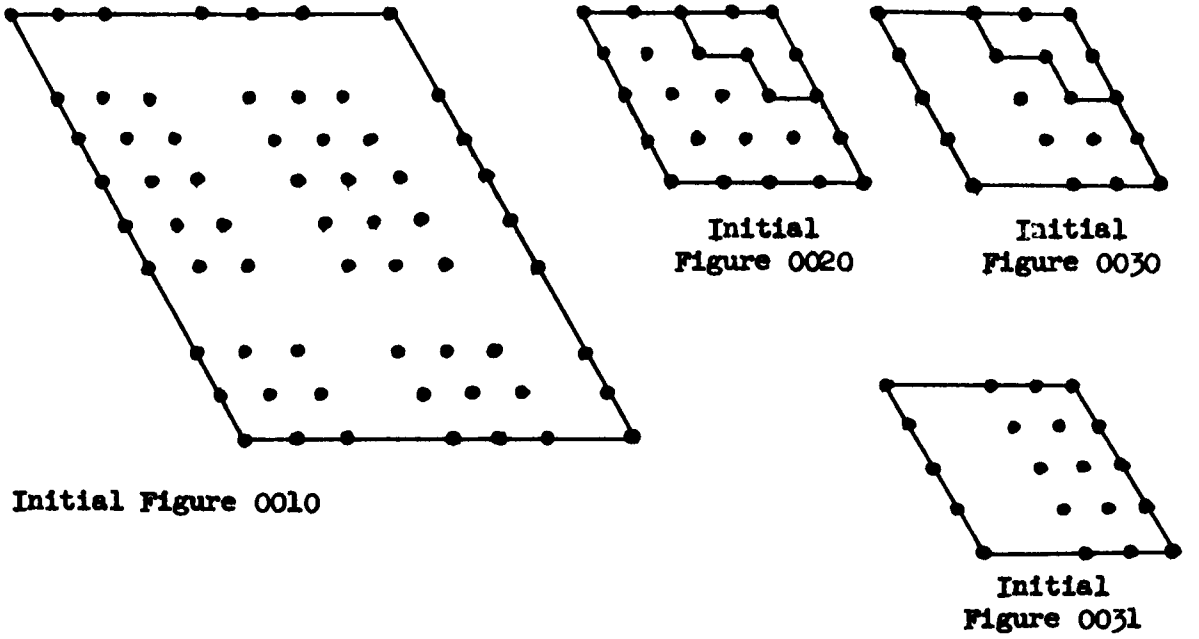
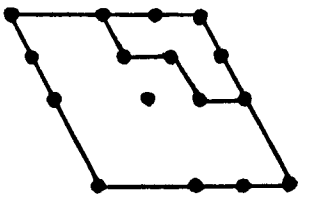


Figure 3.5.7



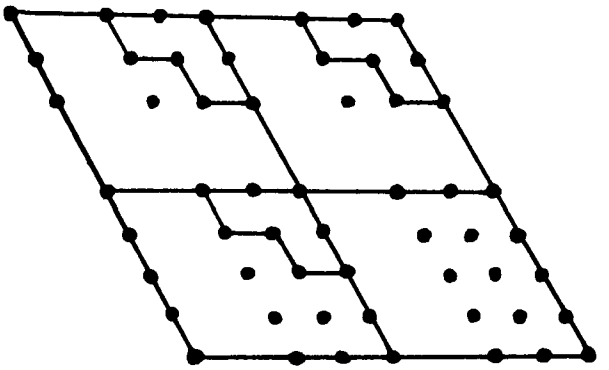


Figure 3.5.8

FIGURE 3.5.9

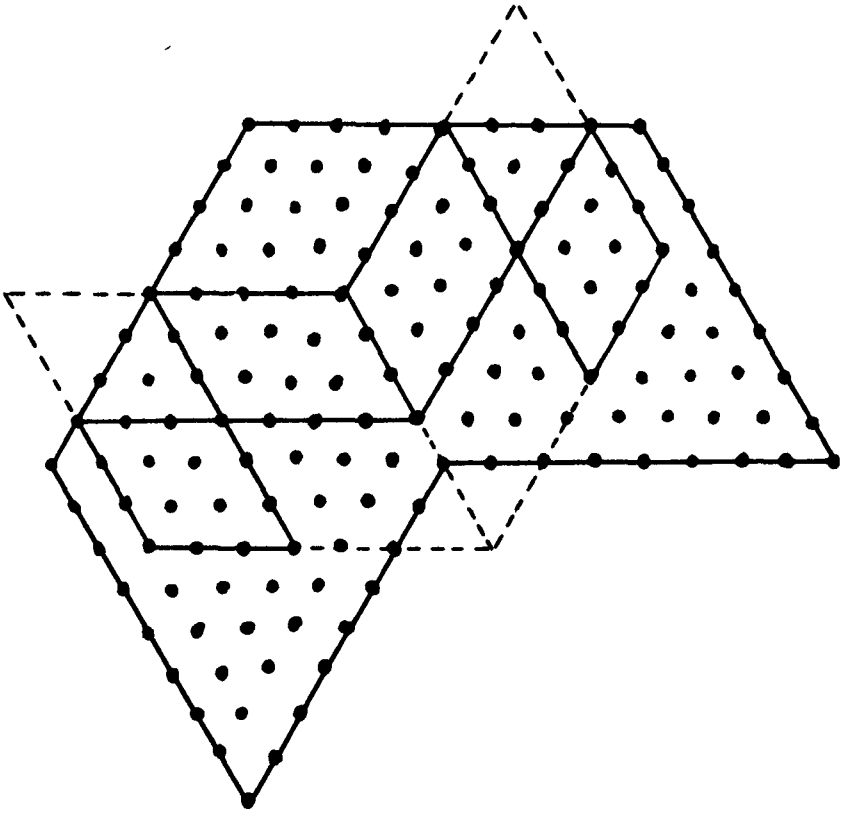


Figure 3.5.9

3.6. GEOMETRY DESCRIPTION: QUADRILATERAL GEOMETRY

In the description of a quadrilateral geometry, the elementary building blocks are called basic figures. Other building units called file figures may be obtained from input File Manager figure files. Both of these sets of figures are used to construct compound figures. Compound figures are created sequentially; as each is produced it may be used as a building unit in succeeding compound figures. One of the compound figures or file figures is defined to be the region of solution. The purpose of the description is to define the spatial position of all mesh points in the solution space and to attach a set of identifiers to all mesh elements. The region of solution to be constructed is a general quadrilateral lattice. A detailed description of this process follows.

BASIC FIGURES

The fundamental entities of a mesh description are basic figures. These building blocks usually correspond to some substructure in the solution grid. Basic figures in quadrilateral geometry are parallelograms oriented in the fourth quadrant as in Figure 3.6.1. A basic figure is identified by a unique alphanumeric label.

A basic figure is descibed by giving:

(1) A unique label.
(2) An internal angle.
(3) A mesh description.
(4) A planar region overlay.
(5) Channel and track indentifiers (if fine blocking).

The internal angle is the interior angle at the origin of the basic figure, and thus the angle of intersection between the parallel rows and columns of the figure. The internal angle must be greater than 0 degrees and less than 180 degrees.

The mesh description consists of giving the size (number of rows and columns) of the basic figure, and the mesh spacings along both row 0 and column 0. This completely defines the number and spatial orientation of all points in the parallelogram.

The PLANAR REGION OVERLAY consists of a series of overlay sets which assign planar region numbers (identifiers) to each of the parallelogram mesh elements in the basic figure. Each overlay set superimposes a particular planar region identifier on a parallelogram subset of the basic figure. The sets are processed sequentially, and any set may overlay areas of the mesh specified in previous sets. For each mesh parallelogram, the last overlay set in which it is included determines its planar region identification number. Every mesh parallelogram need not be assigned a planar region number; i.e., the planar region overlay need not cover the entire basic figure. The elements not assigned a planar region identifier are called TRANSPARENCIES. When a basic figure with such areas is used in the overlaying process descibed below, the transparency produces no change in the part of the grid it superimposes. Planar region numbers may vary from 1 to 999 and need not be sequential.

As an example, the first basic figure in Figure 3.6.1 may be described by overlaying planar region 4 between columns 0 and 5, rows 3 and 4; region 1 between columns 1 and 4, rows 0 and 4; region 2 between columns 0 and 2, rows 0 and 3; region 4 between columns 3 and 5, rows 1 and 3; and region 2 between columns 4 and 5, rows 0 and 1. The second basic figure in Figure 3.6.1 would be described if the second overlay set instead laid down region 1 between columns 1 and 4, rows 3 and 4.

When the fine blocking option (see Section 3.9) has been selected, CHANNEL and TRACK identifiers are also assigned to the non-transparent mesh elements in the basic figure. Channels and tracks are bounded by the straight line rows or columns of the basic figure. Normally channels are bounded by columns and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in a basic figure would have the same channel number, and all mesh

elements between two consecutive rows would have the same track number. This correspondence may optionally be reversed for any basic figure. The effect of this definition is to assign a channel and track identifier to each non-transparent mesh parallelogram in the basic figure. Channel numbers may assume values from 1 to 999,999,999, and track numbers may vary from 1 to 127. Neither need be sequential.

Auxiliary Figures

An auxiliary figure is produced by modifying the planar region overlay and/or the channel and track identifiers (if fine blocking) of a basic figure. If two or more basic figures have the same internal angle and same mesh description (same size and mesh spacings) but some different planar region, channel, or track identifiers, the use of auxiliary figures makes it unnecessary to repeat the mesh and angle specifications. For changing planar regions, only modifications to the planar region overlay need be specified in the form of additional overlay sets. If the channel or track identifiers of some of the mesh columns or rows are different, only the changes need be described. Up to nine auxiliary figures may be defined from each basic figure. Each auxiliary figure is identified by a unique alphanumeric label. The additional planar region overlay sets or changes in channel and track identifiers for an auxiliary figure modify only the data of the original basic figure.

FILE FIGURES

A file figure is a substructure whose completed description is obtained from an input File Manager figure file, as opposed to being described by a building description. These figures may have been generated and saved by a previous problem, or may have been produced by an external geometry generator. A file figure is a lattice of M columns by N rows, some or all of whose mesh elements have been assigned identifiers and some or all of whose mesh points have been spatially defined. An example of the generality attainable using file figures is shown in Figure 3.6.2 which was created by an external geometry generator. Similar to a basic figure, a file figure may contain transparencies. Any figures generated in a problem (basic, auxiliary, and compound figures) may be saved in an output File Manager figure file for subsequent use. File figures are used along with basic figures and auxiliary figures in the construction of compound figures.

It is important to note that no checks are made on the file figures at the time they are input (the file, of course, must be in the proper format). That is, no checks are made as to the legality of the mesh description given by the figures contained in the file. Any violations of the rules for a proper lattice will be flagged only if they result in violations in the final region of solution.

File figures are identified by alphanumeric label. Any file figure contained in an input File Manager figure file for which a building description having the same label exists will be reconstructed using the building description.

INITIAL FIGURES

Initial figure is a collective term referring to the set of all figures which have been defined at any stage in the geometry building process and thus are eligible to be used as building blocks for further construction. Basic figures, auxiliary figures, and file figures are all initial figures. Compound figures, which are generated sequentially, become initial figures in the order in which they are generated and thus become available for use. All initial figures are identified by unique alphanumeric labels.

COMPOUND FIGURES

A compound figure is constructed with initial figures in a lattice containing a prescribed number of rows and columns. Compound figures in quadrilateral geometry are oriented in the fourth quadrant (as in Figure 3.6.3), columns numbered from left to right and rows increasing from top to bottom. Compound figures are generated SEQUENTIALLY using available building units, including basic figures, auxiliary figures, file figures, and previously generated compound figures. Compound figures are identified using unique alphanumeric labels.

A compound figure is described by giving:

(1) A unique label.
(2) A size description (row boundary and column boundary).
(3) An internal angle.
(4) A compound figure overlay.

The size description (number of rows and columns) defines a lattice on which the initial figures are overlaid. Initially this figure may be considered to be a completely flexible lattice of points in M columns and N rows. The point positions and mesh identifiers will be defined by superimposing the initial figures on the compound figure.

The INTERNAL ANGLE of the compound figure is used as the angle of intersection of a coordinate system (see Figure 3.6.3) which will be used to spatially position the initial figure when building the compound figure. The internal angle also serves as a reference for rotating initial figures before positioning them on the lattice, as will be described below. It will be useful to think of this angle as the interior angle of the starting grid of the compound figure (i.e. the angle of intersection between the columns and rows in the original flexible lattice). However, note that since the spatial positions of all points in this initial grid are completely free to move, the angle might in fact appear nowhere in the completed compound figure.

The COMPOUND FIGURE OVERLAY defines the building description by which a compound figure is constructed. This consists of a series of OVERLAY SETS, each of which superimposes a particular initial figure on the compound figure lattice. The initial figure fixes the spatial positions (coordinates) of the points which it overlays and assigns identifiers to the mesh elements which it overlays.

The initial figure is positioned in the lattice by giving:

(1) The point number (I,J) in the lattice to which the origin of the initial figure is to be attached .

(2) A prescription in the form of a pair of indices (Dx,Dy) that determines which point in the compound figure lattice is overlaid by each point in the initial figure.

(3) The exact spatial coordinates (Xo,Yo) of the origin of the initial figure.

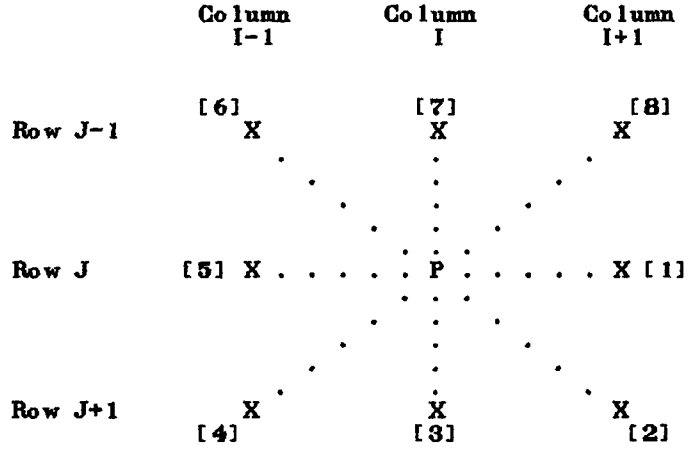
(4) The secondary rotation angle (R2) of the initial figure.

There are two processes involved in superimposing an initial figure on the grid of a compound figure. First, items (1) and (2) above are primarily concerned with determining the set of points in the compound figure which are to be overlaid by the points in the initial figure. Second, items (3) and (4) above are concerned with determining the exact spatial position of the initial figure in the compound figure grid.

The origin of the initial figure is attached to a point in the compound figure by giving the column number (I) and row number (J) of the point in the compound figure lattice on which it is to be overlaid.

The one-to-one correspondence between (a) the remaining points in the initial figure, and (b) the points in the lattice of the compound figure which each is to overlay, is prescribed by the DIRECTIONAL INDICES. For each initial figure two indices are specified, a row directional index (Dx) and a column directional index (Dy). The row directional index represents the direction in the free lattice in which the rows of the initial figure will be superimposed on the compound figure lattice (and thus the set of points in the compound figure lattice which a row will overlay). Similarly, the column directional index defines the orientation in the free lattice of the columns of the initial figure by specifying the direction of the points in the compound figure which they will overlay.

A directional index assumes an integer value from 1 to 8, each of which defines a directed line extending from any point in the compound figure lattice to a particular one of its 8 neighbors. For any point (I,J) in the fourth quadrant lattice of the compound figure, the values of the directional indices are defined as follows:



P = Point (I,J)
X = 8 Neighboring points
[ ] = Directional Indices (relative to P)

For example, assume an initial figure has its origin attached to (I,J); i.e., (0,0) in the initial figure overlays (I,J) in the compound figure lattice. Assume also that the initial figure is laid down with Dx=1 and Dy=3. Referring to the above values for the directional indices, a row directional index of 1 would specify that point (1,0) in the initial figure would overlay point (I+1,J); initial figure point (2,0) overlays point (I+2,J), and so on. Additionally, the column directional index of 3 specifies that initial figure point (0,1) overlays compound figure point (I,J+1); initial figure point (0,2) overlays compound figure point (I,J+2); initial figure point (2,3) overlays compound figure point (I+2,J+3), etc.

Further examples of directional indices are given in Figure 3.6.4. The points in Figure 3.6.4 represent the flexible lattice of a compound figure of 9 columns and 15 rows. The results of superimposing an initial figure with 2 columns and 3 rows using various combinations of directional indices are illustrated as follows:

Laydown	Origin (column,row)	Dx	Dy
A	1,1	1	3
B	4,1	1	2
C	2,8	1	7
D	8,5	3	5
E	4,11	7	4
F	9,11	4	5

Note that Figure 3.6.4 is a UNITIZED MESH example indicating only the sets of points in the compound figure which would be overlaid in each case and not the resulting spatial positions of these points. The grid of the 2 by 3 initial figure which is superimposed will remain rigid while overlaying the particular set of points specified by the directional indices; the surrounding mesh lines in the compound figure will automatically be changed to accomodate the new positions of the points which are overlaid. Thus the same initial figure could be used in all 6 of the laydowns above. In each case, however, varying amounts of distortion in the surrounding mesh lines of the compound figure would result.

Thus the row and column directional indices attach each point in the initial figure to a point in the compound figure. Certain sets of directional indices can be seen to correspond variously to "rotations" or "reflections" (interchanging rows and columns) in the frame of reference of the compound figure lattice. For example, if a 90-degree initial figure is superimposed on a 90-degree compound figure using a row directional index of 5 and a column directional index of 7, this would correspond to rotating the initial figure 180 degrees clockwise about its origin before laying it down. A row directional index of 5 and a column directional index of 3 would correspond to an initial figure rotated 90 degrees clockwise and reflected .

Allowable combinations are illustrated in the following decision table (x indicating a legal combination):

		Dy							
		1	2	3	4	5	6	7	8
Dx	1	-	x	x	x	-	x	x	x
	2	x	-	x	-	x	-	x	-
	3	x	x	-	x	x	x	-	x
	4	x	-	x	-	x	-	x	-
	5	-	x	x	x	-	x	x	x
	6	x	-	x	-	x	-	x	-
	7	x	x	-	x	x	x	-	x
	8	x	-	x	-	x	-	x	-

Table 3.6.1

It should be noted that the following combinations of row and column directional indices are ILLEGAL:

(1) Dx = Dy.
(2) Dx = Dy+4 or Dy = Dx+4.
(3) Dx and Dy both even numbers.

The first two of these illegal conditions describe the degenerate cases where the row and column directional indices are equal (on the same line) or differ by 4 (opposite directions but colinear). The third illegal condition (both directional indices even) results in correspondences between the initial figure points and the overlaid compound figure points which are not one-to-one. All other combinations are permissible.

Having thus specified the set of points to be overlaid, it remains to orient the entire initial figure in space. First, the exact spatial coordinates (Xo,Yo) of the origin of the initial figure must be specified. This point

location is described in a coordinate system (as in Figure 3.6.2) whose axes intersect at an angle equal to the defined internal angle of the compound figure, x values increasing from left to right and y values increasing from top to bottom. Prior to any initial figure being overlaid on the compound figure, the origin (0.0, 0.0) of the coordinate system coincides with the origin (intersection of row 0 and column 0) of the compound figure; the locations of all other mesh points in the compound figure grid are undefined at this time.

If the origin of the initial figure is to be positioned at a point in the compound figure whose spatial coordinates have been defined by a previous initial figure overlay, that existing position may optionally be used to fix the origin of the initial figure. Note, however, that the point must have been defined by a prior laydown at the time it is to be used. One exception is the origin of the compound figure (column 0, row 0) which is defined to have spatial coordinates (0.0, 0.0) before having been overlaid (this may, however, be redefined as the overlay process proceeds).

To complete the spatial definition of the initial figure being superimposed, the initial figure may be rotated in space. The ANGLE OF ROTATION of the initial figure overlay set is defined as the angle of intersection between the x-axis of the compound figure coordinate system and the x-axis in the coordinate system of the initial figure being laid down. The angle of rotation is measured clockwise from the positive x-axis of the compound figure coordinate system to the positive x-axis of the initial figure coordinate system (see Figure 3.6.5).

The angle of rotation (R) of the overlay is determined by:

(1) The row directional index (Dx).
(2) The specified internal angle of the compound figure (A).
(3) The secondary rotation angle of the initial figure (R2).

Specifically, $R = R1(Dx,A) + R2$.

The PRIMARY ROTATION ANGLE (R1) is a function of the row directional index (Dx) and the internal angle of the compound figure (A). Thus the primary rotation angle is IMPLICITLY defined by the specified values of Dx and A according to the following prescription (all angles in degrees):

Dx	R1(Dx,A)
1	0
2	A/2
3	A
4	90 + A/2
5	180
6	180 + A/2
7	180 + A
8	270 + A/2

These primary rotation angles are the angles of lines pointing in each of the eight directions in a unit mesh compound figure with internal angle A. Examples of sets of primary rotation angles are shown in Figure 3.6.6.

The SECONDARY ROTATION ANGLE (R2) provides an optional capability for a fine adjustment of the rotation angle of the initial figure being laid down. When this capability is used, the secondary angle of rotation is EXPLICITLY attached to an initial figure when it is laid down. This angle is capable of describing small arcs of rotation near the primary rotation angle. Possible values of the secondary rotation angle (R2) are related to the values for the primary rotation angle for a given row directional index according to:

$$R2 < [R1(Dx+1,A) - R1(Dx,A)]$$

$$R2 > -[R1(Dx,A) - R1(Dx-1,A)]$$

where $R1(0,A) = R1(8,A)$ and $R1(9,A) = R1(1,A)$. This relationship states that the secondary rotation angle can specify a partial rotation up to the primary rotation angles of each of the two adjacent row directional indices. Note that a positive angle indicates clockwise rotation and a negative angle counterclockwise.

For example, refer to Figure 3.6.6 and assume an initial figure is to be laid down with a row directional index Dx=7 in a 60 degree compound figure. This corresponds to a primary rotation angle of 240 degrees. The secondary rotation angle R2 may turn the initial figure as far clockwise as the next primary angle (300 degrees) or as far counterclockwise as the last primary angle (210 degrees). Therefore, permissible values for R2 in this case lie between (but not including) -30 degrees and +60 degrees.

The secondary rotation angle is optional. In the overlay sets in which the secondary rotation angle is not specified, the angle of rotation of the initial figure is simply equal to the primary rotation angle.

As an alternative to the above description, the angle of rotation may be specified at any stage of the compound figure generation in the context of the initial figures which have already been superimposed on the compound figure. This option may be utilized under the following conditions. Assume that the first two points in row 0 of the initial figure (points (0,0) and (1,0)) are to overlay points (X1,Y1) and (X2,Y2) respectively in the compound figure. Further assume (X1,Y1) and (X2,Y2) are neighboring points in the compound figure and have been defined in the compound figure by a previous overlay at the time this initial figure is being laid down. If the origin of the initial figure is taken as the existing position of the point which it overlays, namely (X1,Y1), then the angle of rotation of the initial figure may be taken to be the angle of the line connecting the points (X1,Y1) and (X2,Y2). This is thus a capability for specifying that a particular initial figure be laid down at an orientation such that its first two columns in the first row "butt against" any two adjacent points in the compound figure which have already been laid down. This is done by specifying the row directional index to be negative, and not specifying either the spatial coordinates of the initial figure origin or the secondary rotation angle. It is emphasized that the points (X1,Y1) and (X2,Y2) must be defined at the time that the initial figure is laid down.

Initial figures may extend beyond the boundaries of the compound figures in any direction; any portion of the initial figure extending outside the compound figure boundary is ignored. The origins of initial figure may actually be positioned outside the compound figure boundary.

In the above process of specifying the spatial position of the initial figure being superimposed on the compound figure, it should be emphasized that the initial figure grid remains a rigid unit while being laid down. That is, the relative locations of the points in the initial figure being laid down remain the same, while the relative locations of the points in the compound figure which are overlaid may change. Note also that the mesh lines connecting points in the compound figure which are overlaid to adjacent points which are not overlaid are automatically bent to accomodate the new point locations.

For example, consider using two initial figures in Figure 3.6.7 labelled STRUCTURE1 and STRUCTURE2 to create a 90-degree compound figure with 8 columns and 7 rows. The grids of these initial figures are illustrated in Figure 3.6.7; assume STRUCTURE1 has a constant mesh of 1.0 along both its rows and columns. First lay down STRUCTURE1 on the compound figure, attach its origin to compound figure point (0,0) and specify Dx=1 and Dy=3. After this laydown, the compound figure has the same constant mesh lattice as STRUCTURE1. Now lay down STRUCTURE2 on the compound figure, attach its origin to compound figure point (6,2) and specify Dx=3 and Dy=5. Since STRUCTURE2 has 2 columns and 3 rows, the set of points in the compound figure which will be overlaid are designated in Figure 3.6.8. If the exact spatial position of the origin of STRUCTURE2 is specified as (5.5,3.0), the mesh of the resulting compound figure is shown in Figure 3.6.9. Additionally, if the secondary angle of rotation is specified as 20 degrees, the resulting compound figure mesh is shown in Figure 3.6.10.

In addition to specifying the correspondence betweeen initial figure points and compound figure points and the spatial positions of these points, the compound figure overlay also assigns identifiers to the mesh elements overlaid. The mesh elements are the triangles produced by dividing the mesh quadrilaterals along one of their diagonals. Thus, in addition to having interfaces along mesh rows or columns (the boundaries of the mesh quadrilaterals), interfaces may exist along either diagonal in a quadrilateral.

Interfaces between mesh elements in the initial figure will naturally become interfaces in the compound figure. Note, however, that the type of interface may change depending on the directional indices, e.g. an interface along a column in an initial figure may become an interface along a diagonal in the compound figure. This need be of concern in only one exceptional instance. When an initial figure containing diagonal interfaces is being laid down with one of its directional indices an even number, illegal triangulation can result. This situation occurs when the direction of the diagonal interface is such that the mesh points on either end of the diagonal are attached to points more than one row or column apart, causing the diagonal to straddle two mesh rows or columns. (All of the diagonal interfaces may not be illegal in this case, only those in the same direction in the initial figure as one of the directional indices used to lay down the initial figure). The compound figure overlay process will provide a warning that this has occured, will zero the mesh identifiers in the overlaid mesh element in the compound figure, and will continue. A later overlay superimposing such mesh elements can result in a valid mesh.

A FINAL FIGURE BIAS is associated with each initial figure overlaid on the compound figure. Each overlaid mesh element is thus assigned a FINAL FIGURE NUMBER which is equal to the sum of the final figure number of the mesh element in the initial figure and the final figure bias attached to the overlay set. (Basic and auxiliary figures have final figure numbers of 0 attached to their mesh elements). This permits different overlays using the same initial figure to be distinguishable, which is important for gross inventory block determination (see Section 3.9) and for editing (see Section 5.2). Final figure biases may have any value, but final figure numbers in the compound figures at any stage of the construction process must have values between 0 and 999. If a final figure number outside these limits is assigned, a warning is issued, all the identifiers of the mesh element in the compound figure are set to zero, and the overlay process continues.

In problems for which the fine blocking option has been selected each mesh element in the initial figure may also have been given a channel and a track identification number. In particular, each mesh element in planar regions designated as fine blocked regions in basic figures will have nonzero channel and track identifiers. The channel and track identifiers in planar regions not to be fine blocked will be zero. These identifiers are assigned to the mesh element in the compound figure which are overlaid. Further, a CHANNEL BIAS may be assigned to each initial figure each time it is overlaid on a compound figure. The channel identifier assigned to the compound figure mesh element is the sum of the nonzero channel number in the initial figure and the channel bias, permitting different overlays using the same initial figure to produce different channel identifiers. This is important for determination of a unique set of fine blocks (see Section 3.9). Channel biases may have any value, but channel numbers in the fine block regions of the compound figures at any stage of construction must be between 1 and 999,999,999. If a channel number in a fine block region outside these limits is assigned, a warning is issued, all identifiers of the mesh element in the compound figure are set to zero, and the overlay process proceeds.

Upon completion of the compound figure overlay process, each mesh element which has been overlaid will be assigned two identifiers in all problems, namely a final figure number and a planar region number. Further, in all fine blocked problems those planar regions designated as fine block regions will also be assigned a channel and a track identifer.

Each OVERLAY SET in the compound figure overlay thus contains the following information: initial figure used, column and row point numbers in the compound figure at which to attach the origin of the initial figure, row and column directional indices, final figure bias, channel bias, spatial coordinates of the origin of the initial figure, and secondary rotation angle. Most of these items are assigned default values when they are not specified; only the initial figure label and the column and row at which to position its origin need always be specified (see Section 10.4). These building descriptions, in the form of overlay sets, may be input from input File Manager mesh figure files.

The compound figure overlay sets are processed sequentially. Portions of the compound figure may remain unspecified when the overlay is complete. As in the case of basic figures, these sections are called transparencies. When any initial figure with such areas is used to overlay a succeeding compound figure,

the transparency produces no change in that section of the grid over which it is superimposed.

SOLUTION FIGURE

One of the constructed compound figures or input file figures is designated to be the SOLUTION FIGURE. The solution figure descibes the two-dimensional region of solution of the problem. The solution figure is checked to assure that a legal lattice with the proper number of columns and rows and having proper identifiers for all mesh elements has been described.

The column boundary and row boundary of the solution figure must be exactly the column and row boundary of the problem. There may be no transparencies; all points must have been assigned spatial locations and all mesh elements must have been assigned identifiers. Each mesh quadrilateral may have at most one diagonal interface. Diagonal interfaces may exist along either diagonal of a quadrilateral except in concave quadrilaterals, where only the diagonal inside the quadrilateral may be an interface.

The set of point locations must describe a grid in which rows do not intersect other rows and columns do not intersect other columns. Mesh quadrilaterals must be described such that none of the sides of the quadrilateral cross or are coincident. Recall that warnings were issued for several violations (illegal triangulation, illegal mesh identifiers, etc.) in the compound figure generation process. Any of these areas will be considered violations if they appear (i.e., are not redefined by a later overlay) in the solution figure.

QUADRILATERAL GEOMETRY EXAMPLES

Three examples of quadrilateral geometry construction are presented below. The first example illustrates the construction of various compound figures. The second example demonstrates the use of quadrilateral geometry for construction of an essentially rectangular grid. The third example constructs a hexagonal compound figure containing local rectangular regions.

Example 1

This example constructs a series of compound figures and illustrates the resulting grids in true mesh. The initial figures to be used are in Figure 3.6.11. Note that these particular initial figures are parallelograms, and therefore could possibly be basic figures, auxiliary figures, compound figures, or file figures. The grids of these figures are illustrated to scale, and the mesh spacings along the columns and rows of the initial figures labelled RECTFIG and HEXFIG are assumed to be 1.0. RECTFIG and INIT90 are 90-degree initial figures, HEXFIG and INIT120 are 120-degree figures, INIT45 is a 45-degree figure, INIT60 is a 60-degree figure, and INIT70 is a 70-degree figure.

The compound figures generated are shown in Figures 3.6.12 - 3.6.14. The grids in these illustrations indicate the final positions of all the mesh points in the compound figure.

COMP1 through COMP11 are 90-degree compound figures with 14 columns and 11 rows. The first overlay on all of these figures is RECTFIG laid down at point (0,0) in the compound figure with (Dx,Dy) = (1,3). Succeeding overlays for each of these compound figures are as follows:

Compound Figure	Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
COMP1	INIT90	6,4	1,3	7.0,4.5	-
COMP2	INIT90	6,4	1,3	7.0,4.5	25.0
COMP3	INIT90	6,4	3,1	7.0,4.5	-
COMP4	INIT90	6,4	5,7	-	-
COMP5	INIT45	5,4	1,2	6.0,4.5	-
COMP6	INIT120	6,9	5,8	5.5,8.5	15.0
COMP7	INIT70	5,4	1,3	5.5,4.5	-
COMP8	INIT70	5,4	1,2	7.0,4.25	-
COMP9	INIT90	5,3	5,3	4.5,3.25	-
"	INIT90	10,2	3,5	8.5,2.25	-20.0
COMP10	INIT90	3,3	3,1	4.0,3.5	-
"	INIT90	6,5	1,3	6.5,5.5	-
COMP11	INIT120	6,9	5,8	5.5,8.5	15.0
"	INIT90	7,5	-1,7	-	-

Compound figures COMP12 through COMP15 are 120-degree compound figures with 10 columns and 11 rows. The first overlay for each of the compound figures is HEXFIG laid down at point (0,0) in the compound figure with (Dx,Dy) = (1,3). Succeeding overlays for each of these compound figures are as follows:

Compound Figure	Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
COMP12	INIT120	7,5	3,6	-	-
COMP13	INIT90	2,3	1,3	2.5,3.5	30.0
COMP14	INIT60	5,2	3,5	5.0,2.5	-
"	INIT60	5,2	2,3	-	-
"	INIT60	2,5	1,2	-	-
COMP15	INIT60	6,3	7,6	5.75,2.75	-

Example 2

This example uses quadrilateral geometry for constructing an inherently rectangular grid, using the mesh bending capability of quadrilateral geometry to conserve the total number of mesh points while describing interfaces accurately. The 90-degree initial figures which will be used are shown in Figure 3.6.15. Assume all mesh spacings in the initial figure CONSTMESH are 1.0. To construct the 90-degree compound figure COMPFIG1 in Figure 3.6.16 the following overlay sets could be used:

Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
CONSTMESH	0,0	1,3	-	-
MESHFIG1	12,4	5,1	12.3,4.6	-
MESHFIG1	2,9	3,1	3.2,9.8	-
MESHFIG2	6,3	3,5	5.2,2.7	-

Then using COMPFIG1 and a 33 x 33 constant mesh (1.0 mesh spacing) initial figure BACKFIG (not illustrated), the following overlay sets would construct COMPFIG2 in Figure 3.6.17:

Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
BACKFIG	0,0	1,3	-	-
COMPFIG1	16,1	5,3	15.5,0.5	-
COMPFIG1	17,2	3,1	17.5,3.0	-
COMPFIG1	1,32	7,1	-	-
COMPFIG1	17,17	1,3	17.0,17.5	-

Example 3

This example uses quadrilateral geometry for constructing an essentially hexagonal grid including certain rectangular structures. The initial figures used are found in Figure 3.6.18. BACKGROUND is a 120-degree initial figure with constant mesh spacings of 1.0. HEXMESH is a 120-degree initial figure, ASSEMBLY1 is a 60-degree figure, and ASSEMBLY2 and RECTMESH are 90-degree figures. The compound figure overlay sets used to generate the 120-degree compound figure labelled COMPOUND1 (see Figure 3.6.19) are:

Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
BACKGROUND	0,0	1,3	-	-
RECTMESH	2,2	-3,5	-	-
RECTMESH	2,2	-1,7	-	-
HEXMESH	0,0	1,3	0.88,0.88	-
ASSEMBLY1	10,4	3,5	-	-
ASSEMBLY1	18,4	5,3	-	-
ASSEMBLY1	4,18	7,1	-	-
ASSEMBLY2	14,14	1,3	15.5,15.0	30.0

The compound figure COMPOUND1 can then be used to construct a second compound figure COMPOUND2. COMPOUND2 is a 120-degree compound figure having 40 columns and 40 rows. COMPOUND1 will be overlaid on COMPOUND2 three times (as in Figure 3.6.20), with the upper right and lower left portions of COMPOUND2 remaining transparent. The overlay sets used for constructing COMPOUND2 are as follows:

Initial Figure	Origin (column,row)	Directional Indices (Dx,Dy)	Spatial Coord. (Xo,Yo)	Secondary Rotation Angle
COMPOUND1	20,20	7,5	10.0,10.0	-
COMPOUND1	20,20	5,2	-	-
COMPOUND1	20,20	7,2	-	-

The grid (excluding the transparencies) of compound figure COMPOUND2 is illustrated in Figure 3.6.21.

FIGURE 3.6.1

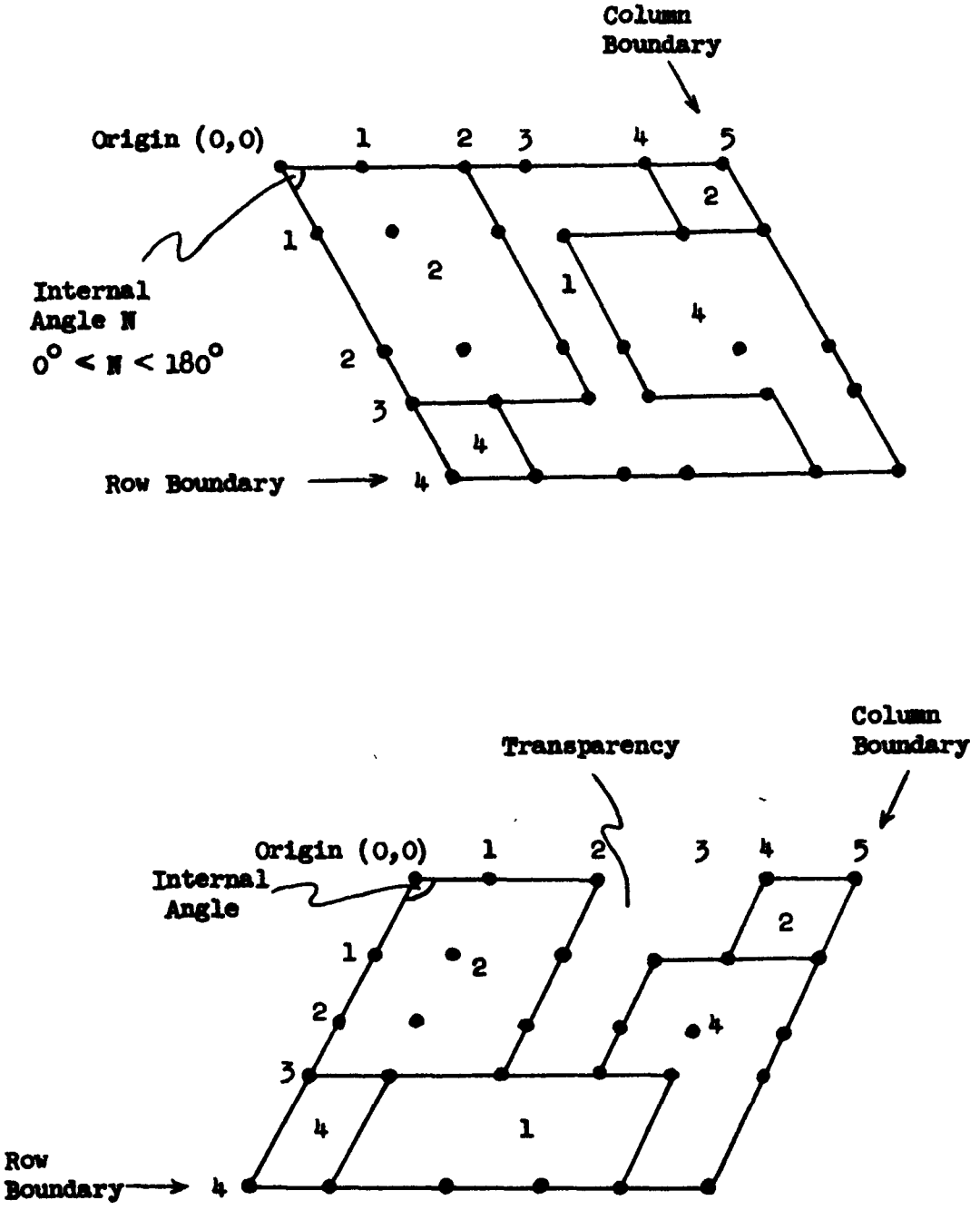


Figure 3.6.1 Typical Quadrilateral Basic Figures

FIGURE 3.6.2

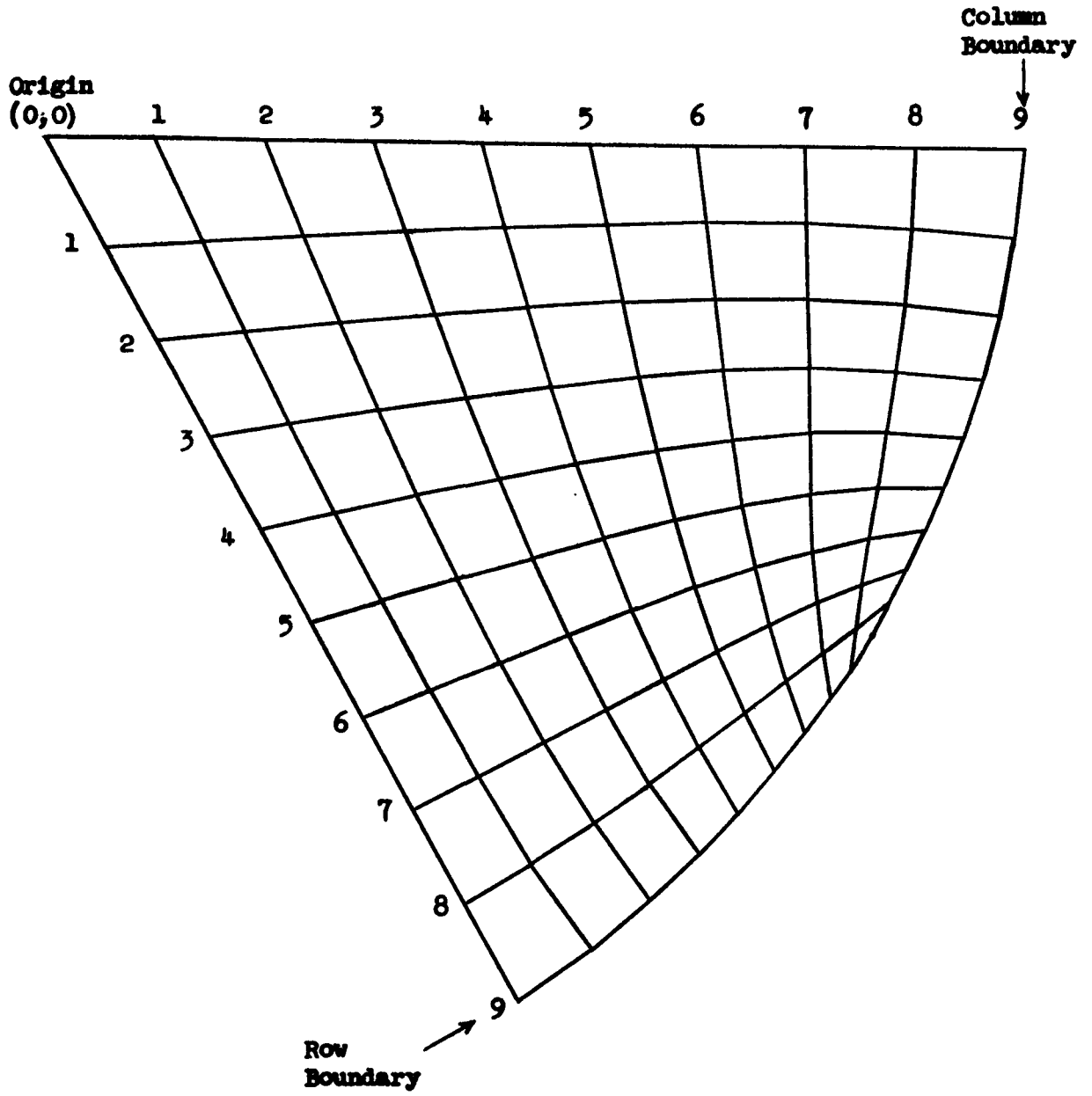


Figure 3.6.2 Quadrilateral File Figure

FIGURE 3.6.3

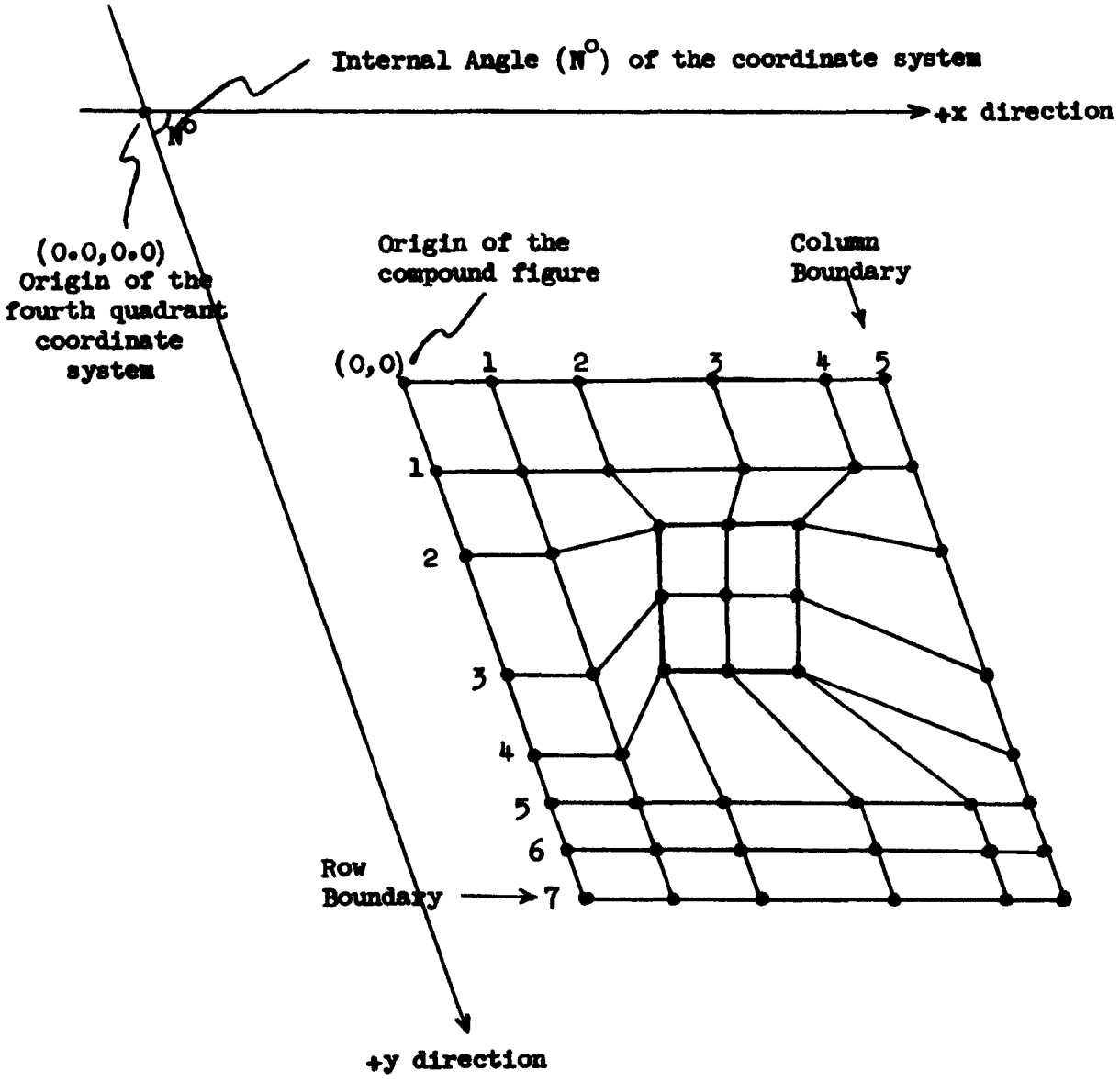
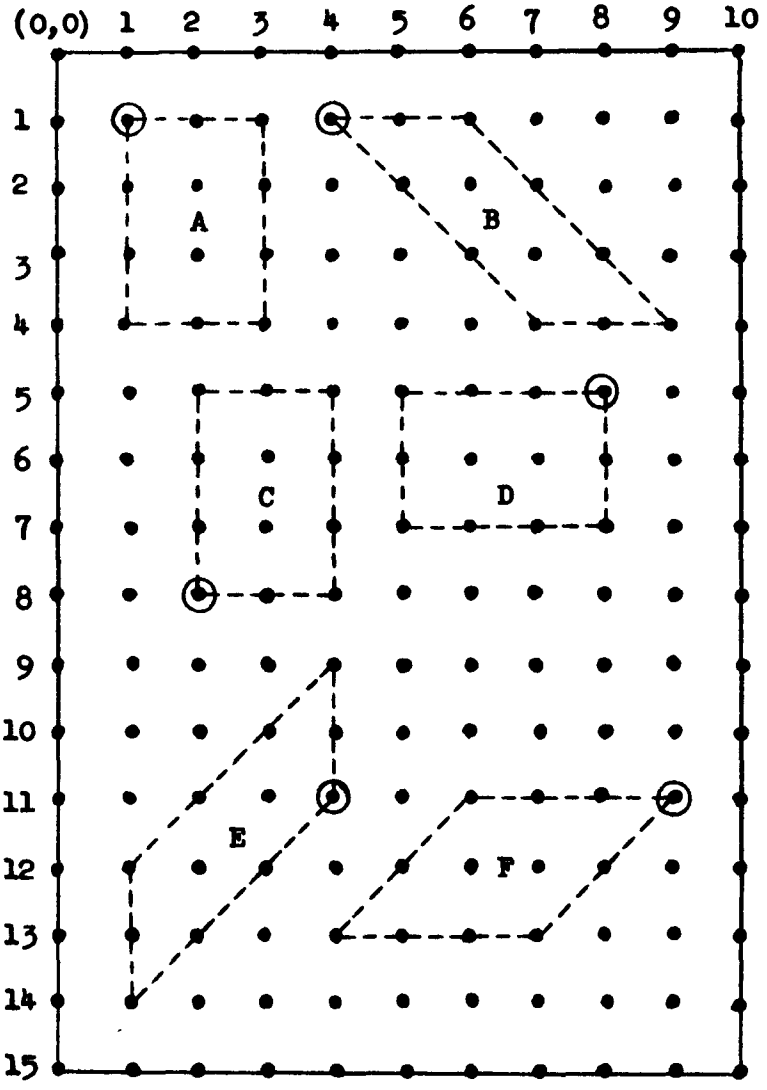


Figure 3.6.3 Compound Figure and Associated Coordinate System

FIGURE 3.6.4



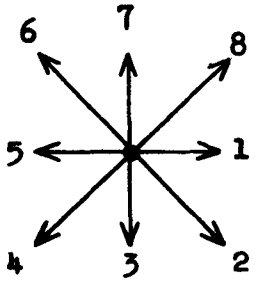


Figure 3.6.4 Directional Indices

FIGURE 3.6.5

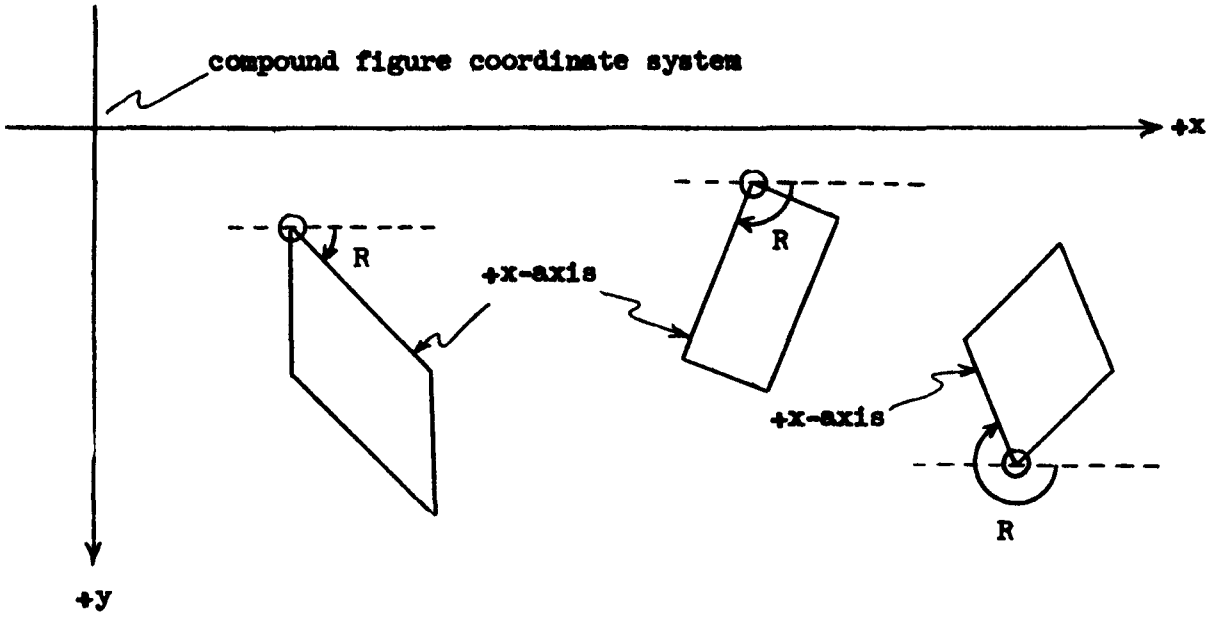
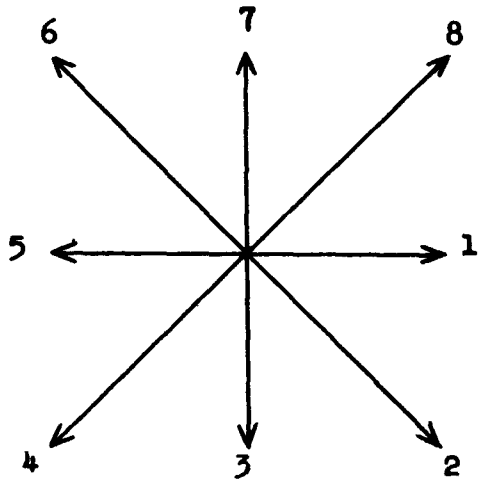


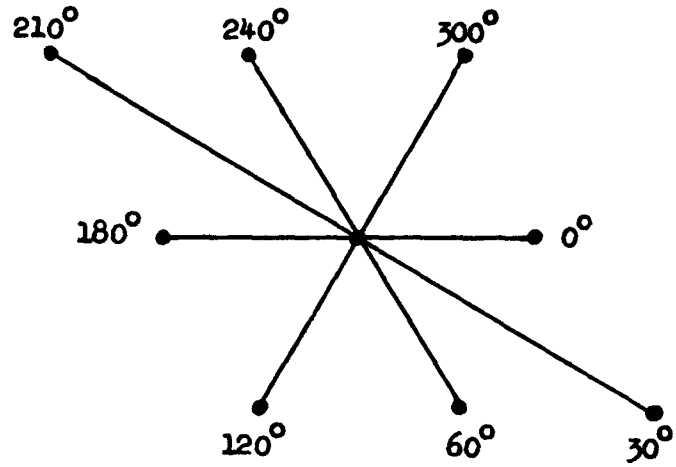
Figure 3.6.5 Angles of Rotation (R) for Several Initial Figures

(Note: the labels "+x-axis" indicate the +x-axis of each initial figure)

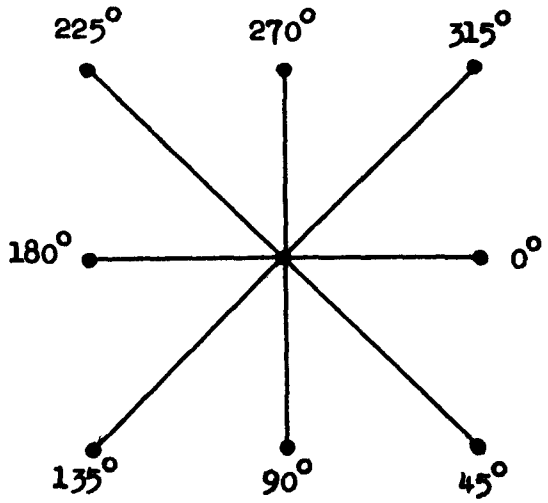
FIGURE 3.6.6



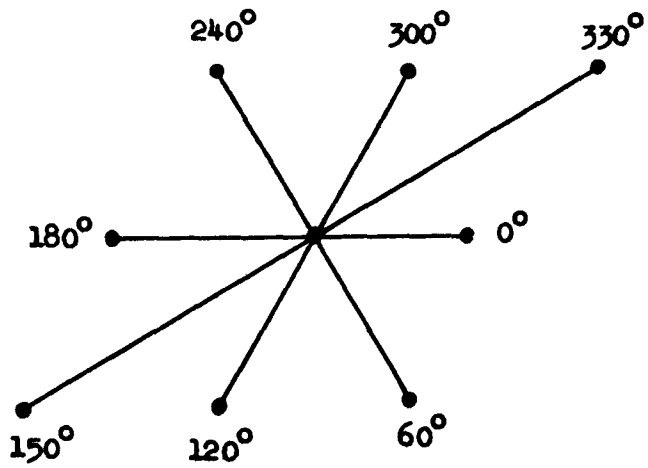
Directional Indices
(unitized mesh)



60-degree
compound figure



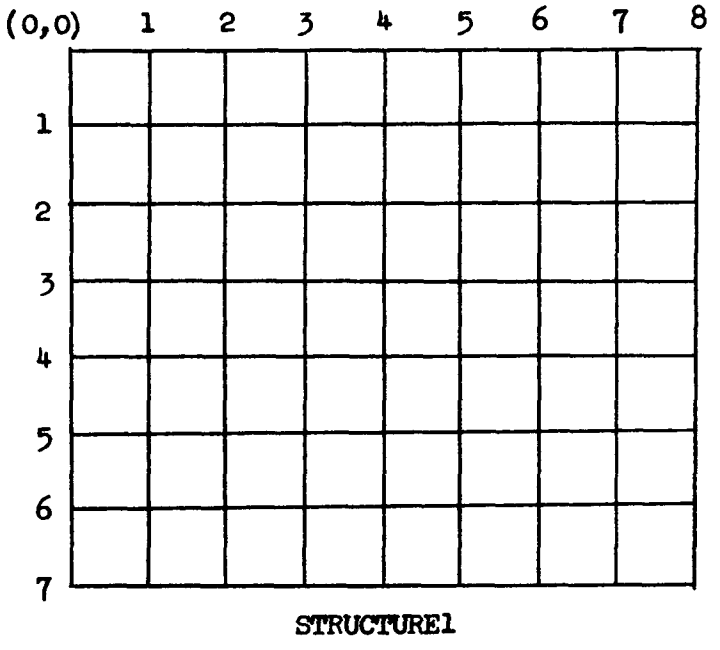
90-degree
compound figure



120-degree
compound figure

Figure 3.6.6 Primary Rotation Angles for Several Compound Figures

FIGURES 3.6.7 - 3.6.8



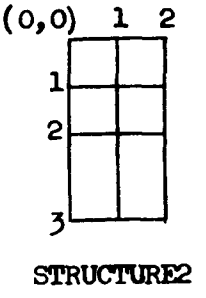


Figure 3.6.7

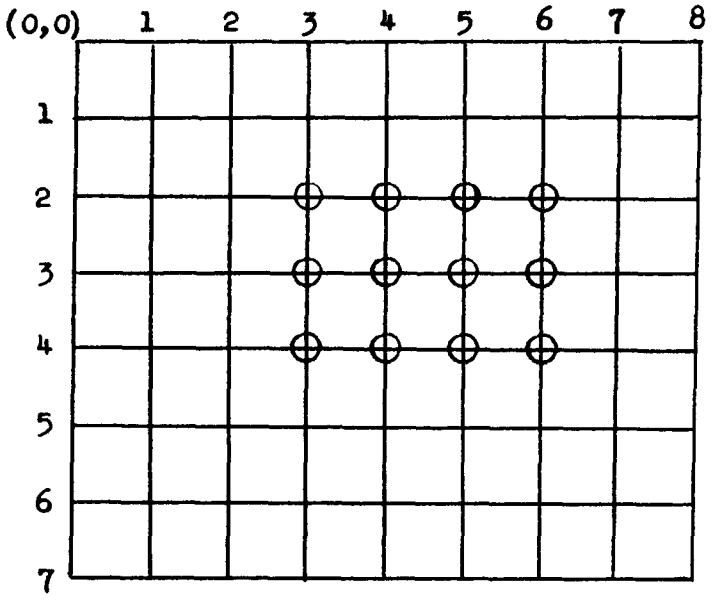


Figure 3.6.8

FIGURES 3.6.9 - 3.6.10

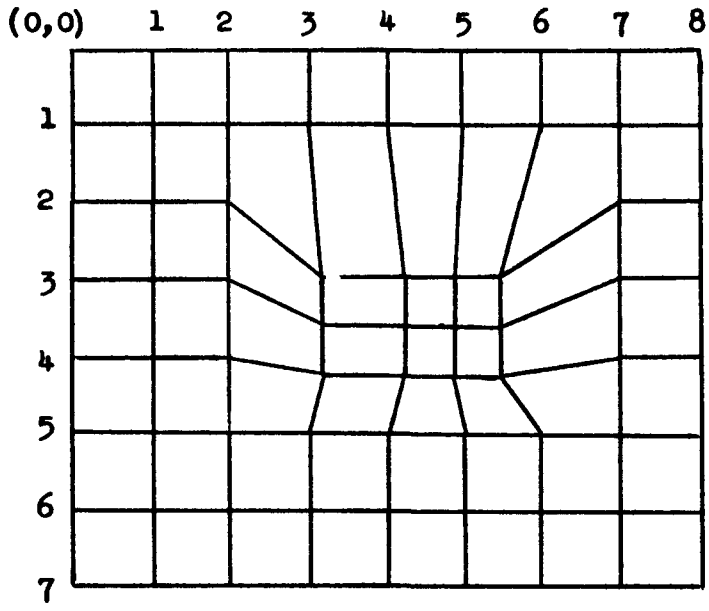


Figure 3.6.9

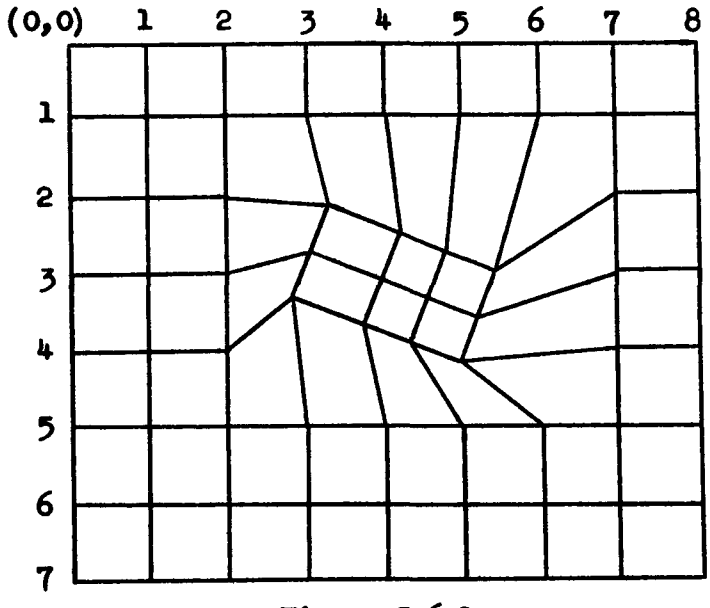
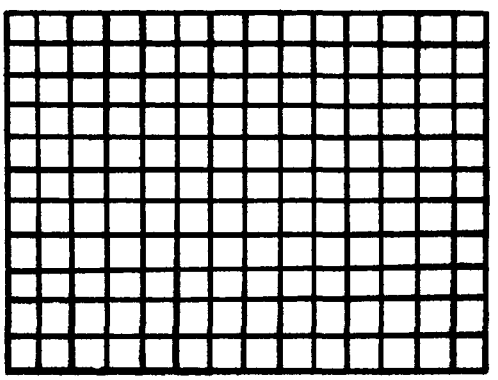
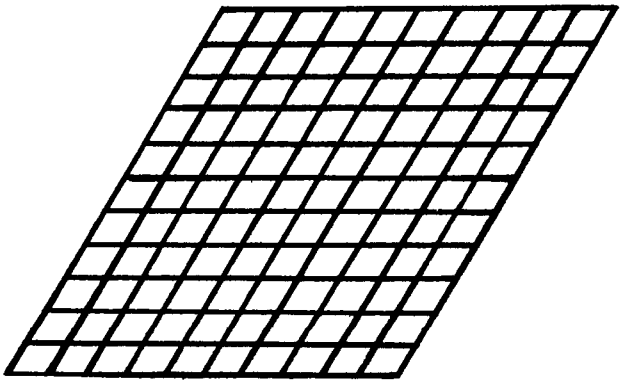


Figure 3.6.10

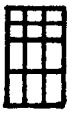
FIGURE 3.6.11



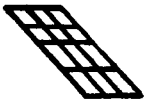
RECTFIG



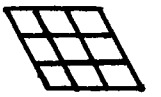
HEXFIG



INIT90

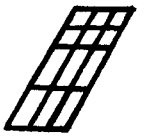


INIT45



INIT60

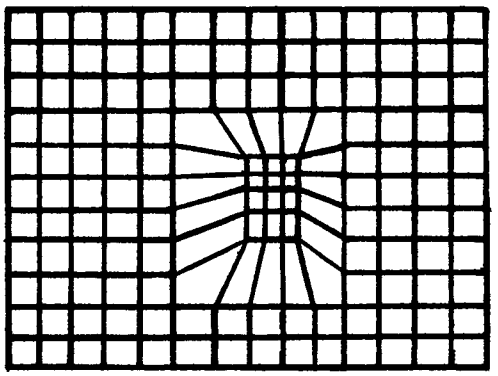
INIT70



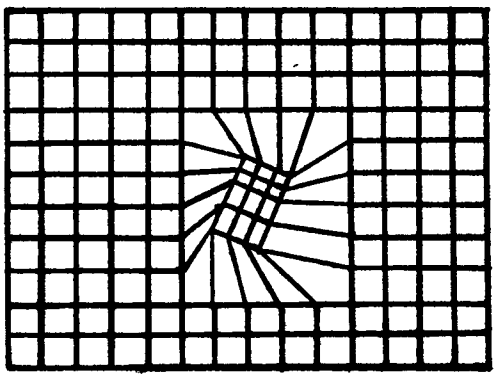
INIT120

Figure 3.6.11

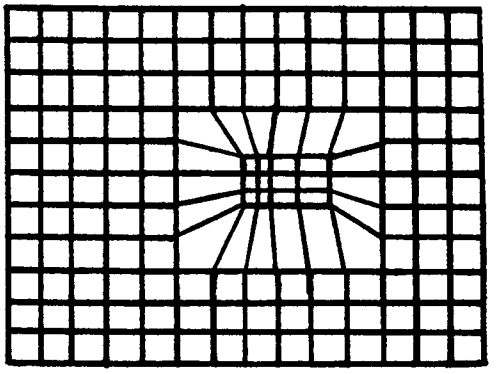
FIGURE 3.6.12



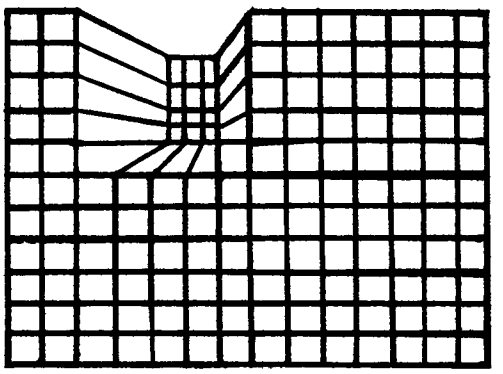
COMP1



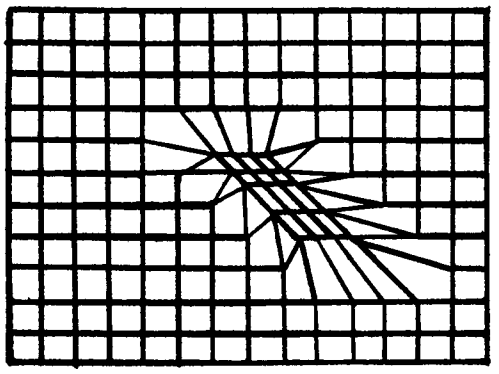
COMP2



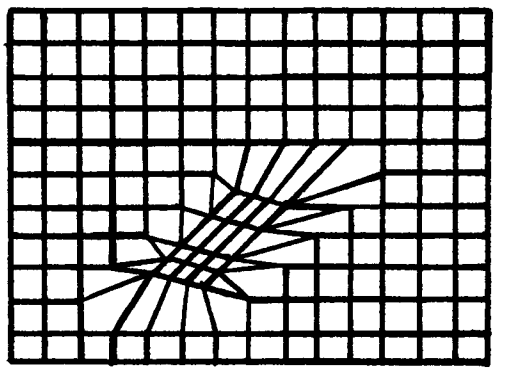
COMP3



COMP4



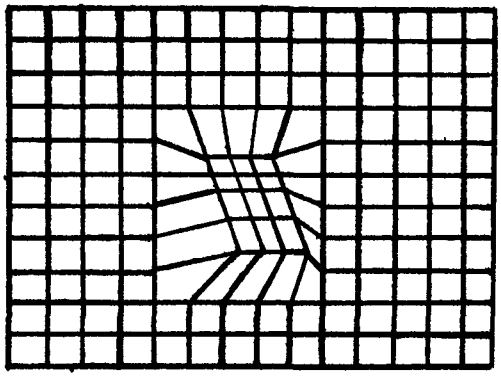
COMP5



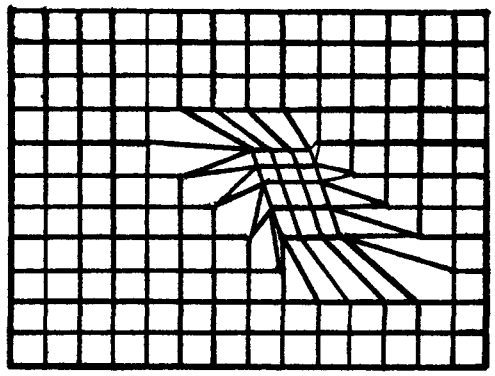
COMP6

Figure 3.6.12

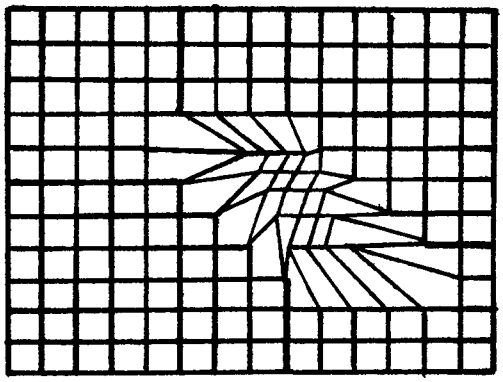
FIGURE 3.6.13



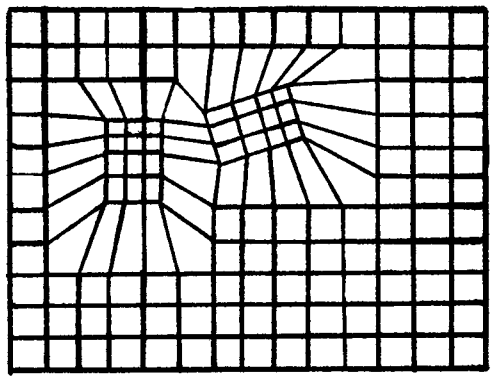
COMP7



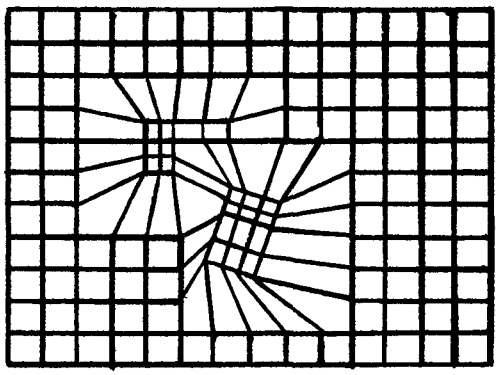
COMP8



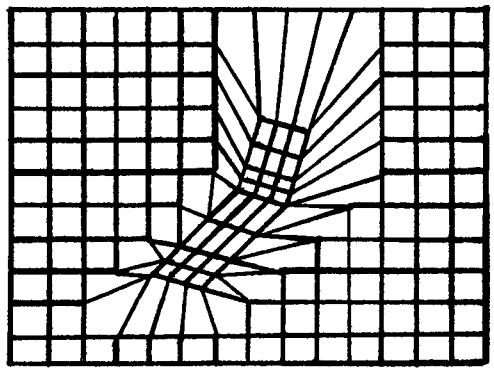
COMP8 (mesh lines)



COMP9



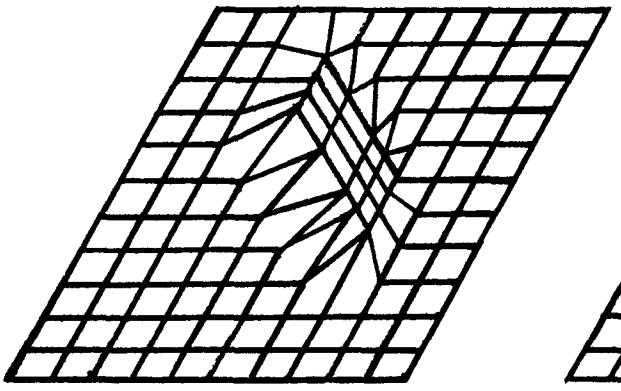
COMP10



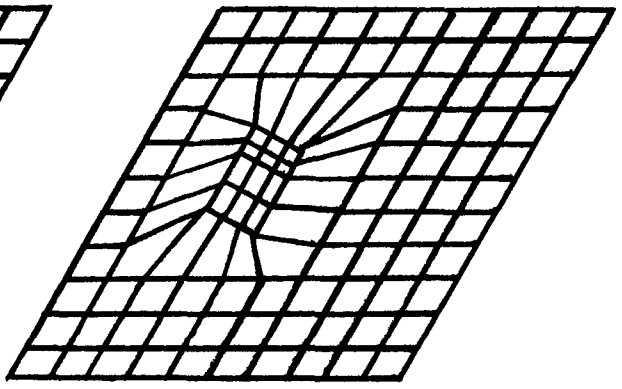
COMP11

Figure 3.6.13

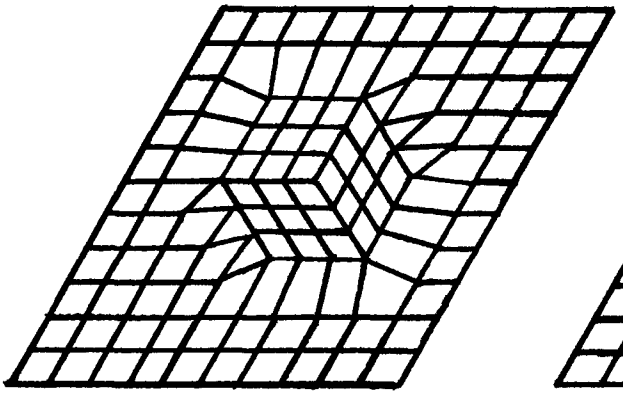
FIGURE 3.6.14



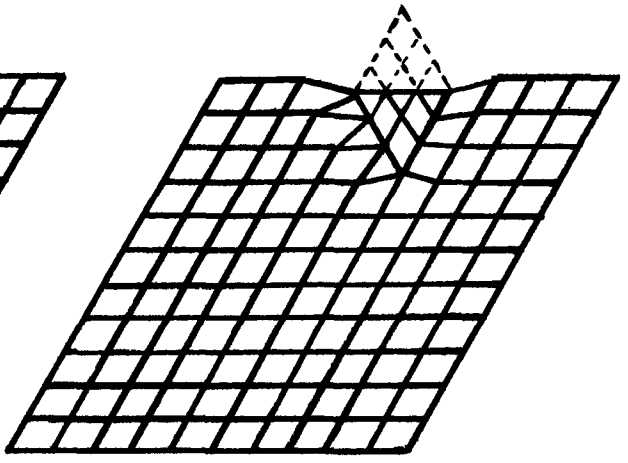
COMP12



COMP13



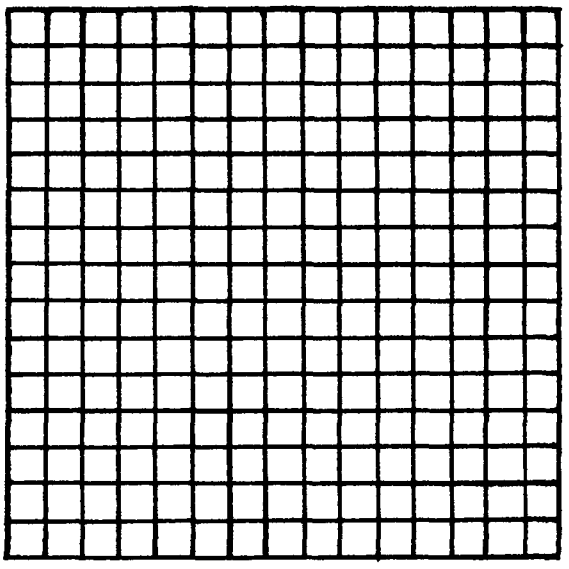
COMP14



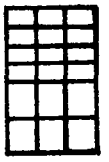
COMP15

Figure 3.6.14

FIGURES 3.6.15 - 3.6.16



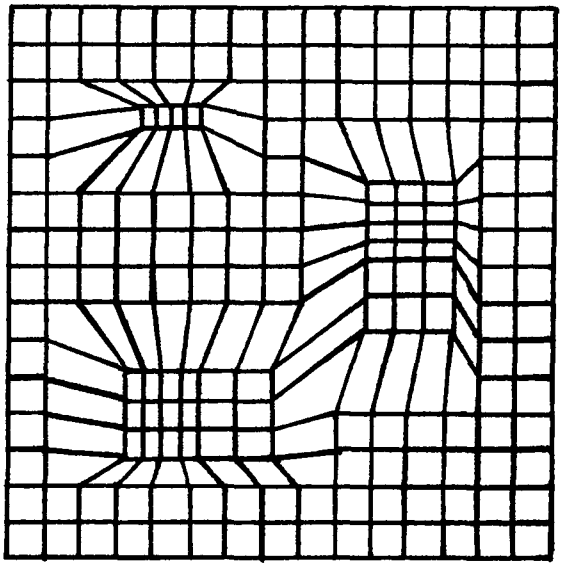
CONSTMESH



MESHFIG1

MESHFIG2

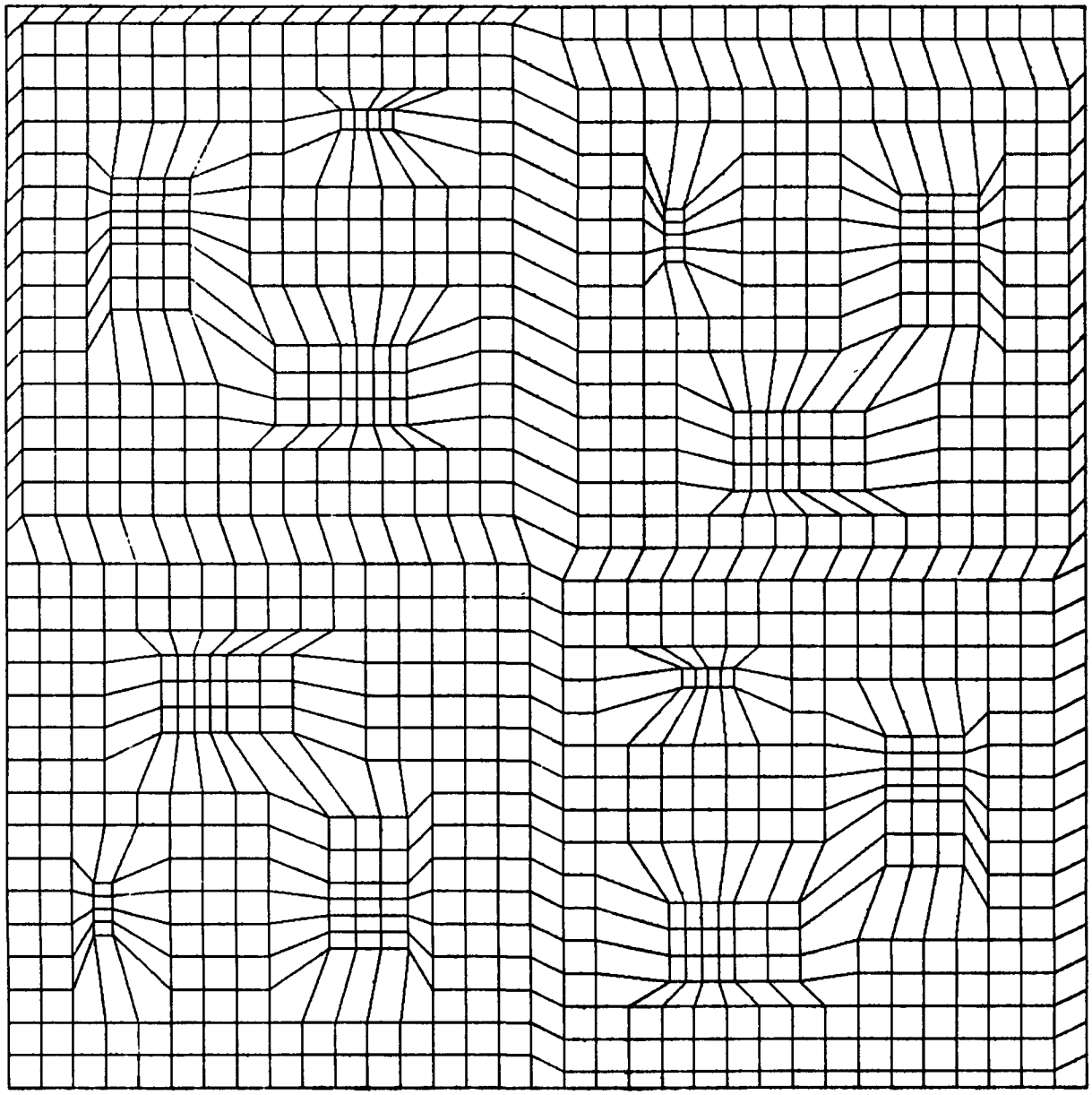
Figure 3.6.15



COMPFIG1

Figure 3.6.16

FIGURE 3.6.17



COMPFIG2

Figure 3.6.17

FIGURE 3.6.18

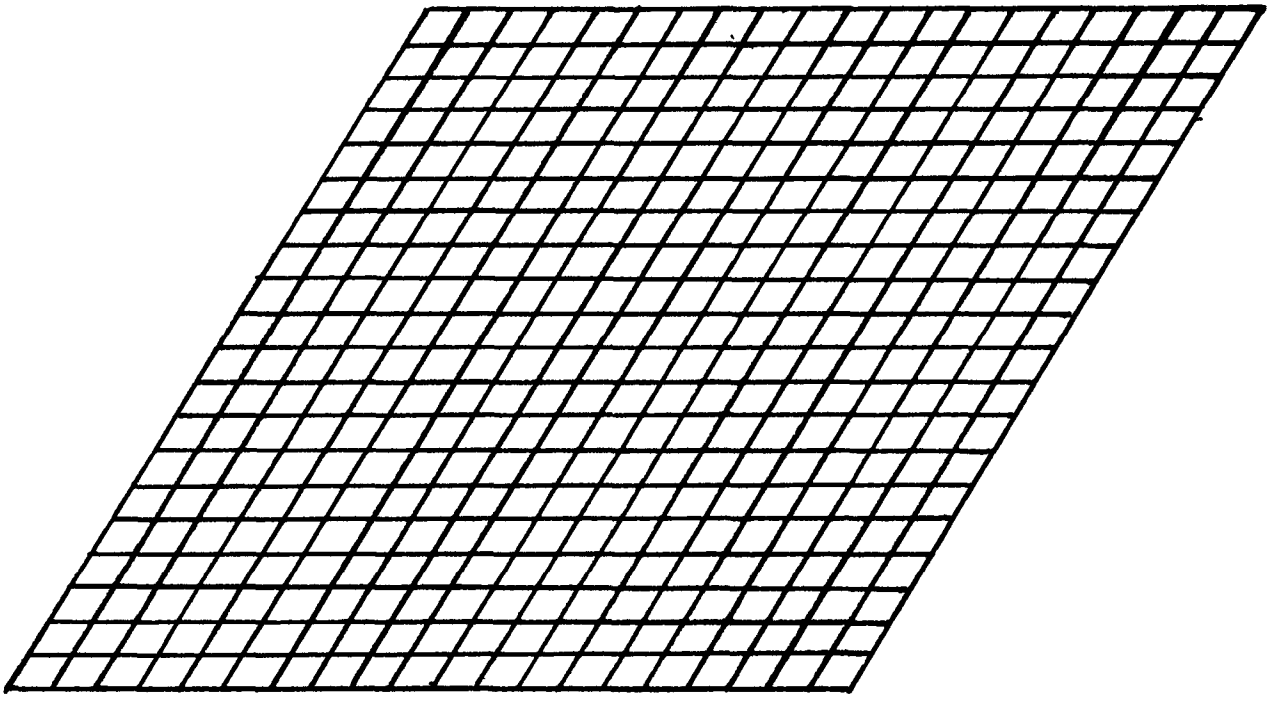
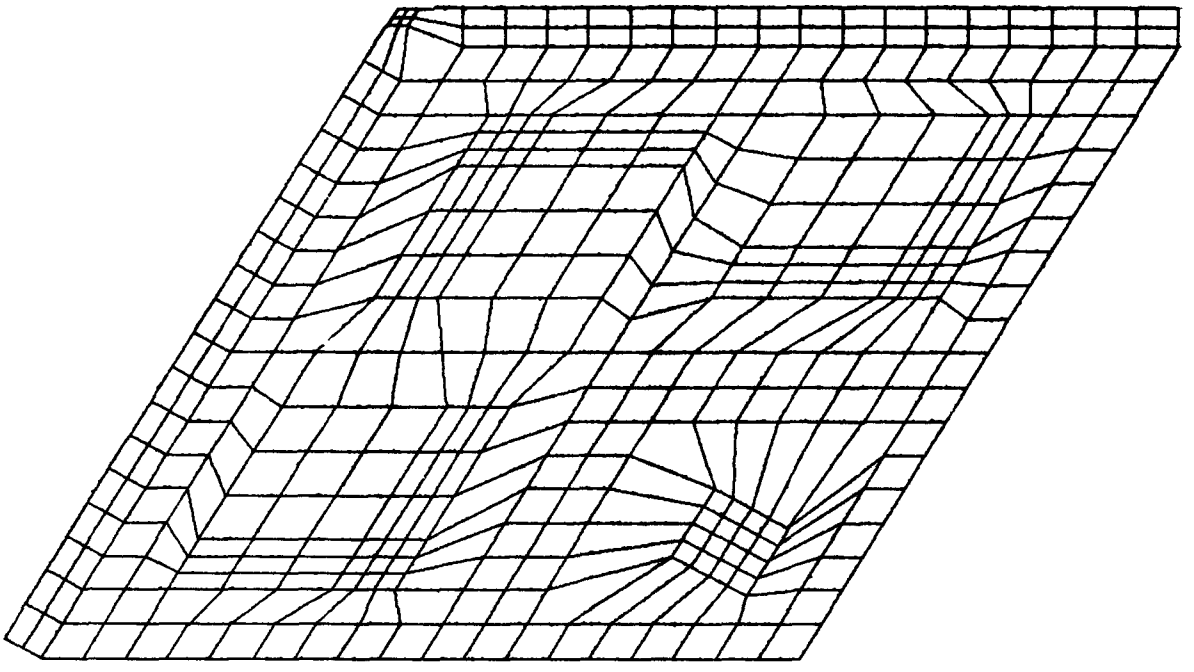


Figure 3.6.18

FIGURES 3.6.19 - 3.6.20



COMPOUND1

Figure 3.6.19

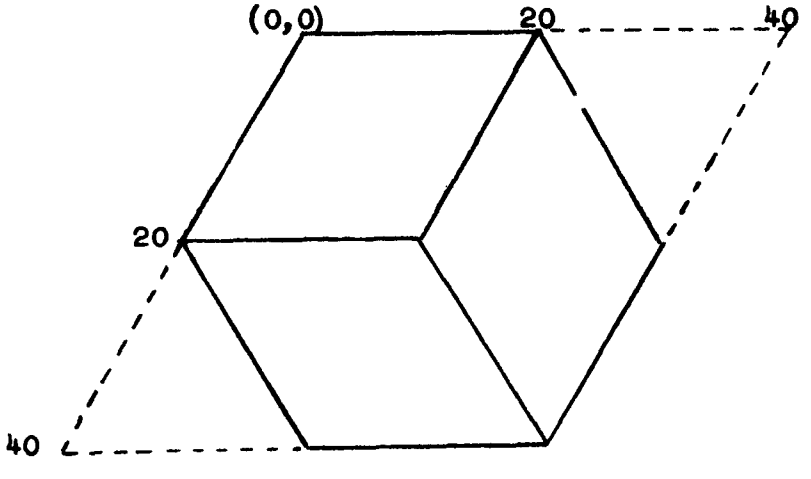
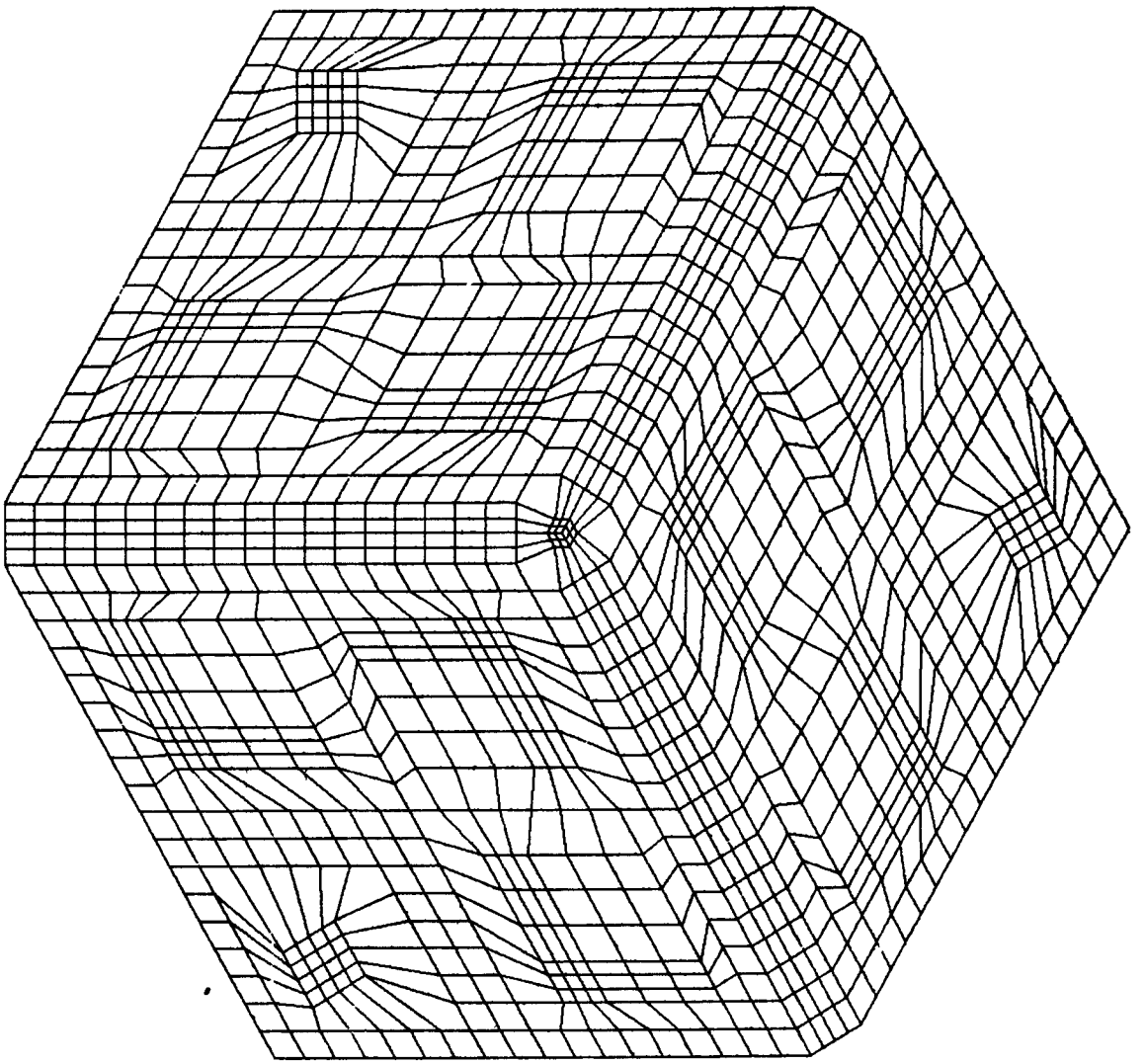


Figure 3.6.20

FIGURE 3.6.21



COMPOUND2

Figure 3.6.21

3.7. GEOMETRY DESCRIPTION: BOUNDARY CONDITIONS

Zero flux, zero current, and fixed flux (in non-synthesis problems) may be applied along each boundary of the region of solution. The left boundary condition (column zero) must be zero current in cylindrical and spherical geometries.

Rotational symmetry may be applied along the top row (row 0) of the x-y geometry in two- and three-dimensional rectangular, hexagonal, and quadrilateral geometry. The program imposes this condition by forcing the flux values on this boundary to be symmetric about the midpoint, and the current values to be symmetric in value but opposite in sign about the midpoint. In hexagonal geometry, the midpoint will always be the mesh point on the diagonal column; in rectangular and quadrilateral geometry the "midpoint" of the row may or may not coincide with a mesh point (it will not when there are an odd number of column mesh lines). The rotational symmetry is 180-degree in rectangular and quadrilateral geometry, and 120-degree in hexagonal geometry. In rectangular geometry, the mesh spacings along the top row must be symmetric about the midpoint of the row. In hexagonal geometry the row 0 mesh spacings must be symmetric about the diagonal column of the chevron. In quadrilateral geometry the sizes and orientations of the mesh spacings must be symmetric (through a 180-degree rotation) about the midpoint of the row. In all cases the boundary condition on column 0 and the column boundary must be the same.

3.8. GEOMETRY DESCRIPTION: BLOCKING

The inventory block is the basic planar mesh unit for depletion, power shape generation, and editing purposes. The program allows the user to define two different sets of blocks: gross blocks and fine blocks.

A GROSS BLOCK defines a collection of mesh elements over which material inventories for all nuclides in the problem are assumed uniform at any given time in life. These inventories define the macroscopic cross sections which determine the solution to the spatial calculation. The flux solution is integrated over each gross block and, in conjunction with the gross block inventories and macroscopic and microscopic cross sections, determines the spatial variation of the parameters used in all integration edits (volume weighted macroscopic data, flux integrals and flux weighted data, isotopic reaction rates, average concentrations, temperature feedback data and xenon feedback data), feedbacks, and gross block depletion.

In 1-D problems, each mesh element is a unique gross block.

In 2-D problems (except cylindrical geometry), the program defines each gross block to be the set of mesh elements having unique final figure - planar region numbers. The gross blocks are ordered first by final figure number, then by planar region within each final figure. Only final figure - planar region pairs which actually appear in the mesh are included in this ordering; the ordering itself is independent of the position of a mesh element in the lattice. Note that mesh elements in a given gross block need not be contiguous.

In 2-D cylindrical problems, the program extends all horizontal and vertical final figure - planar region interfaces in the appropriate direction through the entire lattice. The blocks thus formed are numbered first from left to right, then from top to bottom in the lattice. This method is referred to as rectangular blocking.

In 3-D problems, transverse planar gross blocks are defined exactly as in the 2-D (non-cylindrical) case. Further, contiguous sets of axial mesh planes are grouped into GROSS PLANES to delimit inventory blocks in the z-direction. The user defines these gross planes by specifying the axial mesh points which are to be GROSS PLANE BOUNDARIES. Each gross plane contains the same set of transverse planar gross blocks, so the total number of gross blocks in a three-dimensional problem is the product of the number of planar gross blocks and the number of gross planes.

Note that in all dimensionalities, each mesh element in the problem will be contained in exactly one gross block.

In problems for which the fine blocking option has been selected, gross blocks may be divided into smaller collections of mesh elements to define FINE BLOCKS in specified regions of the solution mesh. Material inventories for a specified subset of the nuclides are assumed uniform over these fine blocks at any given time in life. The microscopic cross sections from the gross block depletion are used for each fine block within a gross block together with the solution flux integrated over each fine block to define the power and depletion behavior of the specified subset of isotopes over each fine block. This fine block power and depletion information has no effect on the rest of the total calculation and is used only for possible printing and filing (as a File Manager file).

In 1-D and 2-D problems, fine blocks are defined as sets of mesh elements with unique gross block - channel - track numbers in those planar regions which are specified to be fine blocked, i.e., those mesh elements with non-zero channel - track numbers. None, part, or all of the mesh elements in any given gross block may be contained in a fine block. Mesh elements in a given fine block need not be contiguous.

In 3-D problems, transverse planar fine blocks are defined exactly as in the 2-D case. Further, contiguous sets of mesh planes within each gross plane are grouped into FINE PLANES to delimit these inventory blocks in the z-direction. These fine planes must be wholly contained within the gross planes. The axial points which are to be FINE PLANE BOUNDARIES may be taken to be the the same as the gross plane boundaries, or they may be specified by the user. Note that gross plane boundaries must always also be fine plane

boundaries. Each fine plane has the same set of transverse planar fine blocks, so the total number of fine blocks in a three-dimensional problem is the product of the number of planar fine blocks and the number of fine planes.

Note that in a fine blocked problem every mesh element which is fine blocked will be contained in exactly one fine block. Each fine block is always wholly contained in a gross block.

3.9. GEOMETRY DESCRIPTION: COMPOSITIONS - CONFIGURATIONS

The material properties of the region of solution are described by attaching a COMPOSITION number to each mesh element in the solution space. The composition number identifies a specific combination of chain list, table set, and set of initial nuclide concentrations which is to be used in a particular area of the mesh (these are discussed in detail in Chapter 4). The placement of compositions is described by assigning a composition number either to each final figure or to each planar region. Thus every gross block is assigned a single composition number, as is every fine block. Because of the method used in constructing the geometry, compositions are usually more readily assigned to planar regions.

In a three-dimensional problem, the set of composition to planar region (or final figure) correspondences may be varied in different axial planes. Composition correspondences may be changed only by gross plane; each axial plane within a gross plane must have the same set of composition correspondences.

A CONFIGURATION identifies a particular set of composition to planar region (or final figure) correspondences. Multiple configurations may be specified only in one-dimensional and two-dimensional problems and are useful in identifying different material arrangements. For example, multiple configurations may be described when creating a geometry description which is then stored in an output File Manager geometry file. When this File Manager geometry file is input to a succeeding problem, the material arrangement may be changed by altering the configuration used.

In one-dimensional problems the multiple sets of composition correspondences have an additional utility. The one-dimensional control search option may be used to manipulate these configurations to obtain a desired reactivity.

The multiple configuration concept may require a slightly different interpretation of how the concentration file is originally constructed and in how concentration replacement is performed. Concentration values from card input define some or all of the problem concentrations if and only if either (a) no File Manager concentration file was input, or (b) concentration replacement is indicated. The placement of concentrations for a problem is initially determined by the placement of compositions, and thereafter the concentrations exist as a file and are not rearranged regardless of which geometric configuration is chosen. If a rearrangement is desired, either no File Manager concentration file should be input or concentration replacement must be done. All of this is true for any problem. For multiple configuration geometries, though, the composition placement is determined by the configuration which is chosen as the initial configuration. Keep in mind that the initial configuration can be specified in three different ways: (1) one - dimensional search specifications; (2) card **030000** (composition correspondence usage card); and, (3) sub-case configuration specification. The configuration chosen for concentration placement is that specified on card **030000**. Note that a card input concentration for a particular nuclide could be specified for a given composition which does not exist in the initial configuration, but this value of the concentration will not be part of the problem concentrations and will not be present even when the search chooses a configuration containing that composition. These problems tend to occur in specifying dummy nuclides. The problem can be avoided by specifying all concentration values in compositions of the initial configuration and obtain the desired effect through nonzero tableset data only in the correct compositions.

4.1. HARMONY: INTRODUCTION

This chapter describes a system called HARMONY which handles the cross section and depletion portions of the diffusion - depletion calculation. The primary emphasis in the design of this system is flexibility. This flexibility increases the range of problems that may be described. Difficulties can arise when attempts are made to use a depletion program for a class of reactors for which the program is *not* specifically designed. This depletion system allows the user to formulate a depletion program to handle the specific nuclides of interest for a particular reactor. Rather than tailoring the reactor to fit the requirements of a particular depletion program, the user is able to tailor the depletion system to describe the reactor of interest.

It has been recognized in the design of this depletion system that for complex problems the amount of data that may be required could become large. While the flexibility of the system is a major advantage to the user, little is gained if the amount of data that must be handled is so large that the probability of entering it into the program correctly is small. An automated scheme for generating the cross section tables has been considered a vital adjunct to the depletion system. The assumption that such a scheme will be used has played an important role in designing the input of the cross section tables. The depletion system, of course, may be used without automated cross section generation. The input description furnished in this report allows all cross section data to be entered on cards. In addition, allowance is made for all cross section data to be entered via a File Manager input file. Further flexibility is provided by allowing any combination of card and File Manager file input of cross sections. In any case, complete input consistency checking is provided.

Various types of isotopic editing are available from the HARMONY system. Concentrations may be edited as individual block values or as volume averaged densities or as integrated loadings. A subset of the possible isotopic reaction rate data may be optionally edited. In particular, integrated power, fission, and absorption reaction rates are available by nuclide and energy group and summed over energy groups for arbitrary regions of the core. For the special case of total problem space, arbitrary combinations of these isotopic reaction rates, densities, and loadings may be obtained.

A "dual" type of depletion in which all nuclides are depleted over larger blocks and a subset of the nuclides is depleted over smaller blocks, provides detailed power and history information efficiently. The method assumes that adequate flux shapes and reactivities throughout depletion lifetimes can be obtained using large - block depletion but that small - block depletion is necessary to obtain adequate local power and history information.

To implement this dual depletion method, the program allows the user to describe two different sets of blocks, gross blocks and fine blocks. Each gross block defines the collection of mesh elements over which material inventories are assumed uniform at each discrete time-in-life. These inventories define macroscopic cross sections which determine the solution to the spatial calculations. The solution flux is integrated over each gross block and in conjunction with the gross block inventories, macroscopic cross sections, and microscopic cross sections, determines the spatial variation of parameters used in all integration edits, feedbacks, and gross block depletion.

The gross blocks may be divided into smaller collections of mesh elements to define fine blocks in specified regions of the solution mesh. At beginning of life, the fine blocks within a gross block contain nuclide concentrations (for some subset of nuclides) which are identical to those in the gross block. The microscopic cross sections from the gross block are used for each fine block within a gross block together with the solution flux integrated over each fine block to define the power and depletion behavior of a specified subset of the nuclides over each fine block. This fine block power and depletion information has no effect on the remainder of the total calculation and is used only for possible editing and filing (as File Manager files) for later use.

As a result of this method of depletion, results can be obtained which are as detailed as those obtainable from a "point" depletion problem, although the depletion portion of the program runs at approximately the speed of a block depletion problem and not at the slower speed of a "point" depletion problem.

4.2. HARMONY: TERMINOLOGY

This section defines some of the more important names of quantities used in the HARMONY descriptions.

1. Nuclide ID:

   a. NUMERIC NUCLIDE ID - any integer not exceeding 65535 in absolute value assigned by the user as an identification of a nuclide. If negative, the nuclide is depleted over both gross and fine blocks. This ID is used in most input descriptions.

   b. ALPHANUMERIC NUCLIDE ID - any one-to-ten characters assigned to a nuclide by the user. This ID is used as a label in the printed output from a problem.

2. Chains:

   a. NUCLIDE CHAIN - a group of nuclides coupled to one another through neutron capture and decay processes.

   b. LINEAR CHAIN - part of a nuclide chain in which each nuclide is fed by a single parent. A nuclide chain must be resolved into linear chains for solution of the depletion equations in HARMONY.

   c. CHAIN LIST - a list of linear chains containing all depletable nuclides to be treated together in a material composition.

   d. CHAIN LIST ASSIGNMENT - the assignment of chain lists to material compositions. This assignment determines which chains will be treated in various regions of the reactor.

3. Time intervals:

   a. BASIC INTERVAL - the depletion time interval between spatial flux calculations.

   b. RENORMALIZATION INTERVAL - the depletion time interval between renormalizations of the thermal flux. The renormalization interval is a subdivision of the basic time interval.

   c. SUBINTERVAL - the depletion time interval between re-evaluation of the microscopic cross sections used in the depletion equations. The subinterval is a subdivision of the renormalization interval.

4. Tables:

   a. MASTER MACRO TABLE - a table of macroscopic cross sections of fixed value containing entries for each type and each group. The table entries must contain the contribution to the macroscopic cross sections of all nuclides not described in the nuclide chains.

   b. MASTER MICRO TABLE - a table of microscopic cross sections of fixed value for a single nuclide and a single group but including all types.

   c. INTERPOLATING TABLE - a method of representing the time dependence of any macroscopic cross-section (for a single group and type), microscopic cross section (for a single nuclide, group, and type), or self - shielding factor (for a set of nuclides and types, and a single group). As many as three nuclide concentrations may be used as the independent variables of the table.

   d. MASK TABLE - the array of independent variables N(i) used in the interpolating tables. One mask may be used for several function tables.

   e. FUNCTION TABLE - values of the dependent variable associated with each of the entries of the mask table. The description of a function table requires not only the entries but an identification of the mask with which it is associated.

f. TABLE SET - a collection of any of the type of tables defined in a, b, c, d, and e. The collection is given an identification so that it can be assigned to material compositions or manipulated in other ways.

5. Compositions:

a. MATERIAL COMPOSITION - a region or regions of the spatial problem designated by the user to have certain material characteristics. Each material composition has one and only one chain list, one table set, and at most one set of initial nuclide concentrations.

b. DEPLETABLE COMPOSITION - a material composition that is assigned both macroscopic and microscopic tables (constant and/or interpolating). Another characteristic of a depletable composition is that it is a material composition to which a non-zero chain list has been assigned.

c. NON-DEPLETABLE COMPOSITION - a material composition that is assigned only macroscopic cross section data in the form of master macro tables.

6. Depletable:

a. DEPLETABLE PROBLEM - a problem which defines nuclide concentrations.

b. DEPLETING PROBLEM - a depletable problem becomes a depleting problem when the basic time interval T(1) - T(0) is nonzero. The two problems (depletable and depleting) differ only in that when T(0) = T(1) the depletion calculation itself is not done and N(T(1)), the nuclide concentrations at time T(1), are set equal to N(T(0)). In all other respects depletable problems are the same as depletion problems.

7. Replacement:

a. COMPOSITION REPLACEMENT - a process which replaces the nonuniform nuclide concentration values (from some preceding calculation) in selected compositions by uniform (card input) values for all nuclides in the composition.

b. NUCLIDE REPLACEMENT - a process which replaces the nonuniform nuclide concentration values (from some preceding calculation) in selected compositions by uniform (card input) values for selected nuclides in the composition.

4.3. HARMONY: DEPLETION CHAINS

The depletion equations to be solved by the program are specified by the user. This specification identifies (1) how each nuclide is formed (radioactive decay or capture) from previous nuclides in the chain, (2) whether or not the nuclide is a direct product of the fission process, and (3) how the nuclide is destroyed (radioactive decay and/or absorption).

The solutions of the depletion equations are evaluated for the time interval between spatial calculations. These solutions assume constant cross sections and constant flux. Allowance is made for time dependent cross sections by breaking the basic time interval into smaller steps and evaluating the cross sections at the beginning of each of the the smaller steps. The time dependence of a cross section thus is represented in the depletion calculation as a step function.

In a similar manner, the user may input so called "flux enhancement factors" to modify the flux in each of these smaller steps so that the time variation of the flux is also represented as a step function in specified regions of the core. The neutron flux used in the solution of the depletion equations is normalized to a specified power level at the beginning of the basic time interval. As the fuel inventory and cross sections change within the time interval, the implied power level also varies. Provision has been made to approximate more closely constant power operation for thermal reactors by use of thermal flux renormalization (see Section 4.7).

4.4. HARMONY: CROSS SECTION REPRESENTATION

Any of the cross sections or shielding factors used in the spatial or depletion calculation may be represented as time dependent. This time dependence is attained by representing the cross section as a function of as many as three nuclide concentrations.

The dependence of the cross sections and shielding factors on nuclide concentrations is attained through the use of interpolating tables. Use is made of one, two, or three dimensional tables to represent the dependence of the cross section on one, two, or three nuclide concentrations. Restrictions are placed on the form of the tables in order to balance an accurate representation of the cross section variation with available computer storage.

It is assumed that the user will give some thought to the question of time dependence of cross sections before preparing the input. While considerable flexibility has been made available with the tabular representation of cross sections, its use is not free. The use of interpolation is more expensive than just selecting a constant cross section. The method used to assign cross section data has been constructed with an eye towards minimizing storage requirements and machine time.

The generality of the interpolating tables has other applications in addition to the representation of the time dependence of microscopic cross sections and self-shielding factors. For instance, macroscopic cross sections could be tabulated versus metal - to - water ratio through hydrogen density. Treating hydrogen as a depletable isotope (with $dN/dt=0$) allows the tables to be interpolated for any hydrogen concentration specified. Survey calculations as a function of metal - to - water ratio could then be performed expeditiously. With a little thought, similar applications of particular interest to the user will become apparent.

Macroscopic cross sections used in the spatial calculation are constructed as the sum of two parts as shown in equation 4.4.1. The first part is the contribution to the macroscopic cross section which is due to all nuclides not described in the nuclide chains. Thus in a non - depletable problem this portion is the entire cross section. This first portion is one element from a MASTER MACRO TABLE (required in every composition) for a particular type of cross section and a given group. The second portion consists of the sum over all nuclides of the product of (1) nuclide concentration, (2) the appropriate type (fission, absorption,...) of microscopic cross section from a MASTER MICRO TABLE, and (3) a self shielding factor resulting from the evaluation of an INTERPOLATING TABLE. Both the master macro table and master micro table may be composition dependent and, in addition, the user may specify any of the macroscopic, microscopic, and self shielding quantities to have a functional dependence on up to three nuclide concentrations; i.e., these quantities may vary spatially from block to block as they are interpolated from nonuniform concentrations.

The microscopic cross sections used in the computation of macroscopic data are only those associated with nuclides assigned via chain lists to the particular composition. The contribution of the non - depletable nuclides in that compositon must be included in the first term (macro table or macro interpolating,table).

The cross section data is input in one of three basic table forms: (1) fixed values (not time dependent) of the macroscopic cross sections; (2) fixed values of the microscopic cross sections; and (3) interpolating tables for macro, micro, or self shielding factors. In the interpolating table, a quantity may be represented as dependent on the local concentration of as many as three of the nuclides. The shielding factors are assumed to be unity unless they are otherwise specified in the interpolating tables. Microscopic cross sections are zero unless specified.

The table in which the fixed values of the macroscopic cross sections are specified (the MASTER MACRO TABLE) must be complete in that values are to be specified for all types t and all groups g. Such a table completely specifies the few - group cross sections for a non - depletable composition. The program requires that each composition, depletable as well as non - depletable, be assigned a master macro table.

The second type of table, called the MASTER MICRO TABLE, is used to specify time independent microscopic cross sections for the depletable nuclides. One such table specifies all types (transport, absorption, removal, fission, nu, kappa) for group g of nuclide i. The reason for identifying the master micro tables separately for each group is that in one group the microscopic cross sections for nuclide i may differ from one composition to another while for another group the same master micro table may be used in several compositions.

The third type of table, called an INTERPOLATING TABLE, allows the macroscopic sub - portion, microscopic portion, or the self shielding factor to be time dependent. When interpolating tables are assigned to a composition, the time dependent cross section is used in place of the fixed value of the cross section that may also be present.

The primary assignment of cross section tables by composition is performed by TABLE SET. A table set is a collection of the three types of tables described above and may (but not necessarily) contain one master macro table, several master micro tables, and several interpolating tables. The use of the table set allows a simple identification of a collection of tables which are usually found together.

A straightforward input of cross section tables would be the construction of a unique table set for each composition. Each table set would contain a master macro table and master micro table for each group for each depletable nuclide. If some of the cross sections were desired to be time dependent, additional interpolating tables would also be assigned to the table set.

The more complicated problems will generally require a large number of tables. However, the program is limited in the total number of data items which can be retained. In order to run large, complex problems which would otherwise exceed the storage capacity there must be some procedure for reducing the total number of tables used. This is done by allowing a table to be used in more than one composition. For example, the user may decide that master micro tables from several table sets are essentially the same and after choosing one of these may discard the others; or, if tables are generated by an automated process, specific tables may be in error and need to be replaced by corrected tables. The TABLE SET OVERLAY input is designed to do this sort of manipulation. Table set overlay is thus a secondary method of assigning cross sections to compositions. This is sometimes called "borrowing".

The interpolating tables allow any macroscopic, microscopic, or self shielding factor to be represented as a function of up to three nuclide concentrations N(j). If desired, one or more of the three independent variables may be designated to be the fraction of N(j) remaining. The interpolating table is divided into two parts, the values of the function (called the FUNCTION TABLE) and the corresponding values of the N(j)'s for which the function value is given. This set of N(j)'s is called the MASK TABLE. The division of the interpolating tables is done first of all in recognition of the fact that several function tables will be used with a single mask table. This reflects the fact that, for a given set of N(j)'s, all the few group cross sections are available from the same spectrum calculations. The capability of relating one mask to several function tables results in economy of data storage. Second, the interpolation strategy used in the program (see Section 4.5) takes advantage of several function tables being related to one mask to minimize the computing time for performing the interpolations.

The structure of the two or three dimensional interpolating tables and the interpolation strategy used reflect a physical characteristic of the depletion problem; i.e., that there is a most likely combination of the two or three independent variables that will occur during the depletion. Particular values of these most likely combinations define the diagonal of the table. It is further anticipated that the number of off - diagonal locations used will be much less than the total number of locations available. The ability to describe the dependence of the functions with tables that are not full is important in the storage of the cross section data.

The interpolation of the multi - dimensional tables assumes that one of the variables N(1) is primary and the other, N(2), is secondary. Thus, the secondary nuclide concentration has some dependence on N(1); i.e., N(2) = f(N(1)). The interpolation proceeds by finding the function versus N(1) from the diagonal entries. In addition, N(2) (and N(3)) versus N(1) are determined.

If the nuclide concentrations of N(2) (and/or N(3)) of interest are not those occurring on the diagonal, a correction term is obtained from off - diagonal entries. The interpolation strategy is described in detail in Section 4.5.

EQUATION 4.4.1

$$\Sigma^{t,g} = \Sigma_o^{t,g} + \sum_i N_i G_i^{t,g} \sigma_i^{t,g} \qquad 4.4.1$$

where:

$\Sigma^{t,g}$ = macroscopic cross section, type t, group g;

$\Sigma_o^{t,g}$ = element from master macro table or result of interpolating macro table, type t, group g;

N_i = concentration of nuclide i;

$G_i^{t,g}$ = 1.0 or interpolating self-shielding factor, type t, group g, nuclide i;

$\sigma_i^{t,g}$ = element from master micro table or result of interpolating micro table, type t, group g, nuclide i.

4.5. HARMONY: CROSS SECTION INTERPOLATION SCHEME

The interpolation performed to obtain time dependent cross sections and shielding factors may have up to three "independent" variables X, Y, and Z. The variables are not truly independent and the interpolation scheme employed takes advantage of the fact that the user has some knowledge of the functional relationship among the three. That is, the function is defined in tabular form with entries defined for combinations of the independent variables most likely to occur (these form the "diagonal" entries of the table) and other entries defined for combinations of the independent variables less likely to occur (these form the "off - diagonal" entries in the table). In general the tables are not full; i.e., if there are N points on the diagonal, there are usually not NxN (if X,Y) or NxNxN (if X,Y,Z) entries in the table because (1) this violates the assumption that there is some definite functional dependence of Y and Z on X and (2) the storage requirements would be prohibitive.

The function values (which form a "function table") are separated from the corresponding independent variable values (which form a "mask"). This is done because the nature of the generation of the table values implies that many function tables will have the same mask. The program generates a formula (which involves only mask values and the particular values of the independent variables X0, Y0, and Z0 for which the function is to be determined) and simply evaluates that formula for as many functions as apply to that mask, thus reducing computing time considerably. Note that this technique of evaluation implies that all interpolations which use the same mask should be of the same order (this is not checked in the input); the independent variable values should also have the same value for a mask regardless of where it is used but this could be violated if fractional nuclide concentration values are used as the independent variable because the N(0) concentration values are carried in the mask and may vary in value from material to material (this, also, is not checked in the input).

The value of the function F at the point (X0,Y0,Z0) is obtained as the result of evaluating the following expression:

$$F(X0,Y0,Z0) = F(X0,Y(X0),Z(X0)) + [Y0 - Y(X0)]\,Y'(X0) + [Z0 - Z(X0)]\,Z'(X0)$$

where Y'(X0) and Z'(X0) are the partial derivatives of F with respect to Y and Z respectively, each evaluated at X0. The functional dependence on Y and/or Z may possibly not be present in one and/or two dimensional tables.

The functional dependence on X is obtained by variable order (K) interpolation or linear extrapolation as is the dependence of Y and Z on X.

The various terms in the expression are obtained as follows: The first term F(X0,Y(X0),Z(X0)) is evaluated using only the diagonal values. That is, it is obtained by (Lagrange) interpolation of order K on only the diagonal values. To obtain the mask values used in this interpolation, the program attempts to "bracket" X0 using from the diagonal (K+1)/2 values less than X0 and (K+1)/2 values greater than X0 if K is odd. If K is even, K/2+1 values less than X0 and K/2 values greater than X0 are used from the diagonal. If this bracketing is not possible but some diagonal values still bracket X0, then the correct number of values is still used. If there are not enough entries to do interpolation of order K, the order is reduced (to the maximum size) automatically. If no values on the diagonal bracket X0, linear extrapolation is used to obtain F(X0,Y(X0),Z(X0)) using two diagonal mask values at the appropriate "end" of the diagonal. If only one mask value exists, the result is always the single function value regardless of the value of X0. Similarly, if they exist, Y(X0) and Z(X0) are obtained.

To obtain Y'(X0) (and similarly Z'(X0)) the program uses the slope FROM the diagonal value TO the "proper" off -diagonal value to obtain Y' at some value of X; i.e. F is assumed linear in Y and Z off the diagonal. Then for another value of X the same procedure is followed. These two slopes are then linearly interpolated (or extrapolated) to obtain Y'(X0). The two values of X (X1 and X2) at which these slopes are obtained are those for which (1) off - diagonal entries exist, (2) the off - diagonal entry is "proper", (3) X0 is bracketed, and (4) X1 and X2 are closer to X0 than any other pair which brackets X0. If X0 cannot be bracketed, then the two (one if only one off - diagonal entry is present) off - diagonal entries which are nearest to X0 are used.

A "proper" off - diagonal entry is defined as follows. Let the off - diagonal entry in position (i,j,j) of the mask be represented by [X(i),Y(j),Z(j)], corresponding to a diagonal entry [X(i),Y(i),Z(i)]; i.e., the value of X must be the same in both entries. Then the entry is "proper" when computing Y'[X(i)] if Z(j) = Z(i) and Y(j) does not equal Y(i). If another off - diagonal entry exists at [X(i),Y(k),Z(i)], the one chosen for use in the slope evaluation at X(i) is that for which Y is closest to Y0. Similarly, when computing Z'[X(i)], the off - diagonal entry is "proper" if Y(j) = Y(i) and Z(j) does not equal Z(i). Also, if another off - diagonal entry exists at [X(i),Y(i),Z(k)], the one chosen for use in the slope evaluation at X(i) is that for which Z is closest to Z0.

The assumptions about the behavior of F(X,Y,Z) are such that the following type of function would yield correct interpolated values.

(1) F is a polynomial of degree not greater than K in X.

(2) Near the "expected values" of X,Y,Z (i.e., on the diagonal) Y and Z are polynomials of degree no greater than K in X.

(3) When F is not near the diagonal then F is linear in Y and Z and these variables (Y and Z) in turn are polynomials of degree not greater than two in X.

Either the function or its inverse may be obtained in this manner. If the inverse is requested, the table values that are input represent the function values, not the inverse. The program then inverts the function table values during input processing (and thus the user is cautioned that there must be no zero function table values present) and the interpolation proceeds as before except that the final result is then inverted.

4.6. HARMONY: NUCLIDE IDENTIFICATION

In general, the specification of the depletion portion of the problem consists of (1) the name of each nuclide given by numeric and alphanumeric identifications (ID's), (2) the description of the equations representing the time behavior of each nuclide, (3) the identification of sets of nuclides which may appear together in a composition and the equation(s) representing the time behavior of each nuclide in that composition, and (4) the initial concentrations of these nuclides. Due to the structure of the program only those nuclides varying with time need be represented. Conversely, each time dependent nuclide must have an equation defining its time behavior.

For the most part, a numeric ID is used for nuclide identification in the input and an alphanumeric ID is used as a label in the output. The numeric ID may be any integer not exceeding 65535 in absolute value. If the ID is negative, that nuclide will be depleted over both gross blocks and fine blocks. Obviously, the list of nuclide ID's must contain unique numbers. The alphanumeric ID may consist of any one to ten characters which can be input. Embedded blanks are allowed and must be included in the character count.

The list of nuclide ID's should not be changed throughout a depletion calculation. Actually only the total number of gross and fine block nuclide ID's must each remain fixed, but it seems that replacing one nuclide by another in the middle of a calculation could have serious side effects and the practice should be discouraged. Since a value for the concentration of each nuclide in the list is carried for each block, the list should not contain redundant entries. For very large three dimensional problems the list should be kept as short as possible because of overall storage limitations and File Manager file sizes; this can sometimes be accomplished by using a single nuclide ID to mean different physical nuclides in different materials in the problem. Extreme caution should be exercised in this case since different chain definitions must be input for the same nuclide for different regions of the problem. Obviously, this can only be done for nuclides which do not appear together in any composition.

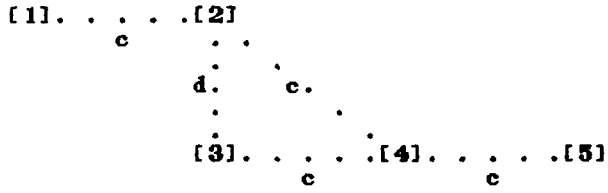
An optional set of input may be included with the nuclide identification data which specifies the atomic weight for each nuclide. This data is used only for editing nuclide loadings in kilograms.

4.7. HARMONY: NUCLIDE CHAIN DESCRIPTIONS

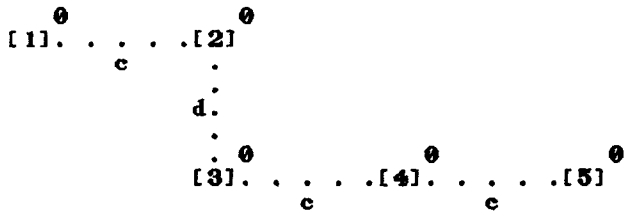
A nuclide can be transformed by several modes of radioactive decay or by neutron absorption; likewise, it can be created when parent nuclei undergo such processes or by direct fission yield. Thus, the concentration of a particular nuclide may depend on more than one immediate parent as well as its own radioactive decay, neutron absorption rate and yield from fission. A complete schematic of all coupling mechanisms between the precursors which feed and transform each nuclide may appear to be quite complicated.

The algorithm used in this program to solve the associated differential equations requires couplings in which nuclei are fed by a single parent (LINEAR COUPLING). However, provided that a nuclide concentration is independent of the concentration of any of its progeny, it is always possible to resolve more complicated couplings into linearly coupled chains of nuclides because of the linearity of the equations.

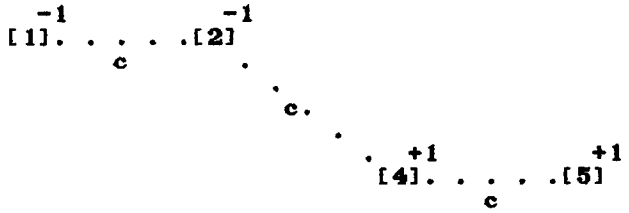
A simple example of a chain of nuclides which can be resolved into two linear chains will serve to illustrate this process of linearization. Let d = decay and c = capture in the following five-nuclide chain.



This chain linearizes into



and



In this example, two linear chains are required. In the first linear chain, the solutions for the first three nuclides give the total concentrations while the values for nuclides 4 and 5 are only partial concentrations. The zeros near each of the nuclides of the first linear chain indicate that these nuclides are appearing for the first time in a linear chain. In the second linear chain, the solution for nuclides 1 and 2 duplicate those of the first linear chain (this is indicated by the -1) while the concentrations of nuclides 4 and 5 must be added to the previous values to obtain final concentrations

(this is indicated by the +1).

The concentration of the i-th nuclide in a linear chain is determined by the equation

$$dN/dt = Y(i) + B(i-1)N(i-1) - A(i)N(i)$$

where Y(i) is the average fission yield rate for nuclide i, B(i-1) is the coupling to the previous nuclide in the chain (decay, capture, or decay plus capture), and A(i) is the loss for this nuclide (decay, absorption, or decay plus absorption). For a detailed definition of these terms, see Equation 4.7.1.

In the first equation of a chain (parent nuclide), the B(i-1)N(i-1) term is missing; in all other equations the B(i-1) term must be nonzero. The term A(i) must be nonzero in all equations (a special case is the use of an equation of the form dN/dt = Y or dN/dt = 0, see below). Chains in which the yield term is missing are called DEPLETION CHAINS; all others are called FISSION PRODUCT CHAINS.

An equation of the form

$$dN/dt = Y$$

is available for special purposes. It must be a one - nuclide chain and can be used to represent lumped fission products. If this chain is called a depletion chain, the equation takes the form

$$dN/dt = 0$$

and can be used as a dummy chain to represent a non - depleting nuclide.

The solution of the set of equations in a chain from time t(0) to time t(1) is described in Section 4.8. For reasons noted there it is recommended that a nonzero decay constant be assigned to each nuclide and that the decay values for nuclides in one chain all be different. Dummy values corresponding to approximately a ten thousand year half life can usually be assigned with differences between values corresponding to a difference of a one hundred year half life.

Assumptions in addition to the linear coupling have been used to derive Equation 4.7.1 from the general depletion equation; namely, Y(i) is the AVERAGE fission yield rate instead of Y(t), and B(i-1) as well as A(i) are evaluated at time t=t(0) and held constant. The time dependence of B(i-1) and A(i) results from the possible dependence of microscopic cross sections and shielding factors on the concentrations of arbitrary nuclides.

Three time - intervals are involved in the depletion calculations. The largest time interval called BASIC INTERVAL is that between spatial calculations; i.e., within this time interval, say from T(0) to T(1), each of the group fluxes is assumed not to vary in shape. The user can effect a flux shape change by supplying non - unity flux enhancement factors.

The second time interval is called a RENORMALIZATION INTERVAL and is a subdivision of the basic interval. The renormalization interval is used to keep the depletion calculation close to constant power by a renormalization of the thermal flux LEVEL. The flux used in the depletion equations is normalized to a specified power level according to Equation 4.7.2.

At time t = T(0) a value of BETA, the flux normalization factor, is determined from Equation 4.7.2 and is used as a multiplicative factor for all groups of flux, both fast and thermal. At the end of each renormalization interval (except the last one), the fission cross sections are recomputed for all groups; BETA for the fast groups remains constant, and a new value of BETA for the thermal group(s) is computed for use in the next interval. The normalized flux, then, is the appropriate BETA factor times the flux from the spatial calculation and BETA for the thermal groups(s) is changed at the end of each renormalization interval. For example, in a highly enriched uranium core the value of BETA for the thermal group(s) will increase from one renormalization interval to the next to account for the decrease in the macroscopic fission cross section.

The renormalization intervals are of equal length DELTA T = (T(1)-T(0))/n. The integer n is determined such that DELTA T does not exceed an input value, DELTMX. In the evaluation of the macroscopic fission cross section used in the calculation of the thermal flux renormalization, the assumption is made that there is no contribution from the master macro table or interpolating macro tables towards the fission cross section. If such a contribution is present, it is ignored.

The renormalization interval DELTA T may be further divided into SUBINTERVALS of equal length. This third time interval allows the cross sections and shielding factors to vary in time. Equation 4.7.1 is then solved for each subinterval. Since the cross sections and shielding factors are evaluated at the beginning of each subinterval and remain constant for the subinterval they are step functions. Another point to note is the evaluation of the fission cross sections and shielding factors used in obtaining Y(i). Since the cross sections and shielding factors used for this evaluation may be functions of nuclide concentrations, the value of the fission cross section may change from equation to equation. This point is discussed in Section 4.9 as is the method used for obtaining the number of subintervals.

In summary, the depletion equations are obtained by establishing linear chains of nuclides which may be fission - product chains or depletion chains. Each chain is described by specifying for each nuclide its decay constant, the coupling to the parent nuclide, the yield fractions (if fission product), and an indication as to whether the resulting nuclide concentration is a total solution, a partial contribution, or a duplication.

In the solution of the equations, renormalization intervals may be used to change the level of the thermal flux to account for a change in fission rate to keep the depletion calculation closer to a constant power level. Note that each renormalization step involves an integration over the entire problem space; thus it requires that the depletion equations be solved over all space for one renormalization interval. To account for the time - dependence of cross sections and shielding factors, each renormalization interval may be divided into subintervals. In this case, however, only those equations for a single block need be solved. Thus, the number of subintervals used should reflect the rate of change of the cross sections and shielding factors for the particular nuclides in the chain list for the block. The number of subintervals may vary from block to block since it is chain list dependent and thus composition dependent.

At the end of every renormalization interval, the nuclides to be depleted over fine blocks are evaluated. This fine block depletion is done using the same subinterval time stepping as previously described. In fact, the depletion is identical to that for gross blocks with three exceptions: (1) the fine block concentrations are used, (2) the fine block fluxes are used, and (3) the microscopic cross sections and shielding factors used in each subinterval are those from the gross block containing the fine block. The normalization factors used are those used for the gross block depletion. Thus, the only additional approximation applied to fine block depletion compared to gross block depletion is that microscopic cross sections which are interpolated and shielding factors use the average concentration in the gross block as the independent variable for interpolation for each fine block in the gross block.

Since the program uses the same user defined chains for fine block depletion as for gross block depletion, all daughter nuclides which are fine block depleted must have parent nuclides which are fine block depleted. However, fine block chains may be truncated so that nuclides later in the chain are ignored during fine block depletion.

EQUATION 4.7.1

$$\frac{dN_i}{dt} = \bar{Y}_i + \alpha_i \beta_{i-1} N_{i-1} - (\lambda_i + A_i) N_i \qquad 4.7.1$$

where

$\bar{Y}_i = \sum_k Y_{ik} (\overline{NF})_k$, the average fission yield rate for nuclide i, the summation k extends over all fissile nuclides;

Y_{ik}, (yield fraction for nuclide i)/(fission of nuclide k);

$(\overline{NF})_k = \frac{1}{2}\left[N_k(t_o) F_k(t_o) + N_k(t_1) F_k(t_1) \right]$;

$F_k(t) = \sum_g \sigma_k^{f,g}(t) G_k^{f,g}(t) \Phi^g(t_o)$, fission probability for nuclide k;

$t_1 - t_o$, the subinterval for which solution is obtained;

$\Phi^g(t_o)$, flux for energy group g normalized to a specified power at t_o;

$G_g^{f,g}(t)$, shielding factor for fission cross section, group g, nuclide k;

λ , decay constant;

A_i , total absorption probability per nuclide i at $t = t_o$, similar to F except that σ^a and G^a are used;

$\beta_{i-1} = \lambda_{i-1}$, C_{i-1}, or $(\lambda_{i-1} + C_{i-1})$, depending on the coupling from precursor i-1;

$C_{i-1} = A_{i-1}(t_o) - F_{i-1}(t_o)$, capture probability of nuclide i-1 at $t = t_o$;

α_i , input quantity, usually unity.

EQUATION 4.7.2

$$P = \beta^{fast}\left(\sum_{\substack{fast\\ g}} \int_R p^g dV\right) + \beta^{th}\int_R p^{th} dV \qquad 4.7.2$$

where

R = spatial region of solution

P = specified total power (watts) developed in region R

$p = \sum_i \kappa_i^g \Sigma_i^{f,g} \varpi^g$

i = fissile nuclide index

g = group index (th for thermal)

ϖ = un-normalized flux

κ_i^g = energy released per fission (watt-sec/fission) of nuclide i in group g.

The normalized flux is

$\phi^{fast} = \beta^{fast} \varpi^{fast}$

and $\phi^{th} = \beta^{th} \varpi^{th}$

4.8. HARMONY: SOLUTION OF DEPLETION EQUATIONS

The method used for the solution of the depletion equations was selected because of its control of rounding errors using only single precision calculations. The set of equations to be solved is given by Equation 4.8.1. The fission yield rate (Y) and the coefficients in Equation 4.8.1 are constant insofar as the solution of 4.8.1 is concerned. The quantities involved in these coefficients are defined in detail in Section 4.7 (see Equation 4.7.1). Also noted in Section 4.7 are the descriptions of basic time interval, renormalization interval, and subinterval. The interval of solution of Equation 4.8.1 is the subinterval.

The solution for the n-th nuclide in a chain at time t(1) (t(1) = t(0) + SUBINTERVAL time) is given by Equation 4.8.2. The interpretation of Equation 4.8.2 is that, during the subinterval, nuclide m (where m is less than n) feeds n indirectly by feeding m+1 which feeds into m+2, etc. The outer summation terms define these contributions; each term can be further resolved into the contribution from the yield source of m [brackets], and the contribution from the accumulation of m present at time t(0) (parentheses).

From this physical interpretation of the terms of Equation 4.8.2 it is clear that for a small subinterval or for large differences of n - m such partial contributions must tend to zero. That is terms in the brackets and parenthesis must become small. Due to the finite number of significant digits carried in the computation (say N), it is also clear that the summation cannot be calculated correctly if it is smaller than N orders of magnitude less than the maximum of the bracketed terms. Thus, when the summation cannot be calculated correctly for some m = u and n = v, this contribution and contributions from all nuclides further removed from n are ignored. That is, the outer summation for the bracketed terms is changed to be from m = u+1 to n for n = v, v+1, ...I. For the CDC-6600/7600 computers N = 12 is used. The above criterion is automatic and no indication is given in the output when it is triggered.

Following the same line of reasoning, small divisors in the terms in parentheses could cause trouble. In this case the program examines Inequalities 4.8.3 and 4.8.4, again with N = 12 on the CDC-6600/7600 computers. The Inequality 4.8.3 is tested for each i in the chain. If it fails, the term is replaced by a value which would satisfy the inequality and a comment in the output indicates that the decay constant of the i-th nuclide in the k-th chain has been so modified. The block location and composition number of the occurrence are also listed. The comment refers to the k-th chain in the chain list for that composition and the i-th nuclide named in that chain.

Similarly, the second criterion (given by Inequality 4.8.4) is then applied to each i in the chain for each j greater than i. If it fails, a comment indicates that the decay of the j-th nuclide in the k-th chain was modified to make it different from the i-th nuclide. Again the block location and composition are identified and i, j, and k are interpreted as above. Comments of this type are made for the first such ten blocks encountered during each renormalization interval. The next time one of the tests fails, a comment indicates that something happened in this block and that such modifications will be made in succeeding blocks without further notification.

Two situations during depletion will cause the program to print a descriptive comment similar to those described above but then immediately terminate. If the coupling to a parent nuclide is identically zero, the program cannot evaluate the depletion chain and so it comments to that effect and terminates. Also, since the negative of decay plus absorption for a nuclide enters into the depletion equation solutions as an exponent, the program checks the sign of this quantity during depletion. If this quantity is negative, a warning similar to the above is given; if this quantity is "large" in magnitude and negative, a comment to that effect is printed and the program immediately terminates.

It is recommended as standard procedure that non - zero decay constants be assigned each near stable nuclide in a depletion chain. That is, if it would normally be nearly zero, values corresponding to a half life of about ten thousand years should be used. Further, the values assigned to nuclides in the same chain should differ by approximately a one hundred year half life to prevent failure of Inequality 4.8.4. For convenience, the general formula for

the decay constant in seconds for a half life T in hours is given by Equation 4.8.5. That equation yields a value of .220-11 for a 10000 year half life, .218-11 for 10100 years, and .200-11 for 11000 years.

When this procedure of supplying such decay constants is followed and the time interval and flux level are appropriate for a general depletion problem, there should be very few comments of this type and the action taken by the program should be correct. However, when such a comment appears it should not be ignored.

If the power level is identically zero, special chain equations may be required to satisfy the requirement of the depletion chain solution that the coupling from parent to daughter nuclide be non - zero. That is, for all nuclides in depletion chains: (a) specify a chain of the form dN/dt = 0, (b) modify the chain lists containing the original chains to contain these new chains, and (c) assign a non - zero decay constant to each fission product nuclide. The temptation will be to circumvent this procedure by using an arbitrarily small power level, but such a procedure may not work.

EQUATIONS 4.8.1 - 4.8.5

$$\frac{dN_i}{dt} = \bar{Y}_i + \delta_{i-1}N_{i-1} - \gamma_i N_i \quad , \quad i = 1,\ldots,I \tag{4.8.1}$$

$$N_n(t_1) = \sum_{m=1}^{n} \delta_m^{-1} \prod_{k=m}^{n} \delta_k \left\{ \bar{Y}_m \left[\frac{1}{\prod_{\ell=m}^{n} \gamma_\ell} - \sum_{j=m}^{n} \frac{\exp\{-\gamma_j \Delta t\}}{\gamma_j \prod_{\substack{i=m \\ i\neq j}}^{n} (\gamma_i - \gamma_j)} \right] \right.$$

$$\left. + N_m(t_o) \left(\sum_{j=m}^{n} \frac{\exp\{-\gamma_j \Delta t\}}{\prod_{\substack{i=m \\ i\neq j}}^{n} (\gamma_i - \gamma_j)} \right) \right\} \tag{4.8.2}$$

$$|\gamma_i \Delta t| \geq 10^{-N} \tag{4.8.3}$$

$$|(\gamma_i - \gamma_j)\Delta t| \geq 10^{-N} \tag{4.8.4}$$

$$\lambda = \frac{0.6931}{T^*(.31536*10^8)} \tag{4.8.5}$$

4.9. HARMONY: CHAIN LISTS AND CHAIN LIST ASSIGNMENT

Once the chain descriptions have been established there must be a mechanism for determining which nuclides will appear together in a composition. This is done in two steps by (1) giving several lists of chains and then by (2) associating one of these chain lists with each depleting composition. A special chain list number of zero must be assigned to all non - depleting compositions.

A chain list is merely a list of chain numbers of those chains which are to be grouped together. Each chain list is checked for erroneous duplication of nuclides and for proper linearization of complicated chains. A list of permissible nuclides can then be prepared for each chain list. Other consequences of the chain list are mentioned later.

Through the chain list assignment, each composition is given a chain list number. Thus, a list of permissible nuclides is assigned to each composition. Any other mention of a nuclide in a composition, such as initial concentration or microscopic cross section table, is checked against the list of nuclides assigned via the chain list to that composition.

Once the chain list assignment has been made, each block of the problem is known to be either depleting or non - depleting. The second consequence of the chain list is that it defines the order in which the depletion equations are solved. This relates to the problem described previously (see Section 4.7) of calculating the fission yield in the fission product chains. The fission yield term includes the nuclide concentration of the fissionable isotopes at t = t(1), the end of the subinterval. The dependence of the yield on t(1) occurs directly through the concentration of the fissile nuclides at t(1), N(t(1)), and also through the dependence of the fission cross section on possibly other nuclide concentrations at t(1). If the fission cross section is independent of the nuclides occurring in the fission product chain and all the depletion chains containing the fissile nuclides occur in the chain list BEFORE the fission product chains, both N(t(1)) and the fission cross sections depending on the concentration of fissile nuclides at time t(1) are available to calculate the yield term. If these two quantities are not available (due to the user specified order of the depletion chains), the values at t = t(0) (the beginning of the subinterval) are used.

In most cases, the depletion chains should be listed first in the chain list, followed by the fission product chains. Regardless of the order of listing, when a fission product chain is encountered where the previous chain in the chain list was a depletion chain (or if it is the first chain of the list), the program recalculates the microscopic fission cross sections for t = t(1) whenever possible and uses them to update the fission rate. When the previous chain was a fission product chain, the fission rate used in the previous chain is used over again. This is the only effect induced by the ordering of the chains in the chain list.

The final consequence of the chain list itself is the determination of the number of subintervals in each block. Associated with each chain is a DELTA T MAX, which is the maximum subinterval length to be used with that chain. The program finds the minimum of these maxima for all chains in a chain list and uses it to determine an EFFECTIVE DELTA TIME interval for all depletion blocks associated with that chain list. That is, the smallest m is determined such that m times the effective delta time interval is equal to the renormalization time interval. Thus, chains are evaluated and cross sections are recalculated at m equal time intervals and this time interval is the effective delta time interval or subinterval.

4.10. HARMONY: CONCENTRATIONS - INITIAL/OTHER

INITIAL CONCENTRATIONS

The initial nuclide concentrations must be included for each depletable composition. They are required to be consistent with the chain list per composition in that no concentrations may be given for non - depleting compositions and values may be given only for permissible nuclides that have been assigned to a depleting composition. This establishes the requirement that each nuclide for which an initial concentration is given appear in at least one chain description which in turn appears in a chain list.

CONCENTRATIONS AFTER DEPLETION

To begin a depletion calculation the initial concentrations are expanded to provide a set of values for each depleting block of the composition. For succeeding calculations the concentrations computed in a previous step are used. The selection of previous results or card input is made implicitly by the presence or absence of a File Manager input concentration file specification. For ALL calculations the initial concentrations are used to provide N(0) for all interpolations in which the fraction N(t)/N(0) is used as an independent variable in the interpolating tables (see Section 4.4). They are also required for the replacement option in which the concentrations from a File Manager input concentration file are replaced either (1) for all nuclides in selected *compositions*, or, (2) for selected nuclides in selected *compositions*. Even if a problem uses nuclide concentrations generated by a previous problem, the initial concentrations must be included in the input. All concentrations not specified are set to zero. Special forms of input allow the specification of nuclide concentrations in one composition to be some (user specifed) constant times those from another composition.

CONCENTRATION REPLACEMENT

The replacement option can be used at any time in a depletion study except, of course, at beginning of life when concentrations are supplied via card input instead of a File Manager input concentration file. Replacement is performed either uniformly by composition or for selected nuclides by composition. When replacement is selected, a list of compositions must be given (presumably depleting compositions) in which the replacement is to be carried out. In addition, if selected nuclide replacement is desired, a list of nuclides must be given. In each (gross and fine) block in such compositions, previous nuclide concentrations are replaced by the spatially independent values supplied in the input for that composition. Any modifications to the properties in the non - depleting compositions can be accomplished with changes in the cross section table assignment and/or the composition assignment.

If it is desired to replace only part of an existing composition, this may be accomplished by assigning a new composition number to that portion of the existing composition through a composition assignment change. A chain assignment to this new composition may be different from the one previously assigned allowing a new set of nuclides to be used. The vital restrictions are that the total number of unique nuclides in the problem and the total number of blocks must remain fixed during the replacement process.

TRANSVERSE CONCENTRATION EXPANSION - FUEL SHUFFLING

The user may request the transverse shuffling of a depleted set of concentrations. This capability may be used to continue depletion after the loss of symmetry at some time in life. For example, if a core has half-core symmetry and is calculated as such but due to a stuck rod or the removal of a portion of the core that symmetry is lost, the concentrations may be expanded so that they will be positioned for a full core calculation. Actually, any kind of expansion can be done such as the addition (or even the deletion) of a module or assembly. In addition, any reordering of concentrations which is physically possible such as is required in fuel-shuffling may be done. The (old) geometry file corresponding to the original concentration file must be supplied to the program in addition to the (new) geometry which describes the current problem containing the desired structure. The user supplies sets of [old final figure, old channel bias, new final figure, new channel bias] to instruct the program on proper placement of the concentrations. Note that this implies that as

concentrations are moved from one place to another, the block structure is held constant, both gross and fine blocking. Within a final figure to be moved, the number of gross blocks and the number of fine blocks per gross block must not vary from old to new placement. This is in keeping with the concept of expansion as a movement and/or replication of a physical structure. All gross blocks in a final figure must have the same order as they did originally (but region numbers may change), and channel numbers may vary only by a constant from old position to new position. Final figure numbers may vary from the old description for the same structure in the new description. For any new figures not explicitly described in this process, a one-to-one transformation is done; in this case, of course, the old and new final figure numbers must be the same for those figures to be transformed one-to-one. If some entirely new structure is to be made, using just a portion of the old structure, the program can be instructed to set all concentrations in a figure to zero so that some other operation such as replacement can be done to supply concentrations for such portions. In this case there need be no figure in the old file which corresponds to the new figure which is to be zeroed. In any case, not all of the old figures need be used in the transformation process. The number of planes cannot change in this process. The same expansion is done for every plane in three dimensions.

GROSS TO FINE CONCENTRATION EXPANSION

The user may request the expansion of a set of gross blocked only concentrations over a set of fine blocks. Thus a core which has been depleted using gross blocking only may, at any point in life, be changed into a gross and fine blocking problem. The input to such an expansion problem contains all normal fine blocking information except for the input File Manager concentration file which is gross blocked only. The gross block concentrations for each nuclide designated as a fine block nuclide are assigned to each fine block within that gross block.

TRANSVERSE CONCENTRATION REDUCTION

The user may request the transverse reduction of concentrations according to a user defined prescription. This capability is useful, especially in three - dimensional problems, for reducing run times if some loss of accuracy is acceptable for the calculation. Note that at beginning of life, if the reduction preserves compositions, no loss in accuracy occurs. A set of figures and regions defines a new block made up of all of the occurrences of those figure - region combinations in the original concentrations. The new block is given the identification numbers of the first figure number in the list and the first region number in the list. All fine blocks (if any) are left unchanged except that those associated with a collection of blocks are collected together and associated with the one new reduced block. The reduction is performed in the same manner for every plane in three dimensions. Any input File Manager file containing block information (concentration, integrated flux, synthesis integral library) will be reduced in a compatible manner. The reduction of concentrations is performed by volume weighting the original concentrations; the other two types of data are in the form of integrals so they are simply summed. The geometry, of course, is reconstructed by the program to be compatible with the reduction that is performed.

AXIAL CONCENTRATION REDUCTION

The user may also request the axial reduction of files in a similar manner. The user defines CONTIGUOUS gross block planes which are to be reduced together. Fine block planes (if any) are left unchanged.

4.11. HARMONY: AREA DISTORTION FACTORS

The use of a reasonable number of mesh points in diffusion - depletion problems sometimes results in the distortion of several regions of the problem. If the distortion consists of an increase (or decrease) in the volume assigned to the region, the nuclide concentrations must be decreased (or increased) to keep the total inventory correct.

The program provides for the input of area distortion factors (or AREA RATIOS) by composition or by planar region - gross plane which allows a single table set and a single set of input concentrations to be used in several compositions, each of which is a distortion in volume by some factor from the composition for which the table set and concentrations were prepared. Use of these factors allows savings in table set generation and storage as well as the use of non - distorted input concentrations. If these factors are not input, values of unity are assumed for all space.

In the following definitions, upper case symbols shall be interpreted as that data which has been distorted due to differences between actual reactor dimensions and those dimensions used to describe the geometry in the problem; lower case symbols shall be interpreted as non - distorted data. The following symbols will be used in the descriptions:

n = some nuclide concentration,
v = some unit of volume,
a = area ratio input.

By definition, the following relationships exist:

$$a = v/V,$$
$$NV = nv,$$
$$N = na.$$

Using these definitions, the area ratio treatment can be described as follows:

A. The geometry input will describe mesh spacings such that each unit of volume will be V.

B. The input nuclide concentrations will be assumed to be n, not N.

C. In the macroscopic cross section calculation, the table set data will yield non - distorted cross sections. This data will be translated to produce "distorted" macroscopic cross sections by dividing the diffusion coefficient and multiplying all other cross sections by the area ratio a.

D. The distorted macroscopic data and areas will be used to calculate the eigenvalue and flux solution.

E. In all integral editing (volume weight, flux weight, average concentrations, ...), non - distorted cross sections and areas are used, possibly in combinations, to produce the required edit data. Note that, in particular, the volume edited is NOT the volume input via the geometry description if non - unity area ratios are supplied. However, the distorted volumes by region WILL be edited in the geometry input edit to reflect the actual input geometry.

F. For spatial power distribution calculations and for integration of power for normalization of flux and power distributions, the non - distorted cross section and volume data are used.

4.12. HARMONY: REQUIREMENTS AND RESTRICTIONS

Since cross section input can consist of an arbitrary mix of card input data and data from a File Manager input tableset file, and since depletion chains are user specified, the opportunity for error in specififying such input is greater than normal. The program has a very extensive set of checks and error diagnostics to assist the user in setting up a problem.

This section summarizes some of the more basic requirements and restrictions of the program with respect to cross section input, chain input, and concentration input.

(1) Each composition must have a master macro table assigned to it, either directly via table set assignment or via table overlay assignment.

(2) Non - depleting compositions may not have a master micro table or an interpolating table assigned to them.

(3) Each depleting composition must have at least one master micro table assigned to it, either directly via table set assignment or via table overlay assignment.

(4) All nuclide ID's listed in a composition (e.g. via assignment of concentrations, micro tables, function tables, mask tables,...) must be in the list of permissible nuclides assigned to that composition as determined by the chain list assignment (see Section 4.9).

(5) A mask table using N(t)/N(0) for any of the independent variables should not be assigned to function tables which are to be used in more than one composition where N(0) varies between these compositions. The program does not make this check. An exception to this occurs if N(0) is the same from composition to composition but is effectively different due only to different area ratios.

(6) In the calculation of the macroscopic fission cross section used in the power calculation for thermal flux renormalization during depletion, the assumption is made that there is no contribution from the master macro table or interpolating macro tables towards the fission cross section. If such a contribution is present, it is ignored.

(7) If the power level is identically zero, special chain equations may be required to satisfy the requirement of the depletion chain solution that the coupling from parent to daughter nuclide be non - zero. That is, for all nuclides in depletion chains: (a) specify a chain of the form dN/dt = 0, (b) modify the chain lists containing the original chains to contain these new chains, and (c) assign a non - zero decay constant to each fission product nuclide. The temptation will be to circumvent this procedure by using an arbitrarily small power level, but such a procedure may not work.

(8) The total number of unique nuclides must not vary during depletion. The number of unique nuclides to be depleted over fine blocks also must not vary during depletion. Fine block depletion can be omitted at any step in the depletion process without affecting the flux calculations. But if fine block depletion is desired at any time, then either the previous time step must have included fine block depletion or the gross to fine concentration expansion option must be used.

(9) All daughter nuclides which are fine block depleted must have parent nuclides which are fine block depleted.

5.1. EDIT CAPABILITIES: INPUT PROCESSING EDITS

The program output always begins with a one page edit of USER NOTICES. These notices describe the latest changes or additions to the program. If the program is executed with no card input data, a special edit is printed. This special edit consists of ALL past user notices and an input CHECKLIST which includes a brief description of every possible input card.

For every case of input, the following are always edited during input processing:

(a) CARDFILE cards in the order they are encountered;

(b) Card data from card files in the order they are processed;

(c) Card input data for the current case;

(d) A one page summary of important problem parameters; and,

(e) In synthesis cases, the trial function descriptions.

If sub-cases are being executed, (a) through (e) are edited only in the parent case but a short summary edit of important problem parameters at the beginning of each sub-case is always included.

All other editing of input data which can occur during input processing (except, of course, error commenting) is optional. There are five major sections of optional input editing which can be requested:

1. Geometry data,

2. Concentration data,

3. Harmony input data,

4. Integration edit definitions, and

5. Geometry pictures.

These edits, as well as all other optional edits in the program, are defaulted "off"; that is, they are not done unless specifically requested. In addition, such edit requests are deleted from case to case and thus must be requested explicitly in each case if desired. Detailed descriptions of these five optional input processing edits can be found in Section 17.1

5.2. EDIT CAPABILITIES: INTEGRATION EDITS

The integration editing includes flux integrals, power fractions, absorption rates, fission rates, group - dependent and group - independent bucklings, K-infinity, K-effective, volume - weighted and flux - weighted macroscopic parameters, average nuclide concentrations, nuclide loadings in kilograms, arbitrary algebraic combinations of nuclide reaction rates and atom counts, edits of concentrations during xenon feedback, and edits of various thermal - hydraulic indicators during temperature feedback. Except for the arbitrary combination edit of nuclide integral data which is over all problem space, all integral editing is performed for defined EDIT SETS and some set of gross planes, either separately or integrated.

Integral data involving flux and macroscopic parameters are edited every case or sub-case. Integral nuclide data are optionally edited during the depletion process and will not be edited if the depletion path chosen is "no depletion". Of course, xenon and temperature feedback integral data is optionally printed only during those feedbacks and will not be printed if such feedbacks are not specified.

An EDIT SET is an arbitrary collection of final figure numbers together with an arbitrary collection of planar region numbers. Each edit set thus defines a region of the mesh, not necessarily connected, which is to be treated as a unit for integration editing purposes. A particular mesh element belongs to each edit set whose definition includes both the final figure number and the planar region number of the mesh figure. Thus, a particular mesh element may belong to any number of edit sets. Every integral quantity is calculated for each edit set in each gross plane. Note that the edit sets are the same in every gross plane since they depend only on final figures and planar regions.

Edit sets which have zero volume (no specified figure - region pairs exist in the solution region) and edit sets for which the integral data is identically zero are not printed.

In three - dimensional problems, the user must define the axial limits of integration. A PLANE GROUPING is a collection of gross planes, not necessarily connected, which is to be treated as an axial integration unit. Note that a particular gross plane may belong to any number of plane groupings. All edit set integrals are summed over the planes comprising a plane grouping before being manipulated and printed. Thus, to identify the region of integration for a single printed quantity requires a list of final figures, a list of planar regions, and a list of gross planes (identified by point plane number limits). The program solves this identification problem by numbering both the edit sets and the plane groupings. The definition of each of these is printed once during input processing, and integral quantities are then identified by edit set number and plane grouping number.

For three - dimensional problems an alternate method of printing, utilizing AXIAL EDITS, is available. An AXIAL EDIT is a collection of edit sets and a contiguous set of individual gross planes, each of which is to be edited. The axial limits of integration for axial edits are the gross plane boundaries. Thus, the program may be directed to provide data integrated over edit set space AND over plane grouping space by the use of plane groupings, or edit sets may be printed individually for each gross plane of interest by the use of axial edits. Not all of the integration edits are available with axial edits. In particular, only the average flux, power, concentrations (density and/or loading), and thermal - hydraulic results may be printed in this manner. Either plane groupings may be printed or axial edits may be printed or they may both be printed. Axial edits may either be printed, printer - plotted in combination or alone, or both. As in the case of plane groupings, the axial edits are numbered and printed once during input processing, and integral quantities are then identified by edit set number and axial edit number.

5.3. EDIT CAPABILITIES: INTEGRAL APPROXIMATIONS

The integral approximations used in each geometry are consistent with the assumptions made in the derivation of the difference equations for the flux solution. The integral of any quantity over a region of the mesh is calculated by summing the integrals for the individual mesh figures comprising the region. Further, since all material properties such as macroscopic and microscopic cross sections are constant within a mesh figure, any cross section times the flux is simply the cross section times the integral of the flux for that mesh.

In rectangular, hexagonal, and quadrilateral geometry the flux integral for a mesh figure is approximated by the numerical average of the flux values at the vertices multiplied by the length (in one - dimension), area (in two - dimensions), or volume (in three - dimensions) of the figure. In hexagonal and quadrilateral geometries, the transverse mesh element is a triangle.

In cylindrical geometry, the one - dimensional integral is approximated by Equation 5.3.1, and the two - dimensional integral is obtained by averaging the integrals along the top and bottom of a mesh element and multiplying by its height.

In spherical geometry, the integral is approximated by Equation 5.3.2.

In three - dimensional synthesis, the flux integral is the integral of the mixing coefficient multiplied by the integral of the transverse planar flux of the trial functions all summed over trial functions as shown in Equation 5.3.3. The mixing coefficient is not a pointwise quantity; rather, it is assumed constant from the mid - point of one mesh interval to the mid - point of the next. Further, trial function zone boundaries occur at mid - points of the mesh. Therefore, the integral of the mixing coefficients is simply the mixing coefficient multiplied by the appropriate half - interval and summed over the intervals in a gross or fine plane.

Finally, for depletion purposes, the average flux in a gross or fine block is given by Expression 5.3.4 where the integrals are evaluated as indicated previously.

EQUATIONS 5.3.1 - 5.3.4

$$\int_{r_1}^{r_2=r_1+h} \phi(r)dV \doteq 2\pi \left\{ \frac{h}{2} [r_1\phi(r_1) + r_2\phi(r_2)] + \frac{h^2}{6} [\phi(r_1) - \phi(r_2)] \right\} \qquad 5.3.1$$

$$\int_{r_1}^{r_2=r_1+h} \phi(r)dV \doteq 4\pi \left\{ \frac{h}{2} [r_1^2\phi(r_1) + r_2^2\phi(r_2)] + \frac{h^2}{3} [r_1\phi(r_1) - r_2\phi(r_2)] + \frac{h^3}{12} [\phi(r_1) + \phi(r_2)] \right\} \qquad 5.3.2$$

$$\int \phi_g dV = \sum_j \int Z_g^j(z)dz \int \phi_g^j(x,y)dxdy \qquad 5.3.3$$

$$\frac{\int \phi_g dV}{\int dV} \qquad 5.3.4$$

5.4. EDIT CAPABILITIES: POINTWISE EDITS

All pointwise editing is done over two specified regions of the mesh, the first for flux and the second for power. These regions are defined as a box containing some contiguous set of columns, rows, and planes. Editing of each pointwise quantity is optional, including the flux in each group, the total thermal flux in a two - thermal group problem, the partition power, and the average or peak point power.

In a three - dimensional synthesis problem, pointwise flux edit indicators may be used to edit either the pointwise flux or the synthesis axial mixing coefficients or both. The mixing coefficients are also printer - plotted, if requested, but in this case are normalized so that they represent the FRACTIONAL FLUX contributions of each trial function at each axial point. The normalization consists of the transverse integral of the trial function divided by the sum of such integrals over all trial functions in that group and that zone. On these printer - plots, trial function zone boundaries are indicated as are functional values of zero and one.

Partition power consists of a value for each mesh figure at each point and is printed only for those points at which any two nonzero values differ from the average power by more than five percent. There are two partition power values per point in one dimension; there are four, six, or eight values per point in two dimensions; and there are eight or twelve values per point in three dimensions. Partition power is calculated using the pointwise flux together with the fission cross sections appropriate to the mesh elements surrounding that mesh point.

NOTE

The fission cross sections used for the calculation of partition power are the GROSS BLOCK fission cross sections. Since all other forms of pointwise power are obtained by operating on the partition power, these gross block fission cross sections are used for all pointwise power values.

Point power may be edited either as the average of the nonzero partition power values at a point or as the largest (peak) of these values. In either case a relative maximum edit may also be obtained which identifies each point at which the power exceeds the value at any of its neighbors.

5.5. EDIT CAPABILITIES: MESHWISE EDITS

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. Any of this data may be edited for each mesh element in non - quadrilateral geometry problems. Since, in general, a block is larger than a single mesh element, this edit smears the data into the appropriate mesh elements so that the data can be printed in a regular grid pattern. There are two different types of mesh edits and, in the case of one - dimensional problems, a third type of mesh edit.

The first type of mesh edit simply prints a value for each mesh element. The region to be edited is specified separately for nuclide concentrations; for the average power, the edit region specified for pointwise power edits is used.

Another type of mesh edit, called a display edit, is very compact since it does not print a value for each mesh element but instead prints a single character for each mesh element. This character represents a "range" of values between a maximum and minimum. A table is included with each item edited giving the characters and the associated ranges. Each item edited may be edited over a separate edit region.

A third type of edit is available for one - dimensional problems. The quantities may be printer - plotted as well as printed.

5.6. EDIT CAPABILITIES: BLOCKWISE EDITS

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. This block data may be edited directly. Such an edit is much more compact than a mesh edit since there is no expansion of the data over all mesh elements associated with a block and there is no imposed mesh grid structure. However, since block identification by block number is difficult to decipher, this type of edit utilizes a user defined structure in the various geometry labels associated with each block to identify the printed data. For gross block data, final figures and planar regions as well as axial plane limits are used to identify the data of interest. For fine block data, channels and tracks as well as axial plane limits are used to identify the data of interest.

These types of edit are called HIERARCHICAL edits because the user defines an ordered set of structures and this set represents a hierarchy of levels of structures. The user creates this structure by defining disjoint fields in the existing geometry labels (final figure and planar region or channel and track). Each field is defined as a set of contiguous decimal digits in the geometry labels. A name is assigned to each set of digits; that is, to each field. These names are then used to identify the output data. These definitions are hierarchical; that is, they have an order and this order determines the order of the data printed. To select an edit, a particular value of each field is selected, from the first (highest) level down to the last specific level desired. The program will then obtain the data associated with the specified field values and print ALL sub-structures included.

For example, the user might define three fields in a channel label and name these fields "CLUSTER", "SUB-ASSEMB", and "ELEMENT"; the entire track label might be named "TRACK". These four labels might represent structures called cluster, sub-assembly, element, and track respectively. Then an edit request might be to print data for a particular quantity such as fine block power, say, for cluster 17. The program would then find cluster 17 and print all fine block power data in that cluster, identifying the various pieces with appropriate labels "SUB-ASSEMB" number, "ELEMENT" number, and "TRACK" number. All sub-assemblies in cluster 17 would be printed in numerical order, all elements in each sub-assembly would be printed in numerical order, and all tracks in each element would be printed in numerical order. Further, in this same example, perhaps only data for sub-assembly 23 in cluster 8 is desired. The program would then scan the data for sub-assembly 23 in cluster 8 and print all data in that structure, identifying the various pieces with the appropriately labeled "ELEMENT" number in numerical order, and for each element print data for all "TRACKS" in numerical order.

Multiple hierarchies may be defined in the same problem. In the example given, the order of the definitions of "SUB-ASSEMB" and "CLUSTER" might be interchanged, with the result that these two fields would be interchanged in the hierarchy. This would then allow, for example, the specification of sub-assembly 14 and the program would print the results for every cluster which contained sub-assembly 14 in numerical order of cluster, then for each such cluster, would print the results for each element in numerical order of element, and finally for each such element would print the results for each track in numerical order of track.

For each quantity edited, the maximum and minimum values and their "location" (given by defined labels as noted previously) are printed. In the scan for maximum and minimum values, zero values are ignored. An option exists to scan a defined structure and print only such maximum and minimum values and their location.

Of course, this edit system depends on the user to include some structure in the various geometry labels. In the example, digits 3 and 4 in a channel label might always represent the cluster number; digits 6 and 7 might always represent the sub-assembly number; digit 1 might always represent the element number. For such a structure, element 3 in sub-assembly 19 in cluster 12 would have a channel label of 1901203. Note that digits are counted from right to left in each field label. The track label in this example contained only a single field so it could contain track numbers in any order convenient for proper identification of results.

In these edits, sub-structures which contain nothing but zero data values are not printed. At the lowest level, data values are printed across a line and leading zero values are skipped.

6.1. FEEDBACKS: CONTROL SEARCH - ONE DIMENSION

In one - dimensional problems, a control search to obtain a specified reactivity is available via a MULTIPLE CONFIGURATION search capability. The multiple configurations are different geometric descriptions, each describing different material arrangements. One final figure - planar region overlay is input and this overlay includes all possible material interfaces for all configurations. Then, configurations are described by specifying composition to planar region (or final figure) correspondences for each configuration. This configuration description is similar to the axial composition assignment as provided in three - dimensional problems to show axial material changes. Configurations must be described such that the calculated eigenvalue increases with increasing configuration number or the search may not converge.

Movable boundaries within a configuration are specified through the use of composition numbers. A movable boundary can only occur at a composition interface. Negative composition numbers specify "movable compositions", and the largest mesh point number in a movable composition is said to be a movable boundary. If a "movable composition" is not contiguous in the composition overlay, more than one movable boundary is defined for that composition.

The mechanics of the multiple configuration search are as follows. To simulate the movement of a control element, boundaries of the control element are moved. The concentrations (if any) are not moved during this process; only the geometry description is altered in the simulation of the movement. Boundary moves are based on the final figure - planar region overlay, the composition correspondence for the current configuration (which defines movable boundaries), and the value of the latest eigenvalues. After each boundary move, an eigenvalue is calculated and the search is terminated or another boundary move is made. The search is terminated if the convergence criterion is met, the maximum number of search tries has occurred, or if no more moves can be made. The program can be directed to terminate just the search or to terminate the entire problem if a desired reactivity cannot be obtained.

A restriction is made on the boundary moves such that no final figure - planar region pair is destroyed; i.e., a movable boundary can move only as close as one mesh interval from the adjacent final figure - planar region pair. Incidentally, multiple movable boundaries are all moved at once; this capability can be utilized to step through a configuration a fixed number of points each move. If no more moves can be made in a configuration, the next configuration (in the appropriate direction) is tried if there exists such a configuration. Each time a new configuration is started, the original geometry description is used and then "perturbed" through boundary moves. A capability is available to start the search in any configuration using either the perturbed geometry description, if available via an input File Manager geometry file or via a previous sub-case, or the original geometry description.

The gross blocking in every one - dimensional problem is one mesh element per gross block. When the multiple configuration search is chosen, fine blocking is not allowed. In addition, when the multiple configuration search is chosen the poison search may not be used.

Information pertaining to the last condition of this search is included in an output File Manager geometry file if such a file is saved. Therefore, if from case to case the search initial state is to be that of the final state in a previous case, an output File Manager geometry file must be saved and that file must then be input to the next case. During sub-case execution, such information is automatically carried from one sub-case to the next.

6.2. FEEDBACKS: CONTROL SEARCH - TWO DIMENSIONS

In two - dimensional cylindrical (R-Z) problems, the program can be directed to position a defined control element axially to obtain a desired reactivity. Since the control element containing concentrations and the material geometry is explicitly moved in the search, this capability can be a MOVABLE FUEL or a CONTROL ROD search. The positioning may be to the nearest discrete (axial) mesh point, or the axial mesh spacings will be adjusted, if possible, to obtain the eigenvalue desired within a specified criterion. The search is terminated if the convergence criterion is met, the maximum number of search tries has occurred, or if no more moves can be made.

The control element may consist of multiple elements, each with a common top and bottom. The control element is specified by giving the top and bottom axial mesh points common to all pieces of the control element. Then left and right pairs are given which are column numbers outlining the radial boundaries of the pieces of the control element. If the search is to obtain an eigenvalue arbitrarily close to a specified value, the axial mesh is changed if possible. To change the axial mesh, the radial (row) interfaces of gross blocks in the fixed and moving portions of the geometry must not line up. If they do, the program will perform a one - point move (incremental) before attempting to change the mesh (non - incremental). If the interfaces still line up after the one - point move, the best point is chosen and the search is terminated. One method of insuring that the program will always be able to adjust mesh spacings is to make the minimum gross block height be at least two (axial) meshes and to make all other gross glock heights an integral multiple of that minimum block height. The program will not allow the minimum mesh spacing to become less than one one - hundredth of the (necessarily constant) mesh specified in the control element.

The axial (row) mesh must be constant in the control element and throughout the axial space that the element may move.

When axial moves are performed, some portion of the material and geometry description will, in general, be destroyed and some new material and geometry description will be inserted into vacated positions. Generallly, this destroyed material is the axial reflector and this determines the strategy used in filling vacated positions. The vacated positions are filled with the material and geometry description from the portion (axially) next to the control element. For example, when moving upward, some portion of the material and geometry description just above the control element is lost and the sections just below the control element are filled with the material and geometry description which exists just below the control element before it is moved. If the control element is already up against a problem extremity, then that portion of the control element touching the extremity is smeared into the vacated positions when required.

All pieces of the control element are moved axially the same amount and in the same direction for every move. Upper and lower limits for movement of the control element as well as the maximum amount of any one move are specified in the input as constraints on the search. The control element may be partially moved out of the top or bottom of the problem mesh description if so desired, but the control element may not be moved entirely out of the problem.

When this control search is chosen, the poison search cannot be used and fine blocking cannot be done.

Information pertaining to the last condition of this search is included in an output File Manager geometry file if such a file is saved. Therefore, if from case to case the search initial state is to be that of the final state in a previous case, an output File Manager geometry file must be saved and that file must then be input to the next case. During sub-case execution, such information is automatically carried from one sub-case to the next.

6.3. FEEDBACKS: CONTROL SEARCH - THREE DIMENSIONS

In three - dimensional problems, the program can be directed to position a defined control element axially to obtain a desired reactivity. For three - dimensional explicit or synthesis problems, a control search which positions an element axially to the nearest gross plane is available. Since the control element containing concentrations and the material geometry is explicitly moved in the search, this capability can be used as a MOVABLE FUEL search, although a control rod search is possible using this technique. For three - dimensional synthesis problems only, a capability is available to position a single axial interface so that the eigenvalue obtained is arbitrarily close to a specified eigenvalue. Since a single interface controls the behavior of the search, this search is called a FAST ROD SEARCH, implying that a control rod is the controlling element. For this fast rod search, it is assumed that there is only one uniform material above and one uniform material below the interface for the entire planar extent of the controlling element. Some of the search mechanisms for these two types of searches are common but their behavior is sufficiently different that two different descriptions will be given.

MOVABLE FUEL SEARCH

In the movable fuel search, the positioning will be to the nearest gross plane boundary to obtain an eigenvalue nearest the specified search eigenvalue. The search is terminated if the nearest gross plane has been found, the maximum number of search tries has occurred, or if no more moves can be made.

The control element is specified by giving the top and bottom axial mesh points for each piece of the control element. These axial mesh points must be gross plane boundaries. The planar pieces of the control element are described by planar regions or final figures (whichever correspond to compositions). The control element may consist of multiple planar pieces, and each may have a different top and bottom.

The axial mesh must be constant in the control element and throughout the axial space that the element may move. In addition, the gross planes and fine planes must contain a constant number of axial meshes per block plane throughout the axial space that the element may move. Also, if fine blocking, there must be a constant number of fine planes per gross plane throughout this same axial space.

When axial moves are performed, some portion of the material and geometry description will, in general, be destroyed and some new material and geometry description will be inserted into vacated positions. Generally, this destroyed material is the axial reflector and this determines the strategy used in filling vacated positions. The vacated positions are filled with the material and geometry description from the portion (axially) next to the control element. For example, when moving upward, some portion of the material and geometry description just above the control element is lost and the sections just below the control element are filled with the material and geometry description which exists just below the control element before it is moved. If the control element is already up against a problem extremity, then that portion of the control element touching the extremity is smeared into the vacated positions when required.

All pieces of the control element are moved axially the same amount and in the same direction for every move. Upper and lower limits for movement of the control element as well as the maximum amount of any one move are specified in the input as constraints on the search. The control element may be partially moved out of the top or bottom of the problem mesh description if so desired, but the control element may not be moved entirely out of the problem.

The mechanism of the movable fuel search may be employed to initially position the element to the gross plane boundary nearest to a location specified by the user. Such an initial move is done after depletion if deplete - first is done, but prior to any other calculations being performed by the program. The search may optionally be continued from this position.

When the movable fuel search is chosen, the poison search cannot be used.

Information pertaining to the last condition of this search is included in an output File Manager geometry file if such a file is saved. Therefore, if from case to case the search initial state is to be that of the final state in a previous case, an output File Manager geometry file must be saved and that file must then be input to the next case. During sub-case execution, such information is automatically carried from one sub-case to the next.

FAST ROD SEARCH

In the fast rod search an interface between two uniform axial materials is positioned such that the eigenvalue may be obtained arbitrarily close to a desired eigenvalue. The search consists of two distinct stages: (1) incremental, in which the interface is positioned to the nearest gross plane boundary, and optionally, (2) non-incremental, in which the interface is positioned to an exact axial location. The search is terminated if the required position has been obtained, the maximum number of search tries has occurred, or if no more moves can be made.

A single control element is specified as in the movable fuel search by giving the top and bottom axial mesh points which bound the element. These axial mesh points must be gross plane boundaries. Since the mechanism of the fast rod search operates primarily on a single axial interface, the user must specify which of the boundaries of the control element (top or bottom) designates the interface. The planar extent of the control element can consist of multiple pieces and is described by final figures or planar regions (whichever corresponds to compositions).

The axial mesh must be constant in the control element and throughout the axial space that the element may move. In addition, the gross planes and fine planes must contain a constant number of axial meshes per block plane throughout the axial space that the element may move. If fine blocking, there must be a constant number of fine planes per gross plane throughout this same axial space. To guarantee that the non-incremental portion of the search will be able to be performed, there must be at least one internal axial mesh point in each inventory plane throughout the axial space in which the element will move. That is, if a non-incremental move is to be made to a position within a particular gross plane, that gross plane must contain an internal axial point. The same is true for fine planes in fine blocked problems.

Axial moves are performed by effectively moving the specified interface and thus altering the axial distribution of the two materials. During the incremental portion of the search this interface is moved only to axial points which are gross plane boundaries. The interface is permitted to cross synthesis trial function zone boundaries during the incremental search. However, a substantial run time increase will be observed for moves in which a zone boundary is crossed.

When the closest incremental position has been obtained, the non-incremental search will begin if it has been requested. The interface is moved from its last incremental position (a gross plane boundary) to a location internal to a gross plane. The interface is attached to the axial mesh point in the gross plane which is (1) not a gross or fine plane boundary, and (2) the closest such point as predicted by the current rod worth (which may be the input worth if no incremental moves have been done). If such a free point does not exist, the search is terminated.

Once attached to such a point, the interface is effectively moved to an exact axial location by altering the axial mesh spacings above and below this point (but keeping their sum constant). Once attached to a particular free point, the program will continue the non-incremental portion of the search by allowing the interface to move only in this band subject to the restriction that the modified axial mesh spacings never go below one one - hundredth of the constant axial mesh in the control element.

A non-incremental move may not cross a synthesis trial function zone boundary. Should moving the interface to the closest free point in the gross plane result in the necessity to cross a trial function zone boundary, this zone boundary will, if possible, be moved by the program within the same gross plane to permit the move to be made.

In the case in which a non-incremental move is performed, it should be noted that although the flux solution is obtained with the interface at the exact axial position, subsequent edits will be done with the macroscopic data at the last incremental position. Similarly, the composition correspondences in the geometry description will reflect the last incremental position.

The mechanism of the fast rod search may be employed to position the interface to an exact location specified by the user. Similar to an actual search, such an initial move is performed in two parts. The incremental portion is done after depletion if deplete - first is done, but prior to any other calculation performed by the program. If the initial move is made only to the nearest gross plane, the search may optionally be continued from this point. If an exact initial position is requested by the user, no searching will be done. The non-incremental portion of an initial exact move will not be performed until other feedbacks (such as xenon or temperature), if any, have been completed.

When the fast rod search is chosen, the poison search cannot be used.

Information pertaining to the last condition of this search is included in an output File Manager geometry file if such a file is saved. Therefore, if from case to case the search initial state is to be that of the final state in a previous case, an output File Manager geometry file must be saved and that file must then be input to the next case. During sub-case execution, such information is automatically carried from one sub-case to the next.

6.4. FEEDBACKS: POISON SEARCH

The POISON SEARCH provides a capability to fractionally vary the concentration of one particular nuclide in each gross block which contains that nuclide to obtain some desired reactivity. This nuclide is given no special treatment by the cross section generation or depletion sections of the program. Thus, the concentration of this nuclide may vary, in its initial state, by composition (card input) and/or by gross block (depletion), and have any allowable cross section effect desired. In addition, the initial state of this nuclide may be zero in some compositions. Of course, if the nuclide is zero everywhere there can be no variation by this search since the concentration is fractionally changed.

The search assumes an initial guess of unity for the fractional multiplier of the nuclide concentration. The input supplies an initial guess for the (assumed linear) variation of the eigenvalue due to a change in the fractional multiplier (worth). Both the fraction value and the worth are updated each search try until the computed eigenvalue satisfies an input specified "closeness" criterion, or until the specified maximum number of search tries have been done, whichever occurs first.

For each case, the initial fraction value is set to unity but if an input File Manager geometry file is present, the initial worth is taken from that file and not from card input. For each sub-case, the initial worth used is that from the previous sub-case and the initial fraction value is unity.

When the poison search is chosen, there cannot exist multiple configurations in the problem and no other control search can be used.

Information pertaining to the last condition of this search is included in an output File Manager geometry file if such a file is saved. Therefore, if from case to case the search initial state is to be that of the final state in a previous case, an output File Manager geometry file must be saved and that file must then be input to the next case. During sub-case execution, such information is automatically carried from one sub-case to the next.

6.5. FEEDBACKS: THERMAL FEEDBACK

The procedure called THERMAL FEEDBACK provides the capability to compute a spatial flux distribution which is consistent with the spatial distribution of fuel temperature, moderator temperature, and moderator density. This feedback procedure consists of first calculating the power distribution assuming some temperature and density distribution and then calculating temperature and density distributions by gross block based on this power distribution. A new power distribution is then calculated using the latest temperature and density distribution. This process is continued until a specified maximum number of thermal calculations has been completed or until some convergence criterion is satisfied, whichever occurs first. The criterion measured is the maximum relative change between iterates of one of the (input specified) three quantities being computed.

The specifications for the thermal calculations performed by the program are given in Reference 14. Those specifications have been slightly extended as noted later in this section. The reference specifies a method of obtaining the fuel temperature, moderator temperature, and moderator density when the power distribution is known. The power distribution results from solving the spatial flux problem and combining this flux with a spatial distribution of the cross sections. The fundamental assumption in the thermal solution is that the moderator flow in the core is known and is independent of the power distribution. The thermal calculations are coupled to the reactor diffusion - depletion calculation through the power distribution and the depletion of the fuel, which influences the thermal conductivity of the fuel material. The moderator temperature and density are calculated for each gross block in the core since the flow rate and power generation in that block are known. The fuel temperature is then calculated after the moderator temperature has been obtained. It should be noted that the model described in the reference was derived for light water moderated and cooled reactors.

The program will accomodate one, one and one-half, and two-pass cores. A one and one-half pass core is one in which part of the flow leaving the first pass goes directly to the outlet, and the remainder is returned for a second pass through the core. The inlet temperature is specified for all non second-pass tracks (a thermal - hydraulic track, not to be confused with the input geometry "track" label, will be defined later in this section). The inlet enthalpy to the second pass is calculated as the average outlet enthalpy from those first pass tracks whose flow is returned for a second pass.

Any geometry in the program which explicitly exhibits the axial direction may be chosen. These geometries include one - dimensional slab (rectangular), two - dimensional cylindrical (R-Z), and three - dimensional (any radial geometry, either explicit or synthesis). The direction of enthalpy rise (flow direction) is optional so that point, line, or plane zero (1-D, 2-D, or 3-D respectively) may be chosen as the top or the bottom of the core, whichever is more convenient. The power is calculated for each gross block and thus the temperatures and density are calculated for these same blocks. For each block, the thermal calculation is performed at one axial level; then, the enthalpy from the top of that block is assumed to be the enthalpy at the bottom of the block in the same track at the next level.

A thermal - hydraulic track is a radial area of the core which runs through the entire axial dimension. Thus a track is composed of many pieces, called levels, all having a common radial shape. At any one level, a track element is a gross block. Thus, in one dimension there is only one track and the track elements are mesh elements which are the gross blocks.

In two dimensions, tracks are defined by the extension axially of all vertical figure - region interfaces and track levels are defined by the extension of all horizontal figure - region interfaces. Thus, track elements are gross blocks which are rectangular in shape. This process of extending all figure - region interface lines is called rectangular blocking and is automatically performed by the program for R-Z geometry.

In three - dimensions, the radial definition of a track is a unique figure - region pair. The height of the track element at any one level is the gross plane height at that level. Thus, again, a track element is a gross block.

The temperatures and density are represented in the program as nuclide concentrations. These particular "nuclides" possess a spatial distribution, then, not as the result of a depletion calculation, but as the result of a thermal calculation. Since the HARMONY cross section calculations do not treat these pseudo nuclides in any special way, these "concentrations" may have the same kind of effect on macroscopic cross sections, microscopic cross sections, and self-shielding factors as any other nuclide concentration. That is, these pseudo concentrations may be assigned microscopic cross sections and self-shielding factors, and/or they may serve as an independent variable in any kind of interpolation table. In order that these temperatures and densities have some effect on the spatial distribution of the power, then, a nuclide chain for each (usually of the form dN/dt = 0) must be assigned to each appropriate composition so that cross section dependency can be established. The concentrations representing these temperatures and densities have the following form.

(1) Fuel Temperature "nuclide" N(Tf) - represented as the square root of the calculated fuel temperature in degrees Rankine minus the square root of the reference fuel temperature in degrees Rankine.

(2) Moderator Temperature "nuclide" N(Tm) - represented as the calculated moderator temperature in degrees Fahrenheit minus the reference moderator temperature in degrees Fahrenheit.

(3) Moderator Density "nuclide" N(Rho) - represented as the calculated hydrogen density minus the reference hyrogen density.

In each case, the reference value is user specified by composition. The pseudo nuclide N(Rho) should be explained in more detail. The moderator density calculation never explicitly calculates the actual hydrogen density. Instead, the fractional density change based on the calculated moderator density and the moderator density obtained from the water property tables using the input reference moderator TEMPERATURE is calculated. This fractional change is then multiplied by the input reference hydrogen DENSITY to obtain N(Rho).

A brief description of some methods for utilizing these pseudo concentrations to obtain the desired effect on cross section behavior is given in Reference 12.

Utilizing a specified system pressure, the program obtains all appropriate water properties from the HOH routines (Reference 15). The system pressure value is assumed constant during the entire feedback process.

The effect of fuel rod clad shrinkage on moderator density may be optionally included in the feedback calculation. In this mode, three additional pseudo nuclides representing the maximum fuel centerline temperature over lifetime, the clad inner radius, and the clad stress must be included in the problem input description. The "concentrations" of these three pseudo nuclides are updated only after the feedback process has converged or the specified maximum number of feedback calculations has been completed.

The changes to the specifications in Reference 14 as implemented in the program are as follows. The fuel element temperature calculation has been modified to allow the fuel conductivity to be input in table form as a function of fuel temperature and depletion. Gap conductance is also input in table form but as a function of heat flux and depletion. The turbulent mixing treatment has been modified to allow a more simple input description. With the exception of the turbulent mixing terms (turbulent mixing is allowed only in R-Z geometry), all flow is assumed to be in the axial direction. This later restriction is in contrast to the referenced specification in which cross flow was permitted. In addition, the flow is input per unit area (lb/hr-sq ft) instead of total flow (lb/hr). It is important to note that the area in such values are the nuclear design homogenized area, not the actual flow area. Also, the equations to determine the fuel temperature have been modified slightly to allow a non-zero gap between the fuel and the clad. If fuel rod clad shrinkage is being calculated, the gap conductance is no longer obtained from interpolation of input data but rather is calculated directly by the program in an iterative fashion. In specified tracks, the program will assign as the moderator temperature the radial-average moderator temperature at each axial level.

6.6. FEEDBACKS: XENON FEEDBACK

The procedure called XENON FEEDBACK provides the capability to compute a spatial flux distribution which is consistent with the spatial distribution of equilibrium concentrations of the iodine and xenon nuclides. This feedback procedure consists of first calculating the power normalized flux distribution assuming some iodine and xenon distribution and then calculating asymptotic iodine and xenon distributions by gross block based on this power normalized flux distribution. A new power normalized flux distribution is then calculated using the latest iodine and xenon distribution. This process is continued until a specified maximum number of xenon calculations has been completed or until some convergence criterion is satisfied, whichever occurs first. The criterion measured is the maximum relative change between iterates of the xenon concentration.

The input request for this feedback identifies the nuclides iodine and xenon. The program obtains all required cross sections, fractional yield terms, and decay terms from the input table set data and depletion chain specifications. Thus, the problem must be depletable and the fission product chain for iodine and xenon must be included. Any type of geometry is allowed with this feedback and the spatial calculation may be either explicit or synthesis.

The equations solved are the asymptotic solutions to the iodine and xenon equations; that is, the time interval is set to infinity in the solution of the iodine and xenon equations. The convergence of this feedback process may be improved by the use of an input extrapolation factor E. This factor is used to combine two successive xenon iterates in an attempt to reduce the probability of calculational flux - xenon spatial instability. The xenon concentrations are extrapolated each feedback try by setting the xenon distribution to E times the latest computed distribution plus 1 - E times the previous distribution.

If in some block the sum of the decay plus absorption for either iodine or xenon is zero, those two isotopes are not changed in that block.

6.7. FEEDBACKS: SEARCH AND FEEDBACK STRATEGY

Three types of control searches to obtain a specified reactivity are available in the program: (1) one - dimensional multi - configuration search, (2) poison search, and (3) two - dimensional or three - dimensional movable fuel or control rod search. The first type of search is available only in one - dimensional problems; the second type of search is available in any depletable problem; and the third type of search is available in two - dimensional cylindrical (R-Z) geometry or any three - dimensional problem. These control searches are mutually exclusive: only one type of control search is allowed in a given case.

Thermal feedback is available in depletable problems whose geometry is either one - dimensional slab, two - dimensional cylindrical, or three - dimensional.

Xenon feedback is available in any depletable problem.

Any one type of control search, thermal feedback, and xenon feedback may be utilized separately or they may occur simultaneously in any combination. Both three - dimensional synthesis and explicit spatial calculations may be utilized with these searches and feedbacks.

In general, all searches and feedbacks proceed simultaneously; that is, for each spatial calculation, a new control prediction (if any) is made, a new thermal calculation (if any) is performed, and a new equilibrium xenon calculation (if any) is performed. Since two and three - dimensional explicit spatial calculations may be very time - consuming, each control search and feedback allows the input of a flux sub - convergence criterion. This allows searches and feedbacks to operate on fluxes and eigenvalues which are not necessarily as converged as those finally computed after the feedbacks and searches are terminated. Since the eigenvalue usually converges much faster than the flux, and since the feedbacks require the flux averaged over rather gross (relative to the pointwise mesh) blocks, it is not always necessary to converge the spatial iterations tightly during the search and feedback processes. The minimum (if more than one) of the search and feedback sub - convergence criteria is used to converge the spatial solution before attempting to use the spatial results for search or feedback processes.

The program forces the following order of convergence on the searches and feedbacks: control search to the nearest (axial) discrete position, then thermal feedback, then xenon feedback. This order is maintained even if, for example, the xenon feedback convergence criterion is satisfied before the thermal convergence criterion. However, if the maximum specified number of tries has been completed, that feedback or search is treated as converged regardless of order.

Certain special exceptions to the order of the search - feedback convergence process exist. Since the multi - configuration control search exists only for one - dimensional problems and the spatial calculation is thus relatively fast, when this control search has converged it is put into a "hold" condition so that the other feedback processes can converge. After the other feedback processes have converged, the temperatures, moderator density, iodine, and xenon are held constant at their converged values and the control search is again activated so that the specified reactivity is guaranteed.

The movable fuel search in two - dimensions and the control rod search in three - dimensional synthesis problems both have a unique characteristic with respect to convergence order. If an "exact" search is specified, the control search is converged to the nearest (axial) incremental position (mesh row in 2-D, gross plane in 3-D), then the feedbacks are allowed to converge, and then the non - incremental "exact" search is converged holding the temperatures, moderator density, iodine, and xenon constant at their converged values.

Another exception to the order of convergence is that the poison search is not permitted to converge prior to the feedbacks.

Again, for all of these special cases, if the specified number of tries has been completed, that feedback or search is terminated and treated as converged independent of the convergence of other searches and feedbacks.

7.1. FILE MANAGER FILES: INTRODUCTION

The program will read (retrieve) eight different file types as input File Manager files: card images, HARMONY tablesets, pointwise flux, concentrations, geometry, integrated flux, synthesis integral library, and quadrilateral figures. In addition, the program will write (store) eleven different file types as output File Manager files: pointwise flux, concentrations, partition power, edit integrals, geometry, gross block power, integrated flux, synthesis mixing coefficients, synthesis integral library, fine block power, and quadrilateral figures. All input files are retrieved during input processing for each case and a comment is added to the printed output after each file has been successfully read. Output files are all saved at the very end of a case or sub-case and a comment is added to the printed output after each file has been successfully written.

There are several uses for such "permanent" files. Some files are for convenience use only while others may be required for continuing the calculation at a later time or for independent post - processing of the data files produced by the program. For example, the program can accept a File Manager file for card image input data as well as a file of HARMONY cross sections, neither of which is written by the program. Further, quantities such as fluxes and concentrations which are calculated in one case are not automatically available to the next case; this coupling of two or more calculations can only be accomplished by including input instructions which cause such information to be stored as File Manager output files in one case and retrieved in a later case, or by the use of sub-cases. In a similar fashion, two - dimensional flux solutions or individual planes from a three - dimensional flux solution serve as the "trial functions" for three - dimensional synthesis solutions; these flux solutions must be generated separately, saved as File Manager output pointwise flux files, and retrieved in the synthesis problem. Finally, the program can be instructed to write File Manager output files containing quantities such as power and edit integrals for use in post - processing but which are never to be used as input files to this program.

Permanent files are stored and retrieved through the File Manager system described in Reference 1. Briefly, this system permits a program to process files in terms of their logical structure, with no knowledge of the physical format of the files required. File processing is also independent of the physical device used for the permanent retention of the file.

Three levels of identification are associated with each file: the integer VERSION number and an alphanumeric SYNONYM of up to ten characters both supplied as input by the user, and an integer DATA TYPE number supplied by the program. Files created in different cases or sub-cases of the same job are usually distinguished by version number and files created in the same case or sub-case are distinguished by data type number. The synonym is simply a temporary identifier which stands for all other identifications required by the File Management system.

An alternate method of saving files is provided which allows a grouping of files with different data types to be written as a single SECTIONED file. Any file type may be written separately as a stand - alone file or it may be combined with any other file type(s) as a sectioned file, but any one file type may be written only once within a single case or sub-case. Multiple sectioned files along with multiple stand - alone files may be written in any one case or sub-case. All sectioned files have the same data type (250). The content of each section in a sectioned file is written exactly as a stand - alone file, including header set(s), for the appropriate file type. Each section is a "named" section whose section name is the three character alphanumeric equivalent of the particular data type. For example, if the pointwise flux (data type 220) were saved in a sectioned file, the name of the section containing this data would be an alphanumeric "220". The program input is the same whether sectioned files or stand - alone files are written. The File Manager store - directives are scanned first for a stand - alone file directive (the appropriate version number, synonym, and data type); if not found, the same version number and synonym pair together with data type 250 are used to scan the File Manager store - directives to assure that such a directive is present. Then all file - store requests with this same condition (stand - alone File Manager store - directive missing for the particular data type) are scanned for the same version number - synonym pair; if a match is found, those files are grouped together into a single sectioned file. Of course, the program is

prepared to read as an input File Manager file either a stand - alone or a sectioned file for any file data type (including those not written by the program) and scans the File Manager files present in exactly the same way as described for writing output files: stand - alone first, then sectioned files. Again, the program input is the same whether sectioned files or stand - alone files are read.

Most of the input File Manager files are required to pass certain compatability checks with respect to the current problem description. These checks are made in order to assure that the files will be at least mechanically correct. The following is a list of such compatability checks made by the program.

(1) Pointwise Flux File

(a) The number of columns and rows in the file must be the same as in the current problem description.

(b) The number of planes in the file must be the same as in the current problem description unless a two-dimensional "slice" calculation is being done in which case the file may contain either the current number of planes or one plane.

(c) The number of groups in the file must be at least as large as the number of solution groups in the current problem description.

(2) Concentration File

(a) If the current problem is fine blocked, there must be the same number of fine blocks per plane and the same number of fine blocked nuclides in the file as in the current problem description unless the gross to fine concentration expansion is being used. If gross to fine expansion is being performed, the input concentration file must be gross blocked only.

(b) There must be the same number of gross blocks per plane and the same number of (gross blocked) nuclides in the file as in the current problem description.

(c) There must be the same number of gross planes in the file as in the current problem description unless a two-dimensional "slice" calculation is being done in which case the file may contain either the current number of gross planes or one gross plane.

(d) If the current problem is fine blocked, there must be the same number of fine planes in the file as in the current problem description with two exceptions. If a two-dimensional "slice" calculation is being done the file may contain either the current number of fine planes or one fine plane. If gross to fine concentration expansion is being used the file must be gross blocked only.

(3) Geometry File

(a) The geometry "type" (rectangular, hexagonal, ...) in the file must be the same as in the current problem description.

(b) The number of columns, rows, and planes in the file must be the same as in the current problem description.

(c) If the geometry type is hexagonal, the value of DIAG (the column number of the main diagonal, see Section 9.1) in the file must be the same as in the current problem description.

(d) If the row zero boundary condition for the current problem description is rotational symmetry, the row zero boundary condition indicated in the file must also be rotational symmetry.

(e) The maximum final figure number and the maximum planar region number in the file must be the same as in the current problem description.

(f) If the current problem is fine blocked, the geometry file must also be fine blocked.

(g) The type of composition correspondence (final figure or planar region) in the file must be the same as in the current problem description.

(h) If composition correspondences are being taken from the file and not from card input, the maximum number of compositions in the file must be the same as in the current problem description.

(4) Integrated Flux File

(a) The number of groups in the file must be the same as in the current problem description.

(b) If the current problem is fine blocked, there must be the same number of fine blocks per plane in the file as in the current problem description.

(c) There must be the same number of gross blocks per plane in the file as in the current problem description.

(d) There must be the same number of gross planes in the file as in the current problem description unless a two-dimensional "slice" calculation is being done in which case the file may contain either the current number of gross planes or one gross plane.

(e) If the current problem is fine blocked, there must be the same number of fine planes in the file as in the current problem description unless a two-dimensional "slice" calculation is being done in which case the file may contain either the current number of fine planes or one fine plane.

(5) Synthesis Integral Library File

(a) The number of gross blocks per plane in the file must be the same as in the current problem description.

7.2. FILE MANAGER FILES: ACCESS TO FILE MANAGER FILES

To facilitate the processing of data contained in the output File Manager files, Sections 7.3 - 7.13 contain detailed descriptions of the pointwise flux, concentrations, partition power, edit integrals, geometry, gross block power, integrated flux, synthesis mixing coefficients, synthesis integrals, fine block power, and quadrilateral figure files. This Section contains general information required for the processing of any of these files and defines the symbols used in describing these formats.

Each of the file "types" is distinguished by a unique DATA TYPE which is given in the description of the file. Alternatively, a grouping of files with different data types may be written as a single SECTIONED file. That is, any file type may be written separately as a stand - alone file or it may be combined with any other file type(s) as a sectioned file. All sectioned files have the same data type (250). The content of each section in a sectioned file is written exactly as a stand - alone file, including header set(s), for the appropriate file type. Each section is a "named" section whose section name is the three character alphanumeric equivalent of the particular data type. For example, if the pointwise flux (data type 220) were saved in a sectioned file, the name of the section containing this data would be an alphanumeric "220".

A single routine, called FMG (Reference 1), is used by the program for all communications with the File Manager, both for reading and writing these files. File Manager files are subdivided into sets of data, and the set structure of a file is fundamental to its processing. Two different set structures are provided by the File Manager and each is used for one or more of the output files. In the first structure, the set size is constant and the total number of sets is known in advance. The set size and number of sets are then given to the File Manager before the file is written and are returned by the File Manager before the file is read. In the second structure, the set size is variable in which case it is assumed the number of sets is not known. Here, the size of each set must be given to the File Manager as the set is written and is returned by the File Manager as the set is read. In this case the number of sets given to the File Manager and returned by the File Manager is zero. The writing program must indicate when it has written the last set and the File Manager will indicate to the reading program when the last set has been read.

The first set in every file is a HEADER set. This set contains important parameters relating to the contents of the file and, in particular, is used by the program to check for problem - file compatability when the file is used as an input file. In some of the files, the first word of the header set is a version number. This should not be confused with the File Manager version number mentioned previously; it is simply an internal indicator that is used to maintain compatability when the file structure must change and previously generated files must still be used.

The data in files written by the program is compressed by two different techniques, called PACK and SQOZ. Pack refers to the storing of several (non - negative) integer items in a single computer word, each item occupying a fixed set of bit positions. Sqoz refers to the storing of two floating point quantities in a single word by decreasing the number of significant digits and the exponent range of each. A set of FORTRAN CALL - able subroutines is available (Reference 1) to pack and sqoz and perform the inverse operations. The statements:

CALL PACK (WORD, NOITMS, NOBITS, ITEMS)

CALL UNPACK (WORD, NOITMS, NOBITS, ITEMS)

may be used to pack (unpack) items into (from) a single computer word. Here WORD is the packed word, NOITMS is the number of items to pack (unpack), NOBITS is an array giving the number of bits for each item, and ITEMS is an array containing (to be filled with) data items. Similarly, the statements:

CALL SQOZ (SQZWDS, FPTWDS, NWORDS)

CALL UNSQOZ (SQZWDS, FPTWDS, NWORDS)

may be used to compress (expand) an array of floating point words into (from) an array of sqoz words. Here SQZWDS is the array of sqoz words, FPTWDS the array

of floating point words, and NWORDS the number of floating point words.

The following table defines the various symbols used in the file descriptions.

ABSNUC - Number of nuclides for absorption rate edit.

B(i) - Highest numbered axial point number in the i-th piece of a 3-D control search element.

BDCOND - Array of six words containing boundary conditions along column 0, column COLBDY, row 0, row ROWBDY, plane 0, and plane PLNBDY.

BEGCON - Current configuration number (-1 if ZIPCON is negative).

BITS1 - Array of five words giving geometry file bit packing pattern for Figure, Region, Channel, Track, Hex transform.

BITS2 - Array of two words giving geometry file bit packing pattern for gross and fine block numbers.

BITS3 - Array of twelve words giving geometry file bit packing pattern for the composition correspondences.

BOTTOM - Highest numbered mesh line (row in R-Z, plane in 3-D) in the control search element.

COLBDY - Column boundary.

COLECT - Number of nuclide edit collections, combinations and constants defined.

COLS - Total number of columns (COLBDY+1).

CONCES - Last edit set for which average nuclide concentrations and loadings computed.

CONNUC - Number of nuclides for average concentration and loading edits.

CORRES - Composition correspondence (1 - composition to figure, 2 - composition to region).

DEFALT - Value used to indicate the "location" of a transparency in quadrilateral figures.

DELTAT - Depletion time - interval in hours.

DEPTIM - Indicator of deplete before spatial (0), deplete after spatial (1), or no depletion (-1).

DIAG - Diagonal column (0 if not hexagonal geometry).

DPLBLK - Number of gross blocks in each gross plane.

DPLPLN - Number of gross planes.

EDTSTS - Total number of edit sets defined.

EDTWDS - Number of words required to describe the edit sets.

FBNUCS - Number of nuclides which are fine block depletable.

FINBLK - Number of fine blocks in each fine block plane.

FINE - Fine blocking indicator (0 - no, 1 - yes).

FINPLN - Number of fine planes.

FISNUC - Number of nuclides for fission rate edit.

FLUXES - Last edit set for which flux integrals and flux - weighted macroscopic data computed.

FNORM - Flux normalization factor.

GEOM - Geometry type.

GROUPS - Total number of groups.

INCHES - Indicator of geometry input units (0 - centimeters, 1 - inches).

K(g) - Number of trial functions in group g.

KMAX - Maximum of K(g) over all groups g.

KSUM - K(1)+K(2)+...+K(GROUPS).

KVAR - [(KMAX*GROUPS*ZONES+KSUM-1)/KSUM] where [X] means "greatest integer in X".

LAMBDA - The problem eigenvalue (input guess if spatial not done).

LIBLEN - Number of integrals in the synthesis integral library file.

MAXCMP - Largest composition number.

MAXFIG - Largest final figure number.

MAXREG - Largest planar region number.

NUCLDS - Total number of nuclides in the master list of nuclides.

P3 - Indicator which is 0 if the P(3) option not used, 1 if the P(3) option used.

PAIRS - Number of element pieces with different (top, bottom) definitions in 3-D control search.

PLANES - Total number of point planes (1 if 1-D or 2-D, PLNBDY+1 IF 3-D).

PLNBDY - Plane boundary (1 if 1-D or 2-D).

PNORM - Power normalization factor.

PNTFIG - Number of mesh figures at a point (2 if 1-D, 4 if 2-D rectangular or cylindrical, 6 if 2-D hexagonal, 8 if 2-D quadrilateral or 3-D rectangular, and 12 if 3-D hexagonal)

POWINT - Power integral (denominator of FNORM and PNORM).

POWNUC - Number of nuclides for power fraction edit.

QFIGS - Number of quadrilateral figures.

QGENS - Number of quadrilateral figures generated.

RATEES - Last edit set for which nuclide power fractions, absorption rates, and fission rates computed.

ROWBDY - Row boundary (1 if 1-D).

ROWS - Total number of rows (1 if 1-D, ROWBDY+1 if 2-D or 3-D).

SOLANG - Internal angle of the solution figure in quadrilateral geometry.

T(i) - Lowest numbered axial point number in the i-th piece of a 3-D control search element.

THGRPS - Number of thermal groups.

TISETS - Last edit set for which thermal - hydraulic integral data computed.

TOP - Lowest numbered mesh line (row in R-Z, plane in 3-D) in the control search element.

TRYS - Number of spatial solutions performed in a case or sub - case.

TZERO - Elapsed time - in - life at beginning of time step.

UNIQUE - Number of unique synthesis trial functions.

WORTH - Latest worth in the control search.

Z(g,i) - Axial mixing coefficient for the i-th trial function in group g.

ZIPCON - Highest configuration number (beginning at zero). Note: in 3-D or in any problem with any control search other than a one - dimensional multiple configuration control search, this value is -1.

ZONES - Number of trial function zones.

Data Type - 220

Set Size - max[8,(COLS+1)/2]

Number of Sets - 1+ROWS*PLANES*(GROUPS+P3)

Header Word		Set Value
1	-	COLS
2	-	ROWS
3	-	PLANES
4	-	GROUPS+P3
5	-	FNORM
6	-	PNORM
7	-	POWINT
8	-	LAMBDA

Each of the remaining sets contains the pointwise flux values for a single row of the mesh. The sets are ordered by row, then by plane, and finally by group. Within a set there are COLS values in sqoz format, requiring [(COLS+1)/2] compressed words. The pointwise flux values are not normalized.

If the simplified P(3) option was used to generate these flux values, the order of the groups of flux is as follows: all of the normal flux groups in order from one through GROUPS, followed by the special P(3) pseudo group - one flux.

Data Type - 252

Set Size - Variable

Number of Sets - Variable

Header Word	Set Value	
1	1	(version)
2	DPLBLK	
3	FINBLK	
4	DPLPLN	
5	FINPLN	
6	POWINT	
7	FNORM	
8	PNORM	
9	NUCLDS	
10	FBNUCS	
11	1000	(maximum set size)

The second set contains the numeric nuclide id's, and the third set contains the alphanumeric nuclide id's. These id's are in the same order as specified in the input master nuclide list, and this is the order in which the concentration values are carried for each gross block in subsequent sets. Negative numeric id's identify nuclides that are fine block depletable. These define an order due to the order of their appearance in the second set, and this is the order in which the fine block concentration values are carried for each fine block in subsequent sets.

The fourth, fifth,... sets are of arbitrary size (see word 11 of the first set), and contain the NUCLDS*DPLBLK*DPLPLN concentration values for the gross blocks. The first word in each set is the (integral) number of gross blocks whose concentration values are contained in the current set. This number is negative in the final set of gross block nuclides. The remaining data in these sets are gross block concentration values in sqoz format. The data values are ordered first by nuclide (same order as numeric id's in the second set), then by gross block, then by gross plane. The final set is reduced to the size necessary to hold the remaining concentration values.

The remaining sets (if fine blocking) are of arbitrary size (see word 11 of the first set), and contain the FBNUCS*FINBLK*FINPLN concentration values for the fine blocks. The first word in each set is the (integral) number of fine blocks whose concentration values are contained in the current set. This number is negative in the final set of fine block nuclides. The remaining data in these sets are fine block concentration values in sqoz format. The data values are ordered first by nuclide (same order as negative numeric id's in the second set), then by fine block, then by fine plane. The final set is reduced to the size necessary to hold the remaining concentration values.

Data Type - 222

Set Size - max[4,(PNTFIG/2)*COLS]

Number of Sets - 1+ROWS*PLANES

Header Word		Set Value
1	-	PNTFIG
2	-	COLS
3	-	ROWS
4	-	PLANES

Each of the remaining sets contains the partition power values for a single row of the mesh. The sets are by row, then by plane. Within a set there are PNTFIG values in sqoz format at each of COLS points, requiring [(PNTFIG/2)*COLS] compressed words. The power values are normalized by PNORM.

In a one - dimensional problem the order of the values at a point is left followed by right. In a two - dimensional rectangular or cylindrical problem, the order is upper left, upper right, lower left, and lower right. In a two - dimensional hexagonal problem, the order is upper left through upper right followed by lower left throught lower right on the right side of the chevron. On the left side of a chevron, the orientation of the values by sextant in absolute space is the same as for the right side but the canonical row direction bends clockwise sixty degrees. In a two - dimensional quadrilateral problem, the eight values at a point are given, in clockwise order, beginning with the first lower right value.

Finally, in a three - dimensional problem, the values above the plane are ordered as in a two - dimensional problem and are followed by the corresponding values below the plane.

Data Type - 224

Set Size - Variable

Number of Sets - Variable

Header Word	Set Value
1	DPLPLN
2	GROUPS
3	THGRPS
4	EDTSTS
5	EDTWDS
6	FLUXES
7	RATEES
8	CONCES
9	POWNUC
10	ABSNUC
11	FISNUC
12	CONNUC
13	FNORM
14	LAMBDA
15	TISETS
16	PNORM
17	TRYS
18	COLECT
19	TZERO
20	DELTAT
21	DEPTIM

The edit set descriptions appear next in the file. The total of EDTWDS words is arranged in arbitrary sized but constant length sets, with the last set reduced in size to the number of words remaining. The description for each edit set consists of a sequence of final figure numbers and a zero followed by a sequence of planar region numbers and a zero. Each sequence is in order of increasing absolute value, with a negative number indicating the previous value through the negative value.

The remainder of the file consists primarily of four major divisions of integral data, some of which may be missing, plus miscellaneous data. Within each division the data is ordered by edit set, then by gross plane. Since the data for each set is in sqoz format, the set size is obtained by adding 1 to the number of values in a set, dividing by 2, and then taking the largest integer in that quotient.

There are (FLUXES*DPLPLN) sets in the first division, each containing volume, flux integrals, and flux - weighted macroscopic data for a single edit set. The data for a set consists first of Integrals 7.6.1, followed by Integrals 7.6.2 for each group. If THGRPS = 2, these quantities are replaced in the last two groups by Integrals 7.6.3. The total number of values per set is [1 + GROUPS + 6*(GROUPS + THGRPS -1)]. Note that the fluxes in these integrals are not normalized. Note also that, in a fixed source problem, the flux - weighted nu sigma fission integral is replaced by a flux weighted source integral.

The second division is present only if at least one of POWNUC, ABSNUC, and FISNUC is non - zero. If present, it is preceded by a set of length (POWNUC + ABSNUC + FISNUC) which contains the numeric nuclide id's for the power fraction, absorption rate, and fission rate edits. The id's are in the same order as specified in the input and this is the order in which the nuclide integrals are carried.

There are (RATEES*DPLPLN) sets in the second division, each containing the power, absorption rate, and fission rate values for a single edit set. The data for a set consists of Integrals 7.6.4 for all groups g, then all power fraction nuclides i; followed by Integrals 7.6.5 for all groups g, then all absorption rate nuclides i; followed by Integrals 7.6.6 for all groups g, then all fission rate nuclides i. The total number of values per set is [GROUPS *(POWNUC + ABSNUC + FISNUC)], and the fluxes in these integrations are normalized by FNORM/10**24.

The third division is present only if CONNUC is non - zero. If present, it is preceded by a set of length of 3*CONNUC which contains the numeric nuclide id's for the average concentration and loading edits, the alphanumeric nuclide id's for these nuclides, and for these same nuclides the atomic weights divided by the Avogadro constant all multiplied by 10**21. The id's are in the same order as specified in the input and this is the order in which the concentration integrals are carried.

There are (CONCES*DPLPLN) sets in the third division, each containing the volume and the concentration integrals for a single edit set. The data for a set consists of Integral 7.6.7 followed by Integrals 7.6.8 for each average concentration or loading nuclide i. The total number of values per set is (1 + CONNUC).

The fourth division is present only if TISETS is non - zero. There are (TISETS*DPLPLN) sets in the fourth division, each containing integrals of thermal - hydraulic data for a single edit set. The data for each set consists of Integrals 7.6.9 where the unit of volume is cubic feet and temperatures are in degrees Fahrenheit.

The next set is present only if TRYS is non - zero. The set contains TRYS final eigenvalues from the spatial solution for every search and/or feedback try.

The next set is present only if COLECT is non - zero. The set contains COLECT (value, name) pairs of nuclide collection data, algebraic combination data, and constant definitions for all such edits requested.

INTEGRALS 7.6.1 - 7.6.3

$$\int dV,\ \int \phi_1 dV,\ \int \phi_2 dV, \ldots,\ \int \phi_G dV \qquad 7.6.1$$

$$\int D_g \phi_g dV\ ,\ \int \Sigma_g^a \phi_g dV\ ,\ \int \Sigma_g^r \phi_g dV\ ,\ \int \nu\Sigma_g^f \phi_g dV\ ,\ \int \kappa\Sigma_g^f \phi_g dV\ ,\ \int \Sigma_g^t \phi_g dV \qquad 7.6.2$$

$$\left.\begin{aligned}
&\int D_{G-1}^1 \phi_{G-1} dV\ ,\ \int D_{G-1}^2 \phi_G dV\ ,\ \int \Sigma_{G-1}^1 \phi_{G-1} dV\ ,\ \int \Sigma_{G-1}^2 \phi_G dV\ ,\ \int \nu\Sigma_{G-1}^f \phi_{G-1} dV,\\
&\int \kappa\Sigma_{G-1}^f \phi_{G-1} dV\ ,\ \int (\Sigma_{G-1}^{t1} \phi_{G-1} + \Sigma_{G-1}^{t2} \phi_G) dV\ ,\ \int R_{G-1} \Sigma_{G-2}^r \phi_{G-2} dV\ ,\\
&\int D_G^1 \phi_G dV\ ,\ \int D_G^2 \phi_{G-1} dV\ ,\ \int \Sigma_G^1 \phi_G dV\ ,\ \int \Sigma_G^2 \phi_{G-1} dV\ ,\ \int \nu\Sigma_G^f \phi_G dV,\\
&\int \kappa\Sigma_G^f \phi_G dV,\ \int (\Sigma_G^{t1} \phi_G + \Sigma_G^{t2} \phi_{G-1}) dV\ ,\ \int R_G \Sigma_{G-2}^r \phi_{G-2} dV\ ,\\
&\int \Sigma_{G-1}^{t2} \phi_G dV\ ,\ \int \Sigma_G^{t2} \phi_{G-1} dV
\end{aligned}\right\} \qquad 7.6.3$$

INTEGRALS 7.6.4 - 7.6.9

$$\int_{\kappa} {}^{g}_{i}\sigma^{f}_{i}, {}^{g}G^{f}_{i}, {}^{g}N_{i}\phi_{g}\,dV \qquad 7.6.4$$

$$\int \sigma^{a}_{i}, {}^{g}G^{a}_{i}, {}^{g}N_{i}\phi_{g}\,dV \qquad 7.6.5$$

$$\int \sigma^{f}_{i}, {}^{g}G^{f}_{i}, {}^{g}N_{i}\phi_{g}\,dV \qquad 7.6.6$$

$$\int dV \qquad 7.6.7$$

$$\int N_{i}\,dV \qquad 7.6.8$$

$$\left.\begin{array}{l} \int T_{F}V_{F}dV \;,\; \int V_{F}dV \;,\; \int T_{M}\bar{\rho}V_{c}dV \;,\; \int \bar{\rho}V_{c}dV \;, \\ \int \Delta N_{H}dV \;,\; \int dV \;,\; \int RV_{c}dV \;,\; \int V_{c}dV \;, \\ \int \phi A_{H}dV \;,\; \int A_{H}dV \end{array}\right\} 7.6.9$$

Data Type - 251

Set Size - Variable

Number of Sets - Variable

Header Set Word		Value
1	-	2 (version)
2	-	COLBDY
3	-	ROWBDY
4	-	PLNBDY
5	-	DIAG
6-11	-	BDCOND(1)-BDCOND(6)
12	-	MAXCMP
13	-	MAXFIG
14	-	MAXREG
15	-	CORRES
16	-	FINE
17	-	DPLBLK
18	-	DPLPLN [or -(ZIPCON+1)]
19	-	TOP
20	-	BOTTOM
21	-	WORTH
22	-	BEGCON
23	-	FINBLK
24	-	GEOM
25-29	-	BITS1(1)-BITS1(5)
30-31	-	BITS2(1)-BITS2(2)
32-43	-	BITS3(1)-BITS3(12)
44	-	SIZE *
45	-	INDEX1 *
46	-	INDEX2 *
47	-	INDEX3 *
48	-	INDEX4 *
49	-	FINPLN
50	-	(not used)
51	-	BLKSIZ *
52	-	SETS4 *
53	-	SETS1 *
54	-	SETS2 *
55	-	SETS3 *
56-62	-	(not used)
63	-	SOLANG
64	-	PAIRS
65-(65+2*PAIRS-1)	-	[(T(i),B(i)),i=1,...PAIRS] (missing if PAIRS = 0)

Words in the header set which are flagged with an asterisk (words 44 - 48 and 51 - 55) are not defined in Section 7.2 but will be defined in this Section since they pertain only to this file. SIZE (word 44 in header set) is the total number of words in the second, third,... sets used to describe mesh spacings, composition correspondence words, and gross and fine plane boundaries. If all of the words from sets two, three,... are put into a one - dimensional array of length SIZE, then INDEX1 - INDEX4 (words 45 - 48 in header set) are relative indices in that array of various data as follows.

INDEX1 - Relative index of mesh spacings. In rectangular, cylindrical, and spherical geometries there are COLBDY + ROWBDY + PLNBDY values beginning at INDEX1 giving column then row then axial mesh spacings (or 1.0 default values for non - existent dimensions). For other geometries, the column and row mesh spacings are meaningless and are not present, but this index is such that when COLBDY + ROWBDY is added to INDEX1, the resultant index points to the first axial mesh spacing. In all geometry types, mesh spacings are in centimeters regardless of the input mesh units.

INDEX2 - Relative index of composition correspondence words. The correspondence gives the composition number of each final figure if CORRES = 1 and of each planar region if CORRES = 2. Thus there are either MAXFIG or

MAXREG composition numbers for each gross plane or configuration. The first six fields in each word are composition numbers and the last six fields indicate a movable (if field value is 1) or a non - movable (if field value is 0) composition for a 1-D control search problem for each of the six compositions in that word. These words are packed according to the bit pattern in the BITS3 array. If ZIPCON is negative, each gross plane begins a new packed word giving a total of [DPLPLN *((N + 5) / 6)] words. If ZIPCON is non - negative, each configuration begins a new packed word giving a total of [(ZIPCON + 1)*((N + 5) / 6)] words. "N" represents either MAXFIG or MAXREG (for CORRES being 1 or 2). If ZIPCON is negative, INDEX2 points to the beginning of the correspondence words for the first gross plane. If ZIPCON is non - negative, INDEX2 points to the beginning of the correspondence words for the configuration specified by BEGCON.

INDEX3 - Relative index of gross plane boundaries. The plane numbers are increasing and the last value is PLNBDY.

INDEX4 - Relative index of fine plane boundaries. The plane numbers are increasing and the last value is PLNBDY.

After sets two, three,... (containing a total of SIZE words), the remainder of the file contains up to four logical "sub - files" and these files, in order, are called "file 4", "file 1", "file 2", and "file 3". Each of these files is written in blocked form with a maximum set size of BLKSIZ (word 51 in the header set). Then SETS4, SETS1, SETS2, and SETS3 (words 52 - 55 in the header set) specify the number of sets in sub - files "file 4", "file 1", "file 2", and "file 3" respectively.

The next SETS4 sets contain geometry label information for each mesh element for one plane ("file 4"). There is one packed word per mesh element, and the mesh elements are ordered first by mesh column (one through the last element in a mesh row), then by mesh row (one through ROWBDY). Each packed word contains five fields which are (1) final figure number, (2) planar region number, (3) channel number (may be zero), (4) track number (may be zero), and (5) hexagonal transform. These words are packed according to the bit pattern specified by the BITS1 array. For hexagonal and quadrilateral geometries, there are 2*COLBDY mesh elements in each row; if ROWBDY = 1 and ZIPCON is non - negative, there are COLBDY mesh elements but 2*COLBDY words are used to describe the row: the first COLBDY words describe the mesh elements as "perturbed" in a control search, and the second COLBDY words describe the original non - perturbed mesh elements; for all other geometries, there are COLBDY mesh elements per row. The data for each row of mesh elements is contained in an integral number of sets, with a maximum set size of BLKSIZ and the last set for each row reduced in size to the number of words remaining.

The next SETS1 sets contain geometry blocking and possibly mesh location information for one plane ("file 1"). There are three forms for this data depending on geometry type.

(1) All geometries except hexagonal and quadrilateral.

There is one packed word per mesh element, and the mesh elements are ordered first by mesh column (one through COLBDY), then by mesh row (one through ROWBDY). Each packed word is a two - field word containing (1) gross block number and (2) fine block number (may be zero). These words are packed according to the bit pattern specified by the BITS2 array. The data for each row is contained in an integral number of sets, with a maximum set size of BLKSIZ and the last set for each row reduced in size to the number of words remaining.

(2) Hexagonal geometry.

For each of mesh rows one through ROWBDY, there are 6*COLBDY+1 words: the first 2*COLBDY words describe blocking for each mesh triangle in the mesh row where each word is a two - field packed word containing (1) gross block number, and (2) fine block number (may be zero); the next 2*COLBDY words are angle values (in radians); and the last 2*COLBDY+1 words are mesh side - lengths (in centimeters). The packed words are packed according to the bit pattern specified by the BITS2 array. A fixed angle - mesh side pattern is used in this description which takes advantage of the fact that

every pair of triangles in a row shares a common side. In this scheme, one extra mesh side value is required for the last triangle (last column) in a row. The triangulation is in a fixed pattern. To the left of the main diagonal (DIAG), triangulation is from column n of one row down to column n+1 in the next row. To the right of the main diagonal, triangulation is from column n of one row down to column n-1 in the next row. The side lengths carried are the column lengths (distance from the mesh point at column n in one row to the mesh point at column n in the next row) alternating with the diagonal (triangulation direction) lengths. The angles carried are the angles enclosed by these side lengths. The data for each row is contained in an integral number of sets, with a maximum set size of BLKSIZ and the last set for each row reduced in size to the number of words remaining.

(3) Quadrilateral geometry.

The first "row" of data contains 2*COLBDY zeroes followed by COLBDY+1 pairs of (X,Y) values. These (X,Y) values are the coordinates of the mesh points zero through COLBDY for point - row zero. Then for each of mesh rows one through ROWBDY, there are again 4*COLBDY+2 words: the first 2*COLBDY words describe blocking for each mesh triangle in the mesh row where each word is a three - field packed word containing (1) gross block number, (2) fine block number (may be zero), and (3) triangulation bit; the last 2*COLBDY+2 words are COLBDY+1 pairs of (X,Y) giving the coordinates of the mesh points in the point - row below the row of mesh elements. All coordinates are in centimeters and are relative to point (0,0) in a 90 degree coordinate system. The packed words are packed according to the bit pattern specified by the BITS2 array except that the third field is always one bit. The triangulation indicator is as follows: for the two triangles in a mesh column quadrilateral, the indicators are 0 and then 1 if triangulation is NW - SE (in the fourth quadrant system) and are 1 then 0 if triangulation is NE - SW. Of the two triangles in every mesh column quadrilateral, the triangle containing the left side of the quadrilateral is always carried first. The data for each row is contained in an integral number of sets, with a maximum set size of BLKSIZ and the last set for each row reduced in size to the number of words remaining.

The next SETS2 sets contain geometry data for each gross block for one plane ("file 2"). A pair of words is carried for each gross block 1, 2, ..., DPLBLK. The first word of each pair is a three - field packed word containing (1) final figure number, (2) planar region number, and (3) the number of fine blocks in that gross block (may be zero). These words are packed according to the bit pattern specified by the BITS1 array. The second word of each pair is the radial area (volume if cylindrical or spherical) of the gross block. The total of 2*DPLBLK words is arranged in sets of size BLKSIZ with the last set reduced in size to the number of words remaining.

The next SETS3 sets (present only if FINE is non - zero) contain geometry data for each fine block for one plane ("file 3"). A pair of words is carried for each fine block 1, 2, ..., FINBLK. The first word of each pair is a four - field packed word containing (1) final figure number, (2) planar region number, (3) channel number, and (4) track number. These words are packed according to the bit pattern specified by the BITS1 array. The second word of each pair is the radial area (volume if cylindrical or spherical) of the fine block. The total of 2*FINBLK words is arranged in sets of size BLKSIZ with the last set reduced in size to the number of words remaining.

Data Type - 254

Set Size - Variable

Number of Sets - Variable

Header Word		Set Value	
1	-	1	(version)
2	-	DPLBLK	
3	-	DPLPLN	
4	-	PNORM	
5	-	1000	(maximum set size)

The remaining sets are of arbitrary size (see word 5 in header set) and contain the average power for the DPLBLK*DPLPLN gross blocks in sqoz format. The power values are normalized by PNORM. The first word in each set is the (integral) number of blocks for which power values are carried in the current set. This number is negative in the final set of gross block power values. The remaining data in these sets are the gross block power values which are ordered first by gross block and then by gross plane. The final set is reduced to the size necessary to hold the remaining power values.

Data Type - 253

Set Size - Variable

Number of Sets - Variable

Header Word		Set Value	
1	-	1	(version)
2	-	DPLBLK	
3	-	FINBLK	
4	-	DPLPLN	
5	-	FINPLN	
6	-	GROUPS	
7	-	FNORM	
8	-	PNORM	
9	-	POWINT	
10	-	1000	(maximum set size)

The second, third,... sets are of arbitrary size (see word 11 of the first set), and contain the (GROUPS+1)*DPLBLK*DPLPLN integrated flux values for the gross blocks. The integrated flux values are not normalized. The first word in each set is the (integral) number of gross blocks whose integrated flux values are contained in the current set. This number is negative in the final set of gross block fluxes. The remaining data in these sets are gross block integrated flux values in sqoz format. The data values are ordered as follows: first the volume integral of the flux for groups one through GROUPS followed by the volume of the block; then by gross block, then by gross plane. The final set is reduced to the size necessary to hold the remaining integrated flux values.

The remaining sets (if fine blocking) are of arbitrary size (see word 10 of the first set), and contain the (GROUPS+1)*FINBLK*FINPLN integrated flux values for the fine blocks. The integrated flux values are not normalized. The first word in each set is the (integral) number of fine blocks whose integrated flux values are contained in the current set. This number is negative in the final set of fine block fluxes. The remaining data in these sets are fine block integrated flux values in sqoz format. The data values are ordered as follows: first the volume integral of the flux for groups one through GROUPS followed by the volume of the block; then by fine block, then by fine plane. The final set is reduced to the size necessary to hold the remaining integrated flux values.

Data Type - 229

Set Size - max[4,KSUM]

Number of Sets - 4+PLANES+KVAR+UNIQUE

Header Set Word	-	Value
1	-	PLANES
2	-	GROUPS

Second Set Word	-	Value
1	-	FNORM
2	-	PNORM
3	-	POWINT

Third Set Word	-	Value
1	-	K(1)
2	-	K(2)
.	-	.
.	-	.
GROUPS	-	K(GROUPS)

Each of the next PLANES sets contains the axial mixing coefficients for a single plane. These mixing coefficients will be represented by Z(g,i) for the i-th position in group g. The number of trial functions (positions) in group g is given by K(g). The data within each set of size KSUM is ordered as follows.

$$\begin{matrix} Z(1,1), Z(1,2), \ldots, Z(1,K(1)), \\ Z(2,1), Z(2,2), \ldots, Z(2,K(2)), \\ \vdots \\ Z(GROUPS,1), Z(GROUPS,2), \ldots, Z(GROUPS,K(GROUPS)). \end{matrix}$$

The next set contains the single value KVAR indicating the number of sets which follow describing the trial function PROBLEM DESCRIPTION. Each of the next KVAR sets contain KSUM words which are integer pointers for the trial functions used for each position, group, and zone. Each pointer is a relative index pointing into the trial function description which follows these sets of data. A value of minus one is given for all positions which do not exist in any group. This data, if read as a one - dimensional array of numbers, can be treated as if it were a three - dimensional array of numbers. The three indices, in order, are: position, group, and zone; and the dimension limits for this three - dimensional array will be [KMAX, GROUPS, ZONES].

The next UNIQUE sets contain the TRIAL FUNCTION DESCRIPTIONS and consist of four word entries for each unique trial function as follows: (1) version number, (2) synonym, (3) group number, and (4) the integral of the trial function over the entire radial space. These sets of data represent the File Manager identification (version, synonym), the group extracted from that file, and finally, the radial integral of that trial function. This data, if read as a one - dimensional array of numbers, can be treated as if it were a two - dimensional array having dimension limits of [UNIQUE, 4]. It is the first index in this array which is given by the pointers in the three - dimensional problem description array previously described.

Data Type - 228

Set Size - Variable

Number of Sets - Variable

Header Set
Word - Value

1 - LIBLEN
2 - DPLBLK

The remainder of the file consists of LIBLEN sets of integral descriptions followed by LIBLEN sets of integral values. The descriptions and values are in a one - to - one correspondence defined by the order of occurrence in the file. The size of the description sets is four and each set contains a packed identification of a single integral. In general, these integrals involve two trial functions, say T1 and T2. The contents of these four word description sets is as follows.

Word	Item	Number of Bits
1	Synonym of T1	60
2	Version number of T1	42
	Group number of T1	4
	Type	3
	(zero, not used)	11
3	Synonym of T2	60
4	Version number of T2	42
	Group number of T2	4
	(zero, not used)	14

The item in word two designated as "Type" indicates the type of trial function integration performed as follows:

Type 1 - Integral of T1.
Type 2 - Integral of the product of the gradient of T1 and the gradient of T2.
Type 3 - Integral of the product of T1 and T2.

The set size of the LIBLEN integral value sets is (DPLBLK+1)/2. Each set contains DPLBLK values of the corresponding integral described in the first half of the file. The integral values in each set are ordered by gross block and are in sqoz form. The flux integrals are not normalized.

Data Type - 255

Set Size - Variable

Number of Sets - Variable

Header Word		Set Value	
1	-	1	(version)
2	-	FINBLK	
3	-	FINPLN	
4	-	FNORM	
5	-	PNORM	
6	-	POWINT	
7	-	1000	(maximum set size)
8	-	1	(values per block)

The remaining sets are of arbitrary size (see word 7 in header set) and contain the average power for the FINBLK*FINPLN fine blocks in sqoz format. The power values are normalized by PNORM. The first word in each set is the (integral) number of blocks for which power values are carried in the current set. This number is negative in the final set of fine block power values. The remaining data in these sets are the fine block power values which are ordered first by fine block and then by fine plane. The final set is reduced to the size necessary to hold the remaining power values.

Data Type - 256

Set Size - Variable

Number of Sets - Variable

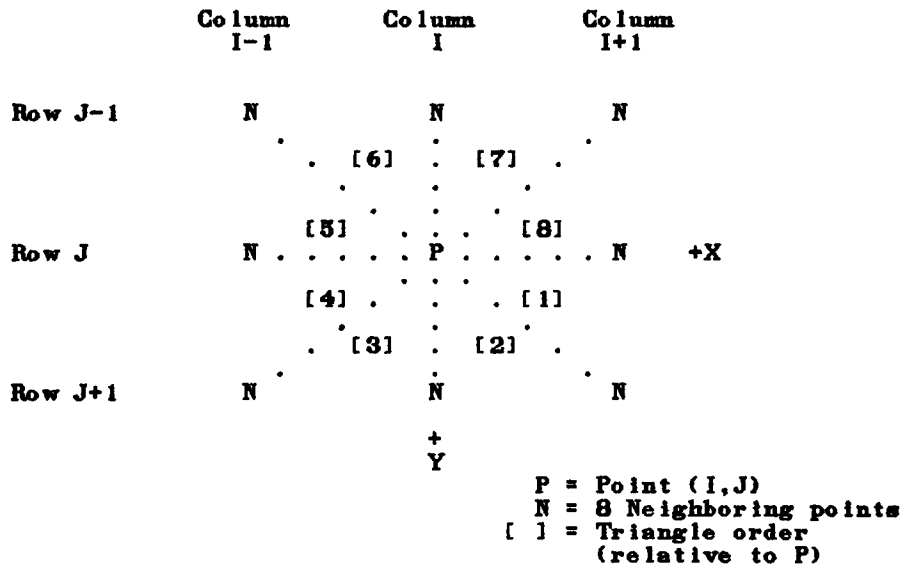
Header Word		Set Value
1	-	1 (version)
2	-	QFIGS
3	-	QGENS
4	-	INCHES
5	-	DEFALT
6-10	-	BITS1(1)-BITS1(5)

The next sets describe the QFIGS quadrilateral figures, if any. For each of .QFIGS figures, a leading eight word header set contains the following information:

(1) label,
(2) column boundary,
(3) row boundary,
(4) internal angle (radians),
(5) minimum X value defined (CM.),
(6) maximum X value defined (CM.),
(7) minimum Y value defined (CM.),
(8) maximum Y value defined (CM.).

Then follows [row boundary + 1] sets, each of size 10*[column boundary + 1]. These sets give a description of the figure, left to right in each of the rows zero through row boundary. In each row, ten words are carried for each of the columns zero through column boundary. The ten words are as follows:

(1) absolute X location (CM.),
(2) absolute Y location (CM.);
if the X,Y location has not been defined at some point (i.e. it is a transparency), then 10*DEFALT is stored for X and for Y at that point;
(3-10) eight packed words (packed using the bit pattern from the BITS1 array), each containing figure, region, channel, track, and hex transform for one of the eight triangles around the point P and in the order shown. A 90 degree example is shown in the picture, but the eight triangles are present for any quadrilateral figure. The figure also shows the positive X and the positive Y directions.



The next sets contain the QGENS quadrilateral figure generation descriptions, if any. For each of QGENS figure generation descriptions, a leading five word header set contains the following information:

(1) label,
(2) column boundary,
(3) row boundary,
(4) internal angle (radians),
(5) number of overlay sets.

Then follows, for each overlay set in the current generation description:

(1) initial figure label,
(2) column number of origin,
(3) row number of origin,
(4) row rotation index,
(5) column rotation index,
(6) final figure bias,
(7) channel bias,
(8) absolute X origin (CM.),
(9) absolute Y origin (CM.),
(10) rotation angle (radians).

If the absolute X or Y origins are not specified, items (8) and (9) are set to 10*DEFALT. Likewise, if the row rotation index is negative (unknown direction), item (10) is set to 10*DEFALT.

8.1. GENERAL INPUT PREPARATION: SYSTEM CONTROL CARDS

All system control cards are punched beginning in column 1. The first card of every input deck is a JOB card whose (fixed field) format is as follows:

Fields 1-9	No. of Columns	Field Type
JOB ID	7	alphanumeric
PRIORITY	1	integer
RUN TIME LIMIT (minutes)	3	integer
SMALL CORE (octal thousands)	3 (140)	integer
LARGE CORE (octal thousands)	4 (1000)	integer
PROGRAM NAME	5 (PDQ08)	alphanumeric
USER NAME	5	alphanumeric
CLASSIFICATION	1 (U/C)	alphanumeric
CHARGE CLASS	1	alphanumeric

These fields are separated by commas, except that there is a period between the LARGE CORE value and the PROGRAM NAME. There is also a period following the CHARGE CLASS which brings the total number of columns to 39. The first four columns of the JOB ID identify the user for accounting purposes, and the next three columns are the job sequence number for this user.

The job deck submitted by the user normally consists of a job card, followed by File Manager directive cards, followed by the program execution card. After these and any other control cards must follow an END-OF RECORD card (7-8-9 punches in column 1). The input data deck follows the end-of-record card. Finally, the entire job deck is always terminated by an END-OF-FILE card (6-7-8-9 punches in column 1).

The File Manager directive card which must be included to obtain the program in an executable form is:

```
PROGM(PDQ08)
```

and the program execution card usually consists of the program name followed by a period such as:

```
PDQ08.
```

Alternatively, the program execution card may consist of the program name followed by one or two file names enclosed in parentheses. This form allows a change in the system file names used by the program to read the input data "deck" and write the "printer" output. For example, the program execution card:

```
PDQ08(INFILE,OUTFILE)
```

will cause the program to obtain the input data "deck" from a system file named "INFILE" and to write the "printer" output on a system file named "OUTFILE". The specification of alternate file names is position dependent; i.e. the first is always a substitute file name for the file named "INPUT", and the second is always a substitute file name for the file named "OUTPUT". Thus, the form:

```
PDQ08.
```

is equivalent to:

```
PDQ08(INPUT,OUTPUT)
```

Either one of the two file names may be substituted separately. For example, the program execution card:

```
PDQ08(INFILE)
```

or, equivalently:

```
PDQ08(INFILE,OUTPUT)
```

will cause the program to obtain the input data "deck" from a system file named "INFILE" and to write the printer output as it normally would on a system file named "OUTPUT". Likewise, the program execution card:

```
PDQ08(,OUTFILE)
```

or, equivalently:

PDQ08(INPUT,OUTFILE)

will cause the program to obtain the input data deck as it normally would from a system file named "INPUT" and to write the "printer" output on a system file named "OUTFILE".

Regardless of the "INPUT" file name, there may be CARDFILE cards (see Section 8.3) within the input data "deck" which identify File Manager files containing card images that are to be a supplemental part of the total input data "deck".

8.2. GENERAL INPUT PREPARATION: INPUT DATA CARDS

In general, the rules for input card manipulation are as described in Reference 1. In particular, input cards need not be sorted; data is converted according to the format of the card ("free field"); and redundant cards are removed automatically to accomodate easy input deck modification.

All input cards including those from File Manager files are listed in the printed output as they are converted. Comment information may follow the data on any card if a dollar sign is punched between the last data item and the comment. An asterisk or a dollar sign in the first non-blank column denotes a card containing only comments. One of the cards in an input deck should be a title card, denoted by an equal sign in the first non-blank column. The information on this card is used to title each page of printer output. If more than one title card is present, the last such card is used. Blank cards in the input deck are ignored.

The first field on a data card is an integer which represents the CARD NUMBER and is followed by a comma. One exception to this is the CARDFILE card (see Section 8.3) used to designate File Manager card files to be used as part of the card input. The card number usually consists of a SERIES number (one or two digits), a SUBSERIES number (zero to three digits), and a SEQUENCE number (remaining digits). The series and subseries numbers identify the type of data on the card; the sequence number begins at 1 for each subseries although not all card series require sequentially numbered cards.

Data cards are divided into fields of arbitrary length, with the fields separated by commas and the comma following the last field optional. Each field contains an integer number, a floating point number, or an alphanumeric identifier. Leading and trailing blanks are ignored in all fields, and embedded blanks are ignored in numeric fields.

The integer format is:

Sxx...xx

and the floating point format is:

Sxx...xxSyy,

where the S stands for either a plus (+) sign or a minus (-) sign and where the leading sign may be dropped if it is plus and where each x and y is a decimal digit or a blank. In the floating point format the decimal point is assumed to precede the fractional part and the signed one or two digit exponent must be present. The floating point format may optionally be signified by using a decimal point in the fractional part, and in this form, the signed one or two digit exponent is optional. An alphanumeric field must contain at least one non-numeric character or must be enclosed in parentheses. A non-numeric character is any character other than +, -, ., 0 through 9, or the blank character. In the body of the text for some sections of this report, alphanumeric data having a "blank" value is mentioned. This type of data can be input by including a field on the input card which consists of from zero to ten blank characters enclosed in parentheses.

Note that all input described in this manual is integer unless floating point or alphanumeric is explicitly indicated. All cards except the CARDFILE card(s) may be continued indefinitely by designating a continuation card as one which has a plus sign as the first non-blank character.

Several different types of input are specified in EXPANSION format. This format consists of sets of data, each set containing one or more data items followed by an integer. The data items are the parameters to be expanded and the integer is the termination point for the expansion. The expansion begins at the termination point of the previous set and continues to the termination point of the current set. These termination points are generally something like composition numbers or mesh point numbers, for example, and always form a strictly increasing sequence. Fixed source values, for example, are specified in the form:

S(1),c(1),S(2),c(2),...,

indicating that S(1) is the source to be associated with compositions 1 through c(1), S(2) with compositions c(1)+1 through c(2), and so forth. Similarly, mesh intervals are specified in the form:

M(1),p(1),M(2),p(2),...

Here M(1) is the mesh associated with each of the intervals between points 0 and p(1) and M(2) with each of the intervals between points p(1) and p(2).

In addition, several different types of input are specified in OVERLAY format. This format consists of triplets of data: the second item in each triplet is expanded over a range whose beginning value is the first item in the triplet and whose ending value is the third item in the triplet. For example, composition correspondences are specified in the form:

r(1),C(1),r(2), r(3),C(2),r(4),...,

indicating that C(1) is the composition number to be assigned to planar regions r(1) through r(2), C(2) is the composition number to be assigned to planar regions r(3) through r(4), and so forth. Within each triplet, the range value r(i+1) must be greater than or equal to the range value r(i), but there is no required relationship of the range values from triplet to triplet. The overlay process is done in order of the appearance of the triplets so that later occurrences of a range value will replace an earlier occurrence. For example, consider the following data for composition correspondences:

300,1,400, 200,2,300, 250,3,350,...,

This set of three triplets will assign composition 2 to planar regions 200 through 249, composition 3 to planar regions 250 through 350, and composition 1 to planar regions 351 through 400.

The number of data fields may vary from card to card in any series or subseries. In general, the input data cards may appear in any order except that continuation cards must, of course, be contiguous except for possible intervening comment cards. If two or more cards have the same card number, however, only the last of these cards is retained. If this last card contains no data (with or without a trailing comma), it also is not retained and thus previous cards with this card number are effectively deleted.

Note that every input restriction stated in this manual is checked by the program. The program makes very extensive consistency checks on the input data and will continue checking through all of the input unless the master control data card (010001) is in error. A problem which violates one or more restrictions will be rejected with appropriate error comments. These comments are usually of the form:

******** ITEM i ON CARD c IN ERROR.

There are other, more explicit, error comments printed for some input errors but it is always true that every possible input error comment printed by the program is headed by eight asterisks, a blank space, then followed by the error message.

In addition, if any card is not used by the program, it is printed in the problem output, it is considered an input error, and the problem is rejected. This condition is usually caused by inconsistent options being designated or by some other dependent input error.

8.3. GENERAL INPUT PREPARATION: MULTIPLE CASES

A single job may consist of several related or unrelated cases. In any case of a job, the case deck may be supplemented by card input from one or more File Manager files. Card file input is designated by the presence of a card with the word CARDFILE in place of the card number and, if present contains from two to three values. These values indicate the File Manager identification and the case number within the card file to extract and add to the current card input. These CARDFILE cards may not be continued but as many such cards may be present as are needed. Note that duplicate CARDFILE cards do not replace each other as do card numbered cards but simply add to each other. The card files are accessed in the order of the CARDFILE cards identifying them and the resultant case deck for the job consists of the card file information (in order of access) followed by the card input for the current case of the job. In the description which follows, it is this effective card input which will be discussed.

An END-CASE card is required between case decks and an END-INPUT card should follow the last case deck. The end-case card is designated by a slash in the first non-blank column and the end-input card by a period in the first non-blank column. Note that the end-input card replaces the end-case card for the last case and that both may not be present.

The input deck for the first case must be complete, but the cards for each succeeding case need only represent changes to be made in the input of the previous case. One such card in each case should be a title card to alter the output page title. If a change card duplicates a card number in the previous case, the new card replaces the old. If the new card contains no data, it also is deleted, thus effectively deleting all previous cards with that card number. If a change card contains a new card number, it is added to the previous case input. Such a card must continue the sequence numbering (if required for that series of cards) of the series to which it is appended. In any case of a job, cards not used by the program are listed and are considered input errors.

From case to case, certain cards are deleted. Hence, if they are desired, these cards must be re-supplied with the input for every case. Most of these cards contain data selecting certain edits which produce a large quantity of printed output. The remaining cards are deleted so that accidental execution of an improperly specified case is less likely to occur. The following is a list of the cards which are deleted from case to case:

CARDFILE	input card file descriptors
010005	pointwise flux, mixing coefficient edit
010006	pointwise, meshwise power edit
010007	meshwise concentration edit
010009	picture edit (non-quadrilateral)
010010	input edits
010034-010035	control search data (2-D,3-D)
010052	control search data (1-D)
010101-010109	replacement compositions
010151-010169	meshwise concentration edit id-s
010171-010179	nuclide replacement id-s
010200	quadrilateral geometry grid distortion edit
010201-010299	quadrilateral geometry picture edit
010300-010399	blockwise edit
017000	block collapsing edit
020101-020399	display edit
030000	composition correspondence selection
200000-211999	sub-case data
600000	synthesis residual edit

In addition, if a geometry file is input to a case, all geometry card input:

050000-059999	planar mesh intervals
060001-061999	block plane boundaries
070001-070999	axial mesh intervals
150001-150999	fine block regions
160000-160999	channel bias data
170001-170999	final figure overlay
180001-180999	planar region areas
700000-799999	channel/track data
800100-899999	basic figure data
900100-999999	super figure (or compound figure) data

is deleted, but only for that case; i.e. if a geometry file is not input to the next case, this data, if present for the current case, will carry over into the next case. If a geometry file is input to a case and composition correspondences are not to be changed, then cards 030001-039999 are deleted in the same way. Likewise, if the problem type is not synthesis all synthesis card input is deleted for that one case to facilitate two dimensional explicit trial function calculations required for synthesis solutions.

One card, if present in any case, is treated in a special way. The card with card number 010022 containing output File Manager filing indicators (or zeroes), is modified in subsequent cases as if the user had replaced the card and incremented by unity each non-zero value on the card. Of course, if this card is changed by the user in some case, the actual data input on the card is used.

With the exceptions noted, the resulting input for a particular case is exactly equivalent to that obtained by removing all preceding end-case cards and running as the first case of a job. To facilitate the restarting of a job in other than the first case, a restart option is available which will simulate the exact case-to-case processing of input down to the selected case to be run. Note also that, in general, the cases of a job are related only through the described processing of the input deck. In fact, cases can be used to run completely unrelated problems; e.g. one case could be a one dimensional problem, the next case a two dimensional problem, and the next a three dimensional problem. In particular, quantities such as flux and concentrations which are calculated in one case are not automatically available to the next case. This coupling of file information can only be accomplished by including control input which causes these files to be stored (in File Manager files) in one case and retrieved in a later case or by the use of sub-cases (see Section 8.4).

8.4. GENERAL INPUT PREPARATION: SUB-CASES

Sometimes the full capability of the program to change any or all input data from case to case is not required; e.g. as in a simple depletion through multiple time steps. In such a problem, it is possible to direct the program to internally retain *most* of the information normally communicated via File Manager files during case to case execution.

Very brief sets of data may be input in one case to accomplish a "multiple case" calculation. Each set of data defines up to eleven quantities to be varied from step to step. These steps are called SUB-CASES. This data can be input in any case and may be used in any problem type except three-dimensional synthesis. The sub-case data cards are deleted from case to case and all are checked in the parent case (the case in which the card data appears) before any sub-case is executed. Sub-cases may be freely intermixed with normal cases.

A sub-case calculation uses card data input to the parent case modified by a set of sub-case data. Also, each sub-case calculation uses any of the tableset, pointwise flux, integrated flux, concentration, and geometry files which may have been input to the parent case or calculated in the previous sub-case whether the calculated files are saved in output File Manager files or not.

It must be emphasized that only certain items of input data may be changed from sub-case to sub-case; that is, the files mentioned previously are automatically carried over (internal to the program) from the previous sub-case and only the specified input sub-case data items (see Section 13.1) may be changed from sub-case to sub-case. All other data items specified in the parent case are assumed to hold for all sub-cases. In particular, all edit requests which are normally deleted from case to case are NOT deleted from the parent case throughout the execution of the sub-cases. However, the edits performed during input processing (geometry, HARMONY, pictures,...) are done only in the first sub-case since the input processing sections of the program are not executed during succeeding sub-cases. Incidentally, some very small problems for which the input processing accounts for a significant portion of the running time can benefit substantially by the use of sub-cases. A restart capability, similar to that described for skipping cases, is available to begin execution at other than the first sub-case.

8.5. GENERAL INPUT PREPARATION: INPUT CHECKLIST

This check list is intended as a brief description of the input to the program. The list is very abbreviated since most of the input described is treated more extensively in other sections of this manual. A copy of this check list is easily obtainable directly from the program: it is the outpnt of a problem having no input data cards. However, unlike the program generated check list, the following includes with each card at least one [Chapter.Section] pair which points to the section of this manual containing a more detailed description of that card.

CARDFILE (optional) [9.2]
Case number, version number, and optional synonym identifying a card file. Card may not be continued but as many cards as required may be present, each identifying one case from one card file to be accessed in the order of these specification cards. Leading, trailing, and embedded blanks are allowed in the word CARDFILE. If the synonym is omitted or is a blank value, the default synonym used is CARDS. The data type for these files is 21. This card is deleted from case to case.

000000 (optional) [16.1]
Card numbers of cards to be deleted for this case only, after card input conversion but before processing. A negative value indicates that cards with card numbers from the previous value through this value are to be deleted. All deleted cards will again appear in the next case (if any) as will card 000000 unless other specific card replacement is done.

0000XX (optional) [16.1]
Override of the explicit-iteration strategy parameters. The parameter specified depends on the value of XX as follows...
01. SIGMA (second to first mode ratio) guess,
02. Inner iteration error reduction criterion,
03. Multiplicative factor in max. flux to test,
04. Yes/no (0/1) inner iteration edit indicator,
05. Maximum number of outer iterations,
06. One or nine (0/1) point sig.-total treatment,
07. First outer iteration to begin Chebyshev extrapolation,
08. Initial Chebyshev cycle number,
09. Criterion on GAMMA to begin Chebyshev,
10. Criterion on EPS. to begin Chebyshev,
11. Minimum Chebyshev degree before new cycle,
12. Criterion for OMEGA convergence,
13. Number of inner iterations per pass in OMEGA,
14. Number of passes per group in OMEGA,
15. Yes/no (0/1) OMEGA iteration edit indicator.
16. Final eigenvalue for checking.
17. Epsilon criterion for final eigenvalue checking.
18. Yes/no (0/1) perform.final spatial after feedbacks.

000100 (optional) [16.1]
Override of the geometry bit packing pattern giving, in order, the bit widths for final figure, planar region, channel, track, and hexagonal transformation number.

000200 (optional) [16.1]
Override of the initial number of tracks per disk. If positive, the use of disks will be forced. If positive and equal to 1 modulo 100, disk checksumming will be done. If zero, the program will decide. If negative, disks will not be used. A second item (if zero) on this card can be used to override automatic restarts after a machine error.

001000 (optional) [16.1]
If this card is present (whether in error or not) and contains any type of input just to indicate the presence of the card, the path indicated on card 010000 is ignored and set to 7 (input check all cases, no filing). This allows an input check of other data on card 010000.

002000 (optional) [16.1]
This card can be used to reduce output volume by controlling the page restores for all editing except at the beginning of a case and all picture

editing and all mesh edits. The first item is the number of lines that can already be printed on a page before a page restore will be done for a new type or collection of output (default to zero), and the second item is the number of lines left on a page for which no new set (of the same type) of output will begin if the whole set will not fit (default to 1/2 page).

010000 (optional) [9.1]
Path, slicing plane, restart case, restart sub-case, and D-source slicing plane. Allowable path values are...
0 = Normal path,
1 = Calculate synthesis library integrals,
2 = Complete re-edit,
3 = Deplete only,
4 = Edit volume-weighted macroscopic data,
5 = Edit pointwise flux,
6 = Input check and filing,
7 = Input check and no filing,
8 = Deplete and calculate power.

010001 [9.1]
Problem type, adjoint indicator, groups, thermal groups, blocking type, geometry type, largest final figure, largest planar region, largest composition, composition correspondence, column boundary, row boundary, plane boundary, diagonal column, input mesh units.

010002 [9.1]
Boundary conditions for column zero, column boundary, row zero, row boundary, plane zero, plane boundary.

010003 [9.1]
Eigenvalue guess, iteration convergence parameter.

010004 [9.1]
CHI values by group.

010005 (optional) [12.3]
Pointwise flux edit and/or synthesis mixing coefficient edit + plot requests. The first six items describe the edit region to be printed (first and last columns, first and last rows, first and last planes) then follow edit indicators for each group followed by a two-thermal-group-sum edit indicator. This card is deleted from case to case.

010006 (optional) [12.3]
Point and mesh power edit requests. The first six items describe the edit region to be printed (first and last columns, first and last rows, first and last planes) then follow the pointwise power edit request, partition power edit request, and block power edit request. For 1-D only, if last plane is negative, block power is printer-plotted as well as printed. For the block power edit, an edit of the maximum block power value for each block plane is also edited, and for this edit, the entire radial space is scanned for the designated planes. If the block power option is negative, only the maximum edit is done. This card is deleted from case to case.

010007 (optional) [12.4]
Edit region description for concentration edits by mesh (first and last columns, first and last rows, first and last planes). This data defaults to be the entire problem volume. For 1-D only, if last plane is negative, concentrations are printer-plotted as well as printed. This card is deleted from case to case.

010008 (depletion) [9.1]
Time zero, time one, delta t max, power level, depletion path indicator.

010009 (optional) [10.6]
Picture edit requests for final figures, planar regions, channels, tracks, hex angle transformations. This card is deleted from case to case.

010010 (optional) [12.1]
Input edit requests as follows...card input geometry data, card input concentrations by composition, harmony input data, edit-set and plane-grouping data, volume-weighted macro data. All items 0/1=no/yes

except use -1 for partial harmony edit. This card is deleted from case to case.

01001X (optional) [9.2]

Each card present contains a version number and optional synonym identifying File Manager input files. If only the version number is supplied or if the supplied synonym is a blank value, a default synonym is used. Each card identifies a different file as follows...

..X..	Type..	Input File Identified.....	Default Synonym
1	200	Tablesets	TABLESETS
2	220	Pointwise Flux	POINTFLUX
3	252	Concentrations	CONCENTRAT
4	251	Geometry	GEOMETRY
5	253	Integrated Flux	INTEGFLUX
6	228	Synthesis Integral Library	SYNTHLIB
7	256	Mesh Figure	FIGURES
8	251	(Old) Expansion Geometry	GEOMETRY

As a special feature, if the version number is -1 (minus one), the program uses that file output in the previous case or subcase (the specified synonym (if any) is ignored). If -1 is specified on these cards in the first case, the output version number less one and the output synonym will be used unless the resulting version number is less than or equal to zero in which case it is treated as if no input file of that type is desired.

010021 (optional) [9.2]

Card contains from 1 to 11 output file synonyms and may be specified whether or not any or all of the output files are to be saved. Default values are supplied for missing or blank values and the order is as follows...

Item..	Type..	Output File Identified.....	Default Synonym
1.	220	Pointwise Flux	POINTFLUX
2.	252	Concentrations	CONCENTRAT
3.	222	Partition Power	PARTPOWER
4.	224	Edit Integrals	EDITINTEG
5.	251	Geometry	GEOMETRY
6.	254	Cross Block Power	CROSSPOWER
7.	253	Integrated Flux	INTEGFLUX
8.	229	Synthesis Mixing Coefficients	SYNTHMIX
9.	228	Synthesis Integral Library	SYNTHLIB
10.	255	Fine Block Power	FINEPOWER
11.	256	Mesh Figure	FIGURES

010022 (optional) [9.2]

Card contains up to 11 output filing indicators for files in the same order as indicated for card 010021. In each position, zero indicates no output filing is to be done and non-zero specifies the output file version number. If this card is missing, each value is assumed to be zero as are any missing values. If the card is present in any case, each successive case and sub-case will increment by one each non-zero value until this card is again supplied.

010031 (control search, 2-D/3-D) [15.2,15.3]

For a poison search... desired eigenvalue, epsilon search criterion, pre-search iteration epsilon, worth guess, maximum number of search tries, numeric ID of nuclide to vary. For a movable fuel or control rod search... only the first three items should be specified.

010032 (control search, 2-D/3-D) [15.2,15.3]

Maximum number of search tries, maximum move per try, minimum bottom, maximum top, reference position.

010033 (control search, 2-D/3-D) [15.2,15.3]

Control element description... for each element, first give the transverse or radial extent, then a zero, then the top and bottom. For 2-D, the radial extent is given by left and right column pairs. For 3-D, the transverse extent is given by final figures or planar regions, whichever correspond to compositions.

010034 (control search, 2-D/3-D) [15.2,15.3]

Top of the control element, bottom of the control element, worth guess. This card is deleted from case to case.

010035 (control search, 2-D/3-D) [15.2,15.3]
Initial position to move to, exact move indicator. This card is deleted from case to case.

010036 (thermal feedback) [15.5]
Maximum number of feedback tries, numeric ID of nuclide to converge, numeric nuclide ID representing moderator density, numeric nuclide ID representing moderator temperature, numeric nuclide ID representing fuel temperature, numeric nuclide ID representing fissions/cc, edit indicator, epsilon criterion for feedback convergence, pre-feedback iteration epsilon. If rod-shrinkage calculations are desired, an optional three additional pseudo-nuclide ID's representing the maximum fuel centerline temperature over lifetime, the clad radius, and the clad stress must be included.

010037 (xenon feedback) [15.6]
Maximum number of feedback tries, numeric nuclide ID of xenon, numeric nuclide ID of iodine, edit indicator, extrapolation factor, epsilon criterion for feedback convergence, pre-feedback iteration epsilon.

01005i (control search, 1-D) [15.1]
Desired eigenvalue, search convergence parameter, up/down indicator, reference point.

010052 (control search, 1-D) [15.1]
Initial configuration. This card is deleted from case to case.

010053 (control search, 1-D) [15.1]
Maximum number of search tries to do, and maximum move allowed on any one search try.

01009S (optional) [10.6]
These cards may be used to specify particular fields of any of the possible picture edits. Each card contains up to ten triplets, each triplet specifying one picture and consisting of... a one word picture name, first digit, last digit. The contiguous (1,2, or 3) digits are counted from right to left. The card sequence number has the following meanings...
S = 1 implies final figures,
S = 2 implies planar regions,
S = 3 implies channels,
S = 4 implies tracks,
S = 5 implies hexagonal angle transformation.
For the figure or region (whichever corresponds to compositions) picture request, if the first and last digits specified are negative, a composition picture of the current configuration (plane zero for 3-D) will be done.

010101 - 010109 (optional) [11.4]
Concentration replacement composition numbers. These cards are deleted from case to case.

0101X0 (optional) [12.2]
Alphanumeric nuclide identifications of collections of nuclide reaction rates or number of atoms to be summed and edited. The form of the data is...name of collection (up to 10 characters), then a set of alphanumeric ID's. If more than one collection is to be given, a blank word separator () must be used between each collection definition. For X = 1, 2, 3, the reaction rates defined are power, absorption, and fission respectively. The summation performed is over the nuclides listed and is the reaction rate for all space and summed over groups. For X = 4, the summation performed is over the nuclides listed and the number of atoms counted is over all space. For X = 9, the form is...alphanumeric name (up to 10 characters), floating point constant pairs. These names can then be used as operands in the algebraic operations defined on cards 01019S. For X = 1, 2, 3, or 4, an already defined collection name (of the same type) can be used as part of a later collection definition.

0101X1 - 0101X9 (optional) [12.2]
Numeric nuclide identifications. The meaning of this data varies with different values of X as follows...
1. Edit of power fractions by edit set,
2. Edit of absorption rates by edit set,
3. Edit of fission rates by edit set,
4. Edit of average concentrations by edit set,
5. Edit of initial concentrations by mesh,
6. Edit of final concentrations by mesh,
7. Selective concentration replacement,
8. Non-contributor to macroscopic cross sections.

For X = 4, if ID is negative, loading (in kilograms) is edited instead of density. For X = 5 and 6, positive ID means gross block data, negative ID means fine block data. Cards with X = 5, 6, and 7 are deleted from case to case.

010191 - 010199 (optional) [12.2]
Definition of algebraic operations to be performed on nuclide collections (cards 0101X0) and then edited. The form of the data is...result name (up to 10 characters), operand name 1, (OP), operand name 2, ... for each result desired. Each operand name must be either a collection name, the name of a constant (from card 010190), or an already defined result name. (OP) must be an alphanumeric +, -, *, /, or ** meaning add, subtract, multiply, divide, or exponentiate respectively.

010200 (optional, quadrilateral geometry) [10.6]
Geometric grid-distortion analysis and edit option. If positive, the maximum, minimum, and average values are printed along with a histogram of the distribution of the measured factors. If negative, the histogram is omitted. The magnitude of the input item determines which factors are measured and they are inclusive
(1) Coupling distances and ratios,
(2) Quadrilateral skew and (1),
(3) Angles and angle ratios and (1), (2),
(4) Triangle area-ratios and (1), (2), (3).
This card is deleted from case to case.

010201 - 010299 (optional, quadrilateral geometry) [10.6]
Picture-print and plot request data, each card containing (1)option name,(2)field name,(3)figure name, (4)first part of title,(5)second part of title,(6)first digit in field, and (7)second digit in field. Cards need not be in sequence and items (4)-(7) are optional. Option name is PRINT or PLOT. Field name is one of FIGURES, REGIONS, CHANNELS, TRACKS, TWIST, FIG/REG, CHAN/TRACK, INTERFACES, MESH, or COMPS. These cards are deleted from case to case.

0103H0 (optional) [12.5]
Hierarchical field definitions for edit of block information. For each hierarchy (H=0,1,...,9), the form of this card is...gross or fine definition (0/1), number of levels in the first (figure or channel) field, then triplets of (sub-field name, first decimal digit, second decimal digit (right to left in the sub-field)). These cards are deleted from case to case.

0103H1 - 0103H9 (optional) [12.5]
Block data edit requests. For each hierarchy (H), each card specifies one edit. The form of the data on each card is...numeric ID (0=power, negative nuclide ID=beginning of time-step concentration, positive nuclide ID=end of time-step concentration), indicator of whether to just print maximum and minimum values or the full edit (0/1), print format desired (fixed/floating=0/1), first plane, second plane, then in the order of the sub-field definitions give the desired (numeric) level values of interest. These cards are deleted from case to case.

010900 (optional) [16.1]
If -1 indicates gross-to-fine concentration expansion. Otherwise, indicator of whether to zero (0) or transform one-to-one (1, default) the concentrations of figures not specified in the 010901 - 010999 data.

010901 - 010999 (optional) [16.1]
Quadruplets of the form (old final figure, old channel bias, new final figure, new channel bias) giving the transformations necessary to expand a concentration file. An (old) geometry file (corresponding to the input concentration file) is required for this expansion.

011000 (optional) [12.2]
Four pairs of (max edit-set, max plane-groupings) used to limit printing of integral data. All data is filed (if requested) whether printed or not. The four pairs refer, in order, to...
1. Volume-weighted macroscopic data,
2. Flux-weighted macroscopic data,
3. Nuclide power fractions, absorption rates, fission rates,
4. Average concentrations, xenon feedback data, thermal feedback data.

A ninth item on this card can be used to reduce or eliminate the axial edits requested with the 016XXS cards.

01XXX1 - 01XXX9 [12.2]
Edit set definitions of the form F1,F2,...,0,R1,R2,... (F refers to final figures, R refers to planar regions) and XXX is a subseries 100-199, 200-299, 300-399, or 400-499. At least one of these subseries must be present. The meaning of these figure-region lists depends on the subseries numbers XXX as follows...
100-199 each subseries (100,101,...) is an edit set,
200-299 each figure (with all regions specified) is an edit set,
300-399 each region (with all figures specified) is an edit set,
400-499 each figure-region combination is an edit set.

015001 - 015999 (3-D only) [12.2]
Plane grouping definitions of the form P1, -P2, P3, -P4, ... where P is an axial point number which must be a gross plane boundary. One set of 015XXS or 016XXS required for 3-D.

016001 - 016999 (3-D only) [12.2]
Definition of edit requests for concentrations, power, flux, and temperature feedback data by gross plane for selected edit-sets. Each XX (in 016XXS) is a request for a particular one of these. For each XX, the form of each request is alphabetic option name (alphanumeric nuclide ID, POWER, FLUX1, FLUX2, FLUX3, FLUX4, FLUX5, - or key-words for temperature feedback data which are FUEL-TEMP, MOD-TEMP, MOD-DENS, VAP-FRACT, and HEAT-FLUX), print / printer-plot indicator (zero means print, one means printer-plot (10 per plot), -N means printer-plot N per plot), P1, P2 (axial point numbers which give axial edit limits and must be gross plane boundaries), then give edit-set numbers E1,E2,... with a negative value meaning the previous edit-set through that one. One set of 015XXS or 016XXS required for 3-D.

017000 (optional) [16.1]
Collapsed blocking data edit request (0 = no edit, 1 = edit).

01XXX1 - 01XXX9 (optional) [16.1]
Blocking definitions of the form F1,F2,...,0,R1,R2,... (F refers to final figures, R refers to planar regions) and XXX is a subseries 700-799, 800-899, or 900-999. Any one, two, or all three subseries may be present. The meaning of these figure-region lists depends on the subseries numbers XXX as follows...
700-799 each subseries (700,701,...) is a new block,
800-899 each figure (with all regions specified) is a new block,
900-999 each region (with all figures specified) is a new block.
The first figure and region in each new block definition are used as the figure and region of the new block.

020001 - 020099 (optional) [11.7]
Area ratios by composition in expansion format.

020X01 - 020X99 (optional) [12.4]
Character display edit requests, one per card. For X = 1, 2, and 3, specify power, initial concentration, and final concentration edits respectively. From 1 to 11 items on a card specify... numeric nuclide ID (1 for power), number of increments to use, minimum value to consider, maximum value to consider, indicator to print picture or just the

frequency chart, and finally the volume element to scan giving first column, last column, first row, last row, first plane, last plane. Missing values default to... 0,36,0.0,0.0,0,0,column boundary,0,row boundary,0,plane boundary. These cards are deleted from case to case.

02G001 - 02G099 (optional) [11.8]
Depletion flux correction factors by composition in expansion format for group G.

030000 (optional) [10.5]
Indicator to replace input geometry file composition data with that from cards, followed by the configuration number. This card is deleted from case to case.

030001 - 030009 (optional) [10.5]
Triplets of the form (N1,C1,N2) which assign (in overlay format), composition C1 to figures (or regions) N1 through N2. This data is required when composition correspondence is not one-to-one.

03PPP1 - 03PPP9 (optional) [10.5]
Modifications at plane (or configuration) PPP to composition correspondences of previous plane (or configuration).

04G001 - 04G099 (fixed source only) [16.1]
Source values by composition in expansion format for group G. This data is required for fixed source problems.

05XXX1 - 05XXX9 [10.1,10.2,10.3]
Planar mesh intervals in expansion format. The subseries number XXX may be any of 1 to 999.

060001 - 060999 (optional) [10.4]
Gross block plane boundaries in increasing order with the last equal to plane boundary. If present, at least two values must be specified. If missing, gross block plane boundaries are the PPP from the 03PPP1-03PPP9 cards.

061000 (optional) [10.4]
Default indicator for fine block plane boundaries. If zero (assumed), each gross block plane boundary is a fine block plane boundary, and if one, each axial point is a fine block plane boundary.

061001 - 061999 (optional) [10.4]
Fine block plane boundaries in increasing order with the last equal to plane boundary. Gross block plane boundaries must fall on fine plane boundaries but not necessarily vice versa.

062001 - 062999 (optional) [16.1]
Collapsed gross plane boundaries in increasing order with the last equal to plane boundary. If present, at least two values must be specified and these definitions must be integral collections of previously defined gross block plane boundaries. The composition correspondences from the lowest numbered original gross plane are used as the correspondences of the collapsed plane.

070001 - 070999 (3-D only) [10.4]
Axial mesh intervals in expansion format.

08G001 - 08G099 (optional) [11.6]
Buckling values by composition in expansion format for group G. For G = 0, specify all values for which group dependent values are not given.

090001 - 090099 (depletion) [11.2]
Chain list assignment by composition in expansion format. Chain list zero implies a non-depletable composition.

09LL01 - 09LL99 (depletion) [11.2]
Sequence of chain numbers defining chain list LL.

10XXX0 (depletion) [11.3]
Composition lists which assign compositions for initial concentration values on cards 10XXX1 - 10XXX9. This data defaults to the one composition number XXX.

10XXX1 - 10XXX9 (depletion) [11.3]
Initial concentration values in the form of pairs..., (numeric nuclide ID, concentration value). This data is assigned to the compositions listed on card 10XXX0 where XXX may be any of 1 - 999.

110001 - 110099 [11.5]
Tableset assignment by composition in expansion format.

111001 - 111099 (optional) [11.5]
Master macroscopic table overlay data of the form... tableset, C1, -C2, C3, -C4 implying that the master macroscopic table from that tableset be overlayed into compositions C1 through C2, C3 through C4, ... These cards specify that the tables described are to be deleted from the designated compositions if the tableset number is zero.

112G01 - 112G99 (optional) [11.5]
Master microscopic table overlay data of the form... tableset, ID1, ID2, ... ,C1, -C2, C3, -C4,... implying that the group G master microscopic tables for nuclides ID1,ID2,... from that tableset be overlayed into compositions C1 through C2, C3 through C4, ... These cards specify that the tables described are to be deleted from the designated compositions if the tableset number is zero.

113G01 - 113G99 (optional) [11.5]
Macroscopic interpolating table overlay data of the form... tableset, type, C1, -C2, C3, -C4,... implying that the group G macroscopic interpolating table from that tableset with the designated type be overlayed into compositions C1 through C2, C3 through C4, ... These cards specify that the tables described are to be deleted from the designated compositions if the tableset number is zero.

114G01 - 114G99 (optional) [11.5]
Microscopic interpolating table overlay data of the form... tableset, type, ID1, ID2, ...,C1, -C2, C3, -C4,... implying that the group G microscopic interpolating tables for nuclides ID1, ID2, ... from that tableset with the designated type be overlayed into compositions C1 through C2, C3 through C4, ... These cards specify that the tables described are to be deleted from the designated compositions if the tableset number is zero.

115G01 - 115G99 (optional) [11.5]
This data is in exactly the same form as for cards 114G01 - 114G99 but the tables referred to are the interpolating tables for shielding factors instead of microscopic interpolating tables. These cards specify that the tables described are to be deleted from the designated compositions if the tableset number is zero.

12MM00 (optional) [11.5]
Mask control card for mask MM specifying... mask dimension, number of diagonal entries, number of off-diagonal entries.

12MMD1 - 12MMD9 (optional) [11.5]
Axis variables for mask MM for each of the dimensions D. For each D = 1, 2, 3, specify the nuclide ID, indicator of whether this mask dimension is to use concentration values or fraction of concentration, then follows a sequence of variable values.

12MM91 - 12MM99 (optional) [11.5]
This data is given only if the number of off-diagonal entries is non-zero for mask MM. If present, this data specifies the off-diagonal positions for the variable values given on cards 12MM11 - 12MM39 in the form of (row,column) pairs if the mask is two dimensional or in the form of (row,column,plane) triplets if three dimensional.

13FFF0 (optional) [11.5]
Function table definition of the form... type of quantity represented (macroscopic, microscopic, or shielding factor), nuclide ID, type of cross section, group, order of interpolation, function/inverse interpolation indicator, followed by (only if shielding factor) pairs of (nuclide ID, type) designators. Table number is FFF.

13FFF1 - 13FFF9 (optional) [11.5]
Function values for table FFF in the order consistent with the order of the independent variable values for the mask eventually assigned to function table FFF.

14CCC1 - 14CCC9 (optional) [11.3]
These cards may be used to specify concentrations in a set of compositions as some factor times those concentrations in composition CCC. The form is... the multiplicative factor followed by the list of compositions.

150000 (optional) [10.1,10.2,10.3]
Default indicator for fine block region definitions, zero if card not present.

150001 - 150999 (optional) [10.1,10.2,10.3]
List of region numbers to fine block if indicator on card 150000 is zero, otherwise it is a list of regions not to fine block.

160000 (optional, non-quadrilateral geometry) [10.1,10.2]
Default indicator for channel bias data. If zero (default value), each final figure laydown is assigned zero bias, if one, each final figure laydown is assigned successive multiples of the maximum input channel number beginning with zero for the first laydown.

160001 - 160999 (optional, non-quadrilateral geometry) [10.1,10.2]
List of channel biases, one for each final figure laydown. These are additive quantities to the channel labels.

170001 - 170999 (non-quadrilateral geometry) [10.1,10.2]
Final figure laydown consisting of sextuplets of the form... final figure number, initial figure or initial super figure number if negative, origin column, origin row, rotation index, reflection indicator.

180001 - 180099 (optional) [10.6]
Planar areas (which will force an area check) by planar region in expansion format.

190001 - 190009 (optional) [11.7]
Triplets of the form (N1,A1,N2) which assign (in overlay format) area ratio A1 to figures (or regions) N1 through N2. This data replaces data (if any) from cards 020001 - 020099.

19PPP1 - 19PPP9 (optional) [11.7]
Modifications at plane (or configuration) PPP to area ratios of previous plane (or configuration).

200000 (optional) [13.1]
First sub-case to execute, last sub-case to execute. This card is deleted from case to case.

2XX001 - 2XX999 (optional) [13.1]
Data for each sub-case. The data definition is a function of the value of XX from 01 to 11 as follows...
(1) Sub-case names (required for sub-cases),
(2) Depletion time intervals (hours, default=0.0),
(3) Depletion power fractions (default=1.0),
(4) Configuration indicators (default=initial config.),
(5) Control eigenvalues (default=from cd. 010031 or 010051),
(6) Thermal feedback indicators (max. tries, default=0),
(7) Xenon feedback indicators (max. tries, default=0),
(8) Concentration replacement indicators (0/1, default=0),
(9) Depletion path indicators (default = item 5 on card 010008),
(10)Output file version number increments (default = 0,1,2...),
(11)Flat/previous flux guess indicators (0/1, default=1).

These cards are deleted from case to case.

300001 - 300299 (depletion) [11.1]
Numeric nuclide identifications.

300300 (depletion) [11.1]
Avogadro constant (optional - default value is .602252+24).

300301 - 300499 (depletion) [11.1]
Atomic weight by nuclide (optional - default values are 1.0).

300501 - 300599 (depletion) [11.1]
Alphanumeric nuclide identifications.

3CC000 (depletion) [11.2]
Nuclide depletion chain definition control card for chain CC of the form... number of nuclides in the chain, chain type, maximum time interval to assume constant cross sections while depleting the nuclides in this chain.

3CCNN1 - 3CCNN9 (depletion) [11.2]
Nuclide depletion chain definition for chain CC. For each nuclide NN=1,2,... in the chain, specify... numeric nuclide identification, form (first/not first indicator), decay constant, then follow with triplets (coupling type, numeric ID of nuclide coupled to, fraction of coupling into nuclide NN).

4TT000 [11.5]
Numeric identification of tableset defined with subseries TT.

4TT001 (optional) [11.5]
Alphanumeric identification of tableset defined with subseries TT.

4TTG00 [11.5]
Master macroscopic table data for group G in tableset identified with subseries TT. Macroscopic cross sections are ordered, for each group, as follows... diffusion (sigma transport if assigned to depletable composition), sigma absorption, sigma removal, nu sigma fission, kappa sigma fission. If G is one of two thermal groups, order is... diffusion(1), diffusion(2) (again, sigma transport if assigned to depletable compositions), sigma(1), sigma(2), nu sigma fission, kappa sigma fission, R term which multiplies the epithermal sigma removal.

4TTG01 - 4TTG99 (depletion) [11.5]
Master microscopic table data for group G in tableset identified with subseries TT. Data for any group G is ordered as follows... numeric nuclide identification, sigma transport, sigma absorption, sigma removal, sigma fission, nu, kappa. If G is one of two thermal groups, following the ID is sigma transport(1), sigma transport(2), sigma(1), sigma(2), sigma fission, nu, kappa.

4TT601 - 4TT699 (optional) [11.5]
Function table and mask assignment to tableset identified with subseries TT. The form for each card is... a mask number followed by a list of function tables associated with that mask.

500001 - 500009 (thermal feedback) [15.5]
Miscellaneous thermal feedback parameters in the order... P, fw, fm, Wt, k1, K, DELTA1, DELTA2, ALPHA, BETA, n, m, GAMMA, KVF, B, LAMBDA. If rod-shrinkage calculations are to be done, an additional fourteen items must be included... ALPHFG, ALPHT, D1, DELTA, DELTAt, E, E1, E2, E3, E4, E5, KAP, RT, Trel.

50001S (thermal feedback) [15.5]
For each of S=1,2,3,4, specify from 1 to 6 polynomial coefficients as follows...
For S=1, specify a(n),
For S=2, specify b(n),
For S=3, specify c(n),
For S=4, specify d(n).

510001 - 510099 (thermal feedback) [15.5]
Flow fraction, mixing coefficient, and inlet temperature by thermal track in expansion format.

520001 - 520099 (thermal feedback) [15.5]
Heat transfer area, flow area, coolant volume, fuel meat volume, radial flow area, and wetted perimeter by composition in expansion format.

530001 - 530099 (thermal feedback) [15.5]
Fuel cladding outside radius, clad inside radius, fuel element outside radius, fuel element inside radius, and rod/plate indicator by composition in expansion format.

540001 - 540099 (thermal feedback) [15.5]
Gap conductance table number RR, and fuel meat conductivity table number TT by composition in expansion format.

550X01 - 550X99 (thermal feedback) [15.5]
Reference values by composition in expansion format. Data represented depends on X as follows...
For X=1, specify reference hydrogen density,
For X=2, specify reference moderator temperature,
For X=3, specify reference fuel temperature.

56RRX1 - 56RRX9 (thermal feedback) [15.5]
Definition of interpolating table number RR for gap conductance. Variables are defined depending on X as follows...
For X=1, specify a sorted set of heat flux values as the first independent variable,
For X=2, specify a sorted set of fissions/cc values as the second independent variable,
For X=3,4,...,9, specify the gap conductance dependent variable values corresponding to the first heat flux value and all fissions/cc values, then for the second heat flux value and all fissions/cc values, etc.

57TTX1 - 57TTX9 (thermal feedback) [15.5]
Definition of interpolating table number TT for fuel meat conductivity. Variables are defined depending on X as follows...
For X=1, specify a sorted set of fuel temperature values as the first independent variable (at least two values),
For X=2, specify a sorted set of fissions/cc values as the second independent variable,
For X=3,4,...,9, specify the fuel meat conductivity dependent variable values corresponding to the first fuel temperature and all fissions/cc values, then for the second fuel temperature and all fissions/cc values, etc.

580001 - 580099 (thermal feedback) [15.5]
If rod-shrinkage calculations are to be done... BETA0, BETA1, BETA2, A1, and R by composition in expansion format.

580101 - 580199 (thermal feedback) [15.5]
If rod-shrinkage calculations are to be done... B1, B2, B3, C1, C2, and C3 by composition in expansion format.

580201 - 580299 (thermal feedback) [15.5]
If rod-shrinkage calculations are to be done... Ar/Aw, A4, Cg, Cs, Pg, and VR by composition in expansion format.

600000 (synthesis) [14.1]
Synthesis residuals edit + plot request (0/1=no/yes). This option creates a special tent function as position one in the trial function description and deletes its use in the spatial calculation. This card is deleted from case to case. This card is ignored if the problem type is not synthesis.

600001 (synthesis) [14.1]
Number of trial functions in each group. This card is ignored if the problem type is not synthesis.

600002 (synthesis) [14.1]
Trial function zone boundaries in increasing order with the last equal to plane boundary. This card is ignored if the problem type is not synthesis.

600003 (optional) [14.1]
Specify two trial function positions. The first will be used as a trial function but not a weight function, the second will be used as a weight function but not a trial function. This holds for all zones. This card is ignored if the problem type is not synthesis.

600II0 (optional) [14.1]
For any of II=1,2,...,49, this card specifies a three dimensional pointwise flux file to be used for trial functions. The items on the card, in order, are version number of the 3-D file, synonym of the 3-D file and the synonym of the two dimensional trial functions which are to be obtained from the 3-D file. If either or both of the synonyms are omitted or have a blank value, the default synonym used is POINTFLUX. These cards are ignored if the problem type is not synthesis.

600II1 - 600II9 (optional) [14.1]
For any of II=1,2,...,49 for which card 600II0 is present, these cards specify (point plane number, version number) pairs giving the plane numbers to be extracted from the 3-D file and associating them with version numbers as used in the trial function description. These cards are ignored if the problem type is not synthesis.

6ZZ001 - 6ZZ009 (optional) [14.1]
(Version number, synonym) pairs specifying trial functions for all groups in zone ZZ. Successive pairs identify sucessive trial function positions within zone ZZ. If a synonym has a blank value, the synonym used is POINTFLUX. If the (version number, synonym) pair is (0,UNITY), a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied. These cards are ignored if the problem type is not synthesis.

6ZZG01 - 6ZZG09 (optional) [14.1]
(Version number, synonym) pairs specifying trial functions for group G in zone ZZ. Successive pairs identify successive trial function positions within zone ZZ. This data overlays that data specified on cards 6ZZ001 - 6ZZ009. If a synonym has a blank value, the synonym used is POINTFLUX. If the (version number, synonym) pair is (0,UNITY), a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied. These cards are ignored if the problem type is not synthesis.

6ZZG11 - 6ZZG19 (optional) [14.1]
Specify a mapping vector of group numbers from successive positions of trial functions in zone ZZ to be used in synthesis group G. If these cards are not present, the mapping is one-to-one. These cards are ignored if the problem type is not synthesis.

660SSS (optional) [14.1]
Specify three (version number, synonym) pairs, where the third trial function identified is to be subtracted from the second to form a difference function. This difference function is used as that trial function identified first on this card and somewhere on the 6ZZ00S and/or 6ZZG0S cards. SSS may be any of 1,2,...,999 not necessarily sequential. If a synonym has a blank value, the synonym used is POINTFLUX. If the (version number, synonym) pair is (0,UNITY), a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied. These cards are ignored if the problem type is not synthesis.

700000 (optional) [10.1,10.2,10.3]
Default indicator for channel/track identifications. If zero is supplied (default value), any initial figure containing non-specified channel/track identification will have a channel and track value of 1 supplied for the non-specified channels/tracks. If one is supplied on this card, the initial figure will have N supplied for the non-specified channels/tracks in column/row N.

7BBB00 (optional) [10.1,10.2,10.3]
Normally channel labels are assigned to columns and track labels are assigned to rows of an initial figure. This card contains an indicator which if zero (default value) does not affect this label process but, if one, reverses this label process for basic figure BBB.

7BBBA1 - 7BBBA9 (optional) [10.1,10.2,10.3]
Channel/track identifiers for basic figure BBB, auxiliary figure A. The data for auxiliary figures 1,2,...,9, modify data specified for auxiliary figure 0. The form of the data is... C0, CH1, C1, CH2, ..., 0, R0, TR1, R1, TR2, R2, ..., where CH1 (TR1) is a channel (track) label to be assigned between columns (rows) C0 and C1 (R0 and R1) and so on for CH2 (TR2) between C1 and C2 (R1 and R2),... If the channel (track) label is negative, the absolute value is used and is incremented by one for each column (row).

800000 (optional, quadrilateral geometry) [10.3]
Internal angle of basic figures in sequential expansion form with last value assumed to extend infinitely. Default value is 90 degrees, 60 degrees if geometry type is -4.

8BBB00 (non-quadrilateral geometry) [10.1,10.2]
Control card for basic figure BBB containing column boundary, row boundary, column interval planar mesh data subseries numbers, zero, row interval planar mesh data subseries numbers. If a transition figure, data is... minus one, row boundary, column interval subseries number, zero, left side subseries numbers then right side subseries numbers.

8BBB00 (quadrilateral geometry) [10.3]
Basic figure control card containing label, column boundary, row boundary, column interval planar mesh data subseries numbers, zero, row interval planar mesh data subseries numbers. BBB need not be sequential.

8BBBA0 (quadrilateral geometry) [10.3]
Card contains the label for auxiliary figure A of basic figure defined for sequence BBB. The value of A is 1 to 9, not necessarily sequential.

8BBBA1 - 8BBBA9 (non-quadrilateral geometry) [10.1,10.2]
Planar region overlay sets (planar region number, left column, right column, top row, bottom row) for auxiliary figure A (0,1,2,...) of basic figure BBB. Data for auxiliary figures 1,2,... all modify auxiliary figure 0. Note that initial figures are numbered BBBA and thus begin with 10.

8BBBA1 - 8BBBA9 (quadrilateral geometry) [10.3]
Planar region overlay sets (planar region number, left column, right column, top row, bottom row) for auxiliary figure A (0,1,2,...) of basic figure BBB. Data for auxiliary figures 1,2,... all modify auxiliary figure 0.

900000 (optional, quadrilateral geometry) [10.3]
Internal angle of compound figures in sequential expansion form with last value assumed to extend infinitely. Default value is 90 degrees, 60 degrees if geometry type is -4.

900001 (optional, quadrilateral geometry) [10.3]
Label of the solution figure. Default label name is SOLUTION.

9BBB00 (optional, non-quadrilateral geometry) [10.1,10.2]
Control card for super figure BBB containing column boundary and row boundary.

9CCC00 (quadrilateral geometry) [10.3]
Compound figure control card containing label, column boundary, row boundary. If only label is present, input figure file overlay sets are accessed and any card input overlay sets are added to them. CCC need not be sequential.

9CCC01 - 9CCC99 (quadrilateral geometry) [10.3]
Compound figure overlay sets, one set per card, consisting of figure label, point column origin, point row origin, row direction index, column

direction index, final figure number increment, channel number increment, absolute X origin, absolute Y origin, delta angle of rotation.

9BBBA1 - 9BBBA9 (optional, non-quadrilateral geometry) [10.1,10.2]
Super figure overlay sets (initial figure number, origin column, origin row, rotation index, reflection indicator), for auxiliary super figure A of super figure BBB. Data for auxiliary super figures 1,2,... all modify auxiliary super figure 0. Note that initial super figures are numbered BBBA and thus begin with 10.

9.1. CONTROL INPUT PREPARATION: CONTROL DATA

The description of input data in this section and in all other sections relating to input data preparation includes the set of restrictions and/or consistency requirements for the data described. All of these requirements ARE checked by the program for both necessary and sufficient conditions. For example, if some option is allowed to have values of 0 or 1 (i.e. those are the only values described in this manual), the program checks that only 0 or 1 is present and any other value is considered an error. This type of checking is done because it is felt that the user may be expecting some action from the program different from that which it is capable of producing.

If any error is found on the first required data card (010001, the master control data card), that fact is noted and the problem is immediately rejected. Otherwise, the input processing sections of the program are always executed so that the entire input for the case is checked for errors regardless of the number of errors encountered.

In this section, each card is first described by specifying the order of successive data fields on the card; then a more extensive description is given for each data item. A short mnemonic name is used for each item; then, in the subsequent descriptions, this name is used when referring to a particular item.

Special Path, Slicing, Restarts

010000 Optional.

(1) PATH - special path definition
(2) SLICE - slicing plane definition
(3) FIRCAS - next case to execute (restart)
(4) FIRSUB - first sub-case to execute (restart)
(5) DSLICE - source plane definition

This card is used to define a calculational path other than normal, to define a two dimensional (slice) calculation to be run from a three dimensional problem description, to begin execution (restart) at other than the next case or sub-case, and to define a plane from which to obtain the source components for a slice calculation. The card is optional and may contain from one to five data items with default values of 0 , -1 , 0 , 0 , 0 for PATH, SLICE, FIRCAS, FIRSUB, and DSLICE respectively.

(1) PATH

PATH is used to specify that the program execute some subset of the normal calculations in a case. These various paths may be used without making substantial changes to a normal set of input, but in all cases the input must be complete in the normal calculational - path sense. It should be stressed that these special paths are mechanical in the program and simply go through the requested program sections to accomplish the required task. All desired options in those sections must be explicitly requested. For example, if the PATH = 5 option (edit pointwise flux) is chosen, the request for pointwise flux edits must be explicitly included in the appropriate input data or pointwise flux edits will not be done. Normal calculation cases may be freely intermixed with these special path cases. In all paths except PATH = 7 (input check and no filing), the problem is rejected if the input is in error, but otherwise multiple cases may be accomplished. If PATH = 7, all cases are processed regardless of the number of input errors found unless the master control card (010001) is in error. Except for PATH = 7, all paths go through the output filing section of the program which writes File Manager files. If a request is made to file data which does not exist (input or calculated), the request is ignored and will not affect that case in any way. If sub-cases are specified, only the first one is executed if PATH is non-zero.

The value of PATH determines the particular path to be executed as follows:

0 = normal path (default)
1 = calculate synthesis integrals
2 = do a complete re-edit
3 = deplete only
4 = edit macroscopic data
5 = edit pointwise flux
6 = input check and filing
7 = input check and no filing
8 = deplete and calculate power

If PATH = 0 (or if this card is missing), a normal calculational path is done.

If PATH = 1, the problem must be synthesis.

If PATH = 2, all calculations otherwise requested except the spatial calculation are performed. If the problem type is synthesis, an integral flux File Manager input file must be provided. If both pointwise and integrated flux File Manager input files are provided, the latter is used in all calculations involving the flux in integrations. Either an integrated flux or a pointwise flux File Manager input file must be provided.

If PATH = 3, meshwise and/or blockwise concentration edits are also performed if requested. Unless the no deplete option is chosen, an integrated flux File Manager input file must be provided.

If PATH = 4, macroscopic cross sections calculated in the case are edited if requested.

If PATH = 5, a pointwise flux File Manager input file must be provided.

If PATH = 6, any File Manager data files written will contain whatever data is provided after input processing but before any calcualtional sections have been executed. This data may be from a File Manager input file or may be generated by the input process itself. Examples of the latter include a flat pointwise flux (1.0 everywhere except 0.0 on zero flux boundaries), a flat integrated flux (flux = 1.0 so that the integral of the flux is just the volume), and the expanded input concentrations.

If PATH = 7, all cases are processed unless the master control card (010001) is in error.

If PATH = 8, meshwise and/or blockwise concentration edits are performed if requested. In addition, meshwise and/or blockwise power is edited if requested. If deplete after spatial is chosen, either an integrated flux or a pointwise flux File Manager input file must be provided.

(2) SLICE

SLICE is used to specify the axial plane at which to slice a three dimensional problem to create a two dimensional problem. The value of SLICE must be greater than or equal to zero and less than or equal to the highest plane number; the problem type must not be synthesis. If a slice is not desired, this value should be set to any negative number. If the problem is two dimensional, this value is ignored. For a slice problem, any File Manager input file may be two or three dimensional except a geometry file (if any) which must be three dimensional. The program will automatically slice out the appropriate plane from all input files. If a three dimensional pointwise flux File Manager input file is provided, the fluxes at axial point number SLICE are used as the flux guess. Composition descriptions, nuclide concentrations, and integral fluxes (if File Manager file provided) are all sliced from the mesh plane between axial point planes numbered SLICE and SLICE+1; if SLICE is the highest axial point number, then these quantities are obtained from the mesh plane between the last two axial points. This option is most useful for generating two dimensional trial functions for use in three dimensional synthesis calculations.

(3) FIRCAS

FIRCAS is used to specify the next case number to execute; that is, restart at other than the current case. The card specifying FIRCAS may appear in any case but, of course, must appear in the first case to be skipped. For example, if the first five cases are to be skipped, this card should be present in the first case and FIRCAS = 6 should be supplied. All input processing of card data for the skipped cases is exactly as if those cases had been executed. In particular, the program automatically determines which File Manager input files are required if such files were being used from case to case in the skipped cases. This option is especially useful in restarting a previous problem which terminated prematurely in that the input deck does not have to be restructured to continue the problem.

(4) FIRSUB

FIRSUB is used to specify the first sub-case to execute; that is, restart at other than the first sub-case. All input processing for the skipped sub-cases is exactly as if those sub-cases had been executed. In particular, the program automatically determines which File Manager input files (if any) are required. This option is especially useful in restarting a previous problem which terminated prematurely in that the input deck does not have to be restructured to continue the problem. If FIRSUB is greater than 1, then: (a) if the problem is depletable, a File Manager input concentration file must be provided; and (b) if any control search or a poison search is being done, a File Manager input geometry file must be provided.

(5) DSLICE

DSLICE is used to specify the axial plane at which to slice a three dimensional problem to obtain the pointwise flux guess and the diffusion coefficient to construct a source. The source will be the product of these two quantities. The problem type will be set to "fixed source", card 010004 (CHI values) and cards 04g0SS (fixed source values) will be deleted temporarily in this case if they are present. The value of SLICE must be non-negative (i.e. a slice problem must be done), there cannot be two thermal groups, and a two-dimensional concentration file cannot be input. Note that, unlike the value for SLICE, a zero value of DSLICE is ignored. The value of the flux - weighted source will be edited in place of the flux - weighted fission cross section; however, if non - unity area ratios are used, the edited source value will be divided by the product of the area ratio from the DSLICE plane and the area ratio from the SLICE plane. Normally, area ratios are transparent in edited quantities and this anomaly is due to the fact that only one area ratio is "known" to the program in each block during editing; the source value, however, in all cases correctly accounts for the proper area ratio value.

Master Control Data

010001 Required in all problems.

(1) PRBTYP - problem type
(2) ADJNT - adjoint indicator
(3) GROUPS - number of groups
(4) THGRPS - number of thermal groups/P(3) indicator
(5) FINE - fine blocking indicator
(6) GEOM - geometry type
(7) MAXFIG - largest final figure
(8) MAXREG - largest planar region
(9) MAXCMP - largest composition
(10) CORRES - composition corespondence indicator
(11) COLBDY - column boundary
(12) ROWBDY - row boundary
(13) PLNBDY - plane boundary
(14) DIAG - diagonal column
(15) CMINCH - centimeters/inches indicator

This is the master control card required in every problem. The card contains important parameters which are used in determining input data consistency.

(1) PRBTYP

PRBTYP is the type of spatial flux solution that is to be performed. There are seven different types possible depending on the value of PRBTYP from -1 through 5 as follows: -1 means simplified P(L), 0 means additive fast source, 1 means fixed source, 2 means eigenvalue, 3 means one iteration, 4 means boundary value, 5 means synthesis. If PRBTYP is -1 or 0, the P(3), adjoint, and two-thermal group options must not be requested and there must be at least two groups. If PRBTYP is 5 (synthesis), the problem must be three dimensional; the two-thermal group and adjoint options must not be requested; and there must be at least two groups.

(2) ADJNT

ADJNT is the specification of whether an adjoint solution is desired. If ADJNT has a value of 0, a direct (non-adjoint) calculation is performed. If ADJNT has a value of 1, an adjoint calculation is performed; in this case, the number of groups must be greater than 1, there must be only 1 thermal group, and the simplified P(3) fast group treatment cannot be used.

(3) GROUPS

GROUPS is the number of groups. This must be a positive value no greater than five.

(4) THGRPS

THGRPS is the number of thermal groups (1 or 2) and, simultaneously, specifies whether the fast group treatment is simplified P(3). If THGRPS is negative (-1 or -2), a simplified P(3) fast group treatment is used. THGRPS must be 1 or -1 if the problem is three dimensional. The total number of groups must not be less than the number of thermal groups. If P(3) is selected, there must be at least one non-thermal group; at least two non-thermal groups if there are two thermal groups.

(5) FINE

FINE is the indicator of whether fine blocking is to be done. The value of this indicator must be either 0 (for no fine blocking) or 1 (for fine blocking). If a problem is set up to do fine blocking with all the appropriate input required and then a calculation without fine blocking is desired, the value of FINE may be set to 0 and the program will automatically delete all other fine block card and/or file data so that this is the only user action that need be taken.

(6) GEOM

GEOM is the indicator of the type of geometry for the problem. The type is determined by the value of GEOM as follows: 1 means rectangular, 2 means cylindrical, 3 means spherical, and 4 means hexagonal. In addition, if the value of GEOM is the negative of any one of the four values described, the geometry grid specified is the generalized quadrilateral grid. Spherical geometry is available only in one dimension; cylindrical geometry only in one and two dimensions; and hexagonal only in two and three dimensions. A quadrilateral geometry grid cannot be specified for one dimension, nor for cylindrical geometry, nor can there be two thermal groups. In addition, if a quadrilateral geometry grid has been specified and the problem is three dimensional, then PRBTYP = 5 (synthesis) is required. Both quadrilateral options -1 and -4 ("rectangular" and "hexagonal" respectively) are slab geometries and differ only in that the geometry building blocks (figures) are assumed to be 90 degree or 60 degree elements respectively unless otherwise specified.

(7) MAXFIG

MAXFIG is the largest final figure number used in the problem. The value of MAXFIG must be positive and less than 1000.

(8) MAXREG

MAXREG is the largest planar region number used in the problem. The value of MAXREG must be positive and less than 1000.

(9) MAXCMP

MAXCMP is the largest composition number used in the problem. The value of MAXCMP must be positive and less than 512.

(10) CORRES

CORRES is the indicator of how the compositions are to be assigned to the geometry structure. If CORRES has a value of 1, compositions will be assigned to final figures; if CORRES has a value of 2, compositions will be assigned to planar regions. If the value of CORRES is negative (-1 or -2), the correspondence will be one-to-one with final figures or planar regions respectively. The correspondence may be one-to-one only if MAXCMP = MAXFIG (or MAXCMP = MAXREG).

(11) COLBDY

COLBDY is the point number (counting from 0) of the last column. The number of solution columns must be greater than two.

(12) ROWBDY

ROWBDY is the point number (counting from 0) of the last row. The number of solution rows must be greater than one in two and three dimensions.

(13) PLNBDY

PLNBDY is the point number (counting from 0) of the last plane. The number of solution planes must be greater than one in three dimensions.

(14) DIAG

DIAG is the point number (counting from 0) of the diagonal column where the chevron bend occurs in hexagonal geometry, zero otherwise. If non-zero: DIAG must be greater than one and less than COLBDY-1; if the row zero boundary condition is rotational, the value of DIAG must be exactly one-half the value of COLBDY.

(15) CMINCH

CMINCH is the indicator of whether the geometry input dimensions are given in centimeters or in inches. If the value of CMINCH is 0, the units are centimeters; if CMINCH is 1, the units are inches.

Boundary Conditions

010002 Required in all problems.

(1) LEFTBC - boundary condition at column 0
(2) RITBC - boundary condition at column COLBDY
(3) TOPBC - boundary condition at row 0
(4) BOTBC - boundary condition at row ROWBDY
(5) UPRBC - boundary condition at plane 0
(6) LWRBC - boundary condition at plane PLNBDY

This card supplies boundary conditions and is required in every problem.

The data items are the boundary conditions for column 0 and COLBDY, row 0 and ROWBDY, plane 0 and PLNBDY respectively. For each boundary, the conditions are specified by one of four values: -1 means rotational symmetry (on row 0 only), 0 means zero flux, +1 means zero current, and +2 means fixed flux. Up to six values may be present in any problem, but only the first two are required in one dimension and only the first four are required in two dimensions. The column 0 boundary condition must be zero current in cylindrical and spherical geometry, and the rotational symmetry condition must not be used in cylindrical geometry. The boundary conditions on column 0 and COLBDY must be the same in the case of rotational symmentry.

Spatial Iteration Parameters

010003 Required in all problems.

(1) LAMBDA - input eigenvalue guess
(2) EPSILN - iteration convergence criterion

This card supplies parameters for the spatial iteration and is required for every problem.

(1) LAMBDA

Lambda is the eigenvalue guess to be used in the iteration or as the problem eigenvalue if the spatial iteration is to be bypassed. This guess should be reasonable in all cases but is extremely important in some problems. In a problem which is being re-edited and the spatial calculation is being bypassed, this eigenvalue guess must be the correct (converged) eigenvalue or certain of the edits will be wrong (K-effective edits, buckling edits). In a synthesis problem, this guess should always be at least as large as the expected eigenvalue because the Weilandt iteration scheme will converge to the eigenvalue nearest this guess and the largest eigenvalue is the solution desired. In a synthesis problem, the program attempts to guarantee this requirement by taking as the actual guess 1.1 times the input guess. In an explicit problem when the converged flux is input and a few more iterations are desired, this eigenvalue guess should be that which was calculated as the last eigenvalue in the previous problem or the problem will run longer than is necessary. If a File Manager pointwise flux file is input to the problem and LAMBDA is zero, the eigenvalue guess will be taken from that file. This is a floating point number.

(2) EPSILN

If EPSILN is positive, it is the iteration convergence criterion for the pointwise flux as used in Equation 2.2.1. If EPSILN is negative, the absolute value is used and it is the convergence criterion for the eigenvalue only; in this case if the problem type (PRBTYP on card 010001) is not an eigenvalue solution, EPSILN is treated as though it were zero. If EPSILN is zero, only one outer iteration is done. This is a floating point number.

Chi Values

010004 Required in non fixed-source problems

(1) CHI1 - chi value for group 1
(2) CHI2 - chi value for group 2
( ) . - .
( ) . - .
(G) CHIG - chi value for the last (G-th) group

This card supplies values of chi, the fraction of fission neutrons born, for each group.

This card must not be present in fixed source (PRBTYP=1) problems and is required in all other problems. These are floating point numbers.

Depletion Time, Power Level Definition

010008 Required in depletable problems.

(1) T(0) - time at beginning of step
(2) T(1) - time at end of step
(3) DELTMX - maximum renormalization time
(4) POWER - power level in watts
(5) DEPTIM - depletion path indicator

This card is required if and only if the problem is depletable; i.e. nuclide concentrations are defined in the problem.

(1) T(0)

T(0) is the time (in hours) at the beginning of the depletion interval. T(0) must be non negative. This is a floating point number.

(2) T(1)

T(1) is the time (in hours) at the end of the depletion interval. T(1) must be greater than or equal to T(0). This is a floating point number.

(3) DELTMX

DELTMX is the maximum time interval (in hours) to deplete before performing a thermal flux renormalization. DELTMX must be non negative and if T(0) is not equal to T(1) it must be strictly positive. This is a floating point number.

(4) POWER

POWER is the power level (in watts) extracted from that portion of the core volume represented by the problem. The value must be non negative. This is a floating point number.

(5) DEPTIM

DEPTIM is the indicator of whether the depletion is to occur before or after the spatial flux calculation or not at all. The value of DEPTIM determines when the depletion is to occur: 0 means before the spatial, 1 means after the spatial, and -1 means not to deplete. This number is optional and the default value is 1 (deplete after spatial). All isotopic integral editing is performed in the depletion section of the program so that if the DEPTIM = -1 (do not deplete) option is chosen, no isotopic integral editing will be done.

NOTE

If DEPTIM = 0 (deplete before spatial) is chosen and T(0) is not equal to T(1) and POWER is non-zero, an integrated flux File Manager input file is required.

9.2. CONTROL INPUT PREPARATION: FILE MANAGER DATA

This section describes card input data which can be used to specify both the reading of input File Manager files and the writing of output File Manager files. Three levels of identification are associated with each File Manager input and output file: the integer VERSION number and alphanumeric SYNONYM of up to ten characters both supplied as input by the user, and an integer DATA TYPE number supplied by the program. Files created in different cases or sub-cases of the same job are usually distinguished by version number and files created in the same case or sub-case are distinguished by data type number. The synonym is simply a temporary identifier which stands for all other identifications required by the File Management system.

Not all of the card input data describing File Manager file input is included in this section. In particular, card input data identifying the two and three dimensional pointwise flux files to be used as trial functions in a three dimensional synthesis problem are not included. That data is more properly included in the synthesis input description (see Section 14.1) since the File Manager identification of trial functions is closely associated with the synthesis problem description.

Input File Manager Card Files

CARDFILE Optional.

(1) CASENO - case number in card file
(2) VERSNO - version number of card file
(3) SYNONM - synonym name of card file

This card is used to designate that some or all of the input data cards for the current case are to be obtained from a File Manager input card file. The DATA TYPE for such card files is 21. The word CARDFILE is used in place of the usual card number. For example, to extract the sixth case from a File Manager input card file identified by version number 123 and synonym name DECK, the following form could be used:

```
CARDFILE , 6 , 123 , DECK
```

There may be leading, trailing, or embedded blanks in the word CARDFILE. These cards may not be continued but as many such cards may be present as are needed. Multiple CARDFILE cards do not replace each other as do card numbered cards but simply add to each other, each card designating one case of data to be extracted from one File Manager input card file. The card files are accessed in the order of the CARDFILE cards identifying them and the resultant case deck for the job consists of the card file information (in order of access) followed by the card input for the current case of the job. Thus, card data from later card files can modify card data from earlier card files and card input can modify card file input. CARDFILE cards must not be present in the input card files.

(1) CASENO

CASENO is the case number within the identified File Manager card file which contains the card data to extract. Of course, the identified card file must contain at least CASENO cases of data.

(2) VERSNO

VERSNO is the version number of the desired File Manager input card file. This value must be greater than zero and less than 1000.

(3) SYNONM

SYNONM is the synonym name of the desired File Manager input card file. This data item is optional; if it is missing or is a blank value, the name CARDS is used. This data is alphanumeric, consisting of from one to ten characters.

Input File Manager Files

01001s Optional.

(1) VERSON - version number of an input file
(2) SYNONY - synonym name of an input file

Each of these cards, for s=1,2, ... ,7, can be used to designate an input File Manager file for various types of data. The type of input data file specified depends on the sequence number s as follows (File Manager DATA TYPE is shown in parentheses):

s = 1 means HARMONY cross sections (200),
s = 2 means pointwise flux (220),
s = 3 means isotopic concentrations (252),
s = 4 means geometry (251),
s = 5 means integrated flux (253),
s = 6 means synthesis integral library (228),
s = 7 means quadrilateral figures (256),
s = 8 means (old) expansion geometry (251).

(1) VERSON

VERSON is the version number of the File Manager input file. This number must be a positive integer less than 1000. As an exceptional case, if the version number is -1 (minus one), the program will read as the input file that File Manager file of the same type which was output in the previous case or sub-case; the synonym, if any, is ignored. If VERSON = -1 in the first case, the first case output file version number less one and the output file synonym name is used to obtain the input file unless the resultant version number is zero or less in which case the request for that input file is ignored.

(2) SYNONY

SYNONY is the synonym name of the File Manager input file. The synonym name is optional; if missing, a default name is supplied depending on the sequence number s as follows (File Manager DATA TYPE is shown in parentheses):

s	Value	Default Synonym	Input File Identified
	1	TABLESETS	HARMONY tablesets (200)
	2	POINTFLUX	pointwise flux (220)
	3	CONCENTRAT	concentrations (252)
	4	GEOMETRY	geometry (251)
	5	INTEGFLUX	integrated flux (253)
	6	SYNTHLIB	synthesis integrals (228)
	7	FIGURES	quadrilateral figures (256)
	8	GEOMETRY	geometry for concentration expansion (251)

This data is alphanumeric, consisting of from one to ten characters.

Output File Manager File Synonyms

010021 Optional.

(1) SYN01 - synonym name for pointwise flux
(2) SYN02 - synonym name for concentrations
(3) SYN03 - synonym name for partition power
(4) SYN04 - synonym name for edit integrals
(5) SYN05 - synonym name for geometry
(6) SYN06 - synonym name for gross block power
(7) SYN07 - synonym name for integrated flux

(8) SYN08 - synonym name for synthesis mixing coeff.
(9) SYN09 - synonym name for synthesis integrals
(10) SYN010 - synonym name for fine block power
(11) SYN011 - synonym name for quadrilateral figures

This card is used to supply synonym names for output File Manager files which may be written. The presence or absence of this card in no way implies a request to write such output files. The position of the item on the card determines which output file is being defined. The card is optional and from one to eleven output file synonym names may appear on the card.

Default synonym names are supplied automatically for missing or blank values as follows (File Manager DATA TYPE is shown in parentheses):

Position	Default Synonym	Output File Identified
(1)	POINTFLUX	pointwise flux (220)
(2)	CONCENTRAT	concentrations (252)
(3)	PARTPOWER	partition power (222)
(4)	EDITINTEG	edit integrals (224)
(5)	GEOMETRY	geometry (251)
(6)	GROSSPOWER	gross block power (254)
(7)	INTEGFLUX	integrated flux (253)
(8)	SYNTHMIX	synthesis mixing coeff. (229)
(9)	SYNTHLIB	synthesis integrals (228)
(10)	FINEPOWER	fine block power (255)
(11)	FIGURES	quadrilateral figures (256)

This data is alphanumeric, consisting of from one to ten characters.

Output File Manager File Version Numbers

010022 Optional.

(1) VERS1 - version number for pointwise flux
(2) VERS2 - version number for concentrations
(3) VERS3 - version number for partition power
(4) VERS4 - version number for edit integrals
(5) VERS5 - version number for geometry
(6) VERS6 - version number for gross block power
(7) VERS7 - version number for integrated flux
(8) VERS8 - version number for synthesis mixing coeff.
(9) VERS9 - version number for synthesis integrals
(10) VERS10 - version number for fine block power
(11) VERS11 - version number for quadrilateral figures

This card is used to indicate a request for File Manager output files to be written. The card is optional and may contain from one to eleven indicators for files in exactly the same order as for card 010021. That is, the position of the indicator on the card determines which output file is being defined as follows (File Manager DATA TYPE is shown in parenthesis):

Position	Output File Identified
(1)	pointwise flux (220)
(2)	concentrations (252)
(3)	partition power (222)
(4)	edit integrals (224)
(5)	geometry (251)
(6)	gross block power (254)
(7)	integrated flux (253)
(8)	synthesis mixing coeff. (229)
(9)	synthesis integrals (228)
(10)	fine block power (255)
(11)	quadrilateral figures (256)

Each indicator is an integer with value zero (no) or non-zero (yes) indicating

whether or not to write that particular file. The non-zero values are each a positive integer less than 1000, and each specifies the version number of that file to be written. If this card is missing in the first case, zero (nothing to be saved) is assumed for each value. Each missing value is likewise assumed to be zero. If this card is present in any case, succeeding cases will automatically increase the non-zero version numbers from the preceding case by one if the card is not re-supplied to override such an incrementing process. The intent of this incrementing is to provide an easy method to save files identified by a common synonym name and consecutive version numbers in a multi-case problem.

10.1. GEOMETRY INPUT PREPARATION: RECTANGULAR GEOMETRY DATA

This section describes the data used for the transverse planar mesh description in rectangular geometry. A description of the method of construction and terminology used can be found in Chapter 3.

Data used in the rectangular geometry construction process is described via card input. If the same geometry is to be used in several problems, the complete geometric description which is constructed may be saved in an output File Manager geometry file. This File Manager geometry file may then be input to succeeding problems eliminating the need for repeatedly constructing the geometry. It should be noted that an input File Manager geometry file contains a complete geometric description, and only the material assignments (composition correspondences) may be changed in a problem which uses the file. Geometry cards may or may not be present when a File Manager geometry file is input; if present, they will be deleted by the program.

The card series used to define a transverse rectangular geometry mesh are as follows:

05XXXS	Planar mesh interval data
150SSS	Fine block planar region data
8BBBAS	Basic and auxiliary figure data
7BBBAS	Channel/track data
9BBBAS	Super figure data
170SSS	Final figure data
160SSS	Channel bias data

Some of these card series have subseries numbers (XXX or BBBA) whose meanings will be explained below. All of the card series having sequence numbers (S or SSS) must begin with 1 and be used sequentially.

Additional geometry data necessary for the axial description of the grid in 3-D problems can be found in Section 10.4. The fine block planar region data, channel/track data, and channel bias data are used only in problems which are fine blocked. If these cards are present in a problem which is not fine blocked, they will be checked by the program but will not be used.

MESH INTERVAL DATA

Planar mesh interval data is specified in expansion format, each set consisting of a floating point interval value followed by a point number. The series number is 05 and any of the three-digit subseries 001-999 may be used. Each such subseries specifies a sequence of intervals extending from point 0 to an arbitrary termination point. The data might consist of the following cards, for example, defining mesh subseries 3, 17, and 256:

```
050031, 1+1, 1, 5+1, 2

050171, 2+1, 2, 3+1, 3, 1+1, 5

052561, 4+1, 1
```

The mesh sequences described on this series will be used to define the row and column mesh spacings in basic figures.

FINE BLOCK PLANAR REGION DATA

In fine blocked problems the set of planar regions which are to be fine blocked is input on the 150 series. Card 150000 is the default indicator for this series. This card contains a single integer item, zero or one. If zero, then cards 150001-150999 contain the planar regions to be fine blocked; if one, then all planar regions except those on cards 150001-150999 are to be fine blocked. If this card is not present, zero is assumed.

The cards 150001-150999 contain a list of planar region numbers:

R(1), +-R(2), +-R(3), ... , +-R(N)

with the form R(i), -R(i+1) meaning all of the planar regions from R(i) through R(i+1).

BASIC FIGURE DATA

A control card is required for each basic figure. This card contains the column boundary, the row boundary, a set of column interval subseries numbers, a zero separator, and a set of row interval subseries numbers. The series number for this basic figure control card is 8, the subseries number is the three-digit basic figure number BBB followed by a zero, and the sequence number is 0. The control card for basic figure 7 might be:

800700, 6, 9, -17, 256, 0, 3, 17, 3

where the interval subseries numbers refer to those given in the examples on the 05 series above. This basic figure has a column boundary of 6 and a row boundary of 9, the column intervals consist of subseries 17 (reversed because it is specified as negative) followed by subseries 256. The row intervals consist of those in subseries 3 followed by those in subseries 17 followed by those in subseries 3. Thus the column intervals are equivalent to a single subseries of the form

1+1, 2, 3+1, 3, 2+1, 5, 4+1, 6

and the row intervals are equivalent to a single subseries of the form

1+1, 1, 5+1, 2, 2+1, 4, 3+1, 5, 1+1, 8, 5+1, 9

The advantage of using multiple subseries is that repeating sequences of intervals need be specified only once. Note that the number of meshes assigned by the column subseries must be exactly equal to the column boundary of the basic figure, and similarly the number of row intervals must be row boundary. Note also that the column and row boundaries may be as small as 1 and as large as desired.

Planar region overlay data for the basic figure consists of five-word sets: (1) planar region number; (2) left column; (3) right column; (4) top row; and (5) bottom row.

The column and row numbers must define a nondegenerate rectangle which does not extend outside the basic figure boundaries. The series number for this data is 8, and the subseries number is the initial figure number consisting of the three-digit basic figure number followed by a one-digit auxiliary figure number. A complete overlay is given using auxiliary figure number 0, and then modifications to this overlay are given for each auxiliary figure 1,2, ...

In fine blocked problems a method exists to partially fine block a planar region. If a negative planar region number is specified in any planar region overlay set, then if the planar region was to be fine blocked (from the 150SSS series) it will not be fine blocked for the mesh elements in this overlay set only. Conversely, if the planar region was not to be fine blocked, it will be fine blocked in this overlay only.

The complete set of card numbers used to define basic figure 16 and its two auxiliary figures might be:

801600 basic figure control information
801601 basic figure planar region overlays
801602 basic figure planar region overlays
801611 additional overlays for first auxiliary figure
801621 additional overlays for second auxiliary figure
801622 additional overlays for second auxiliary figure

Note that basic figure must be numbered sequentially from 1, and for each basic

figure the auxiliary figures (if any) must also be numbered sequentially from 1. It is not necessary, however, that every basic figure and auxiliary figure defined actually be used in the final figure overlay.

CHANNEL/TRACK DATA

In a fine blocked problem, each mesh element in a basic figure (and auxiliary figure) is assigned a channel and a track identifier through the data on the 7 series. Channel/track data serves to label the mesh elements and delineate the columns and rows of the initial figure which are channel and track boundaries. Normally channels are bounded by columns in the basic figure and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in an initial figure would have the same channel number and all mesh elements between two consecutive rows would have the same track number. This convention may be reversed for any basic figure as described below.

Card 700000 (which is optional) may be used to default the channel/track data in any initial figure for which no explicit channel/track input is present. There may be a single item on this card, either zero or one. If zero, the entire initial figure mesh is assigned a channel number of 1 and a track number of 1; if one, channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the initial figure and each mesh line is made a channel/track boundary. If this card is missing, zero is assumed.

The convention to assign channel numbers to columns and track numbers to rows may be reversed for a basic figure and all of its auxiliary figures by use of the optional card 7BBB00. The single item on this card may be zero or one. If zero, the labels are as normally assigned; if one, the labels are reversed (i.e., channels are assigned to rows and tracks to columns). If this card is missing, zero is assumed.

The default channel/track data (defined by card 700000) is assigned to the basic figure (auxiliary figure 0) except for any modifications specified by cards 7BBB01 - 7BBB09. For all auxiliary figures 1 through 9, the channel track data for the basic figure (auxiliary figure 0) is assigned except for any modifications specified by cards 7BBBA1 - 7BBBA9, A=1,2,...9.

The form of the data on cards 7BBBA1 - 7BBBA9 is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where the C(i) < C(i+1) are column numbers, the Ch(i) are the column labels (usually channels), the R(i) < R(i+1) are row numbers, and the Tr(i) are the row labels (usually tracks). All of the Ch(i) and Tr(i) which are to be assigned must be integers greater than zero. If -Ch(i) is specified, the mesh elements bounded by columns C(i-1), C(i-1)+1, C(i-1)+2, ..., C(i) are labelled Ch(i), Ch(i)+1, Ch(i)+2, ... Similarly, if -Tr(i) is specified, the mesh elements bounded by rows R(i-1), R(i-1)+1, R(i-1)+2, ..., R(i) are labelled Tr(i), Tr(i)+1, Tr(i)+2, ... If +Ch(i) is specified, all of the mesh elements bounded by columns C(i-1) to C(i) are labelled Ch(i); if +Tr(i) is specified, all of the mesh elements bounded by rows R(i-1) to R(i) are labelled Tr(i).

The specification:

0, 0, R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

will serve to label only the rows of an initial figure while the specification:

C(0), Ch(1), C(1), Ch(2), ..., Ch(N), C(N)

will serve to identify only columns. In any case, the default values previously described will be used for any non-specified labels.

As an example of the use of this series, the card

700701, 0, 100, 2, -500, 5, 600, 6, 0, 0, -3, 9

assigns the following channel/track data to basic figure 7: channel 100 between columns 0 and 2; channel 500 between columns 2 and 3; channel 501 between columns 3 and 4; channel 502 between columns 4 and 5; and channel 600 between columns 5 and 6. Tracks are numbered sequentially starting with track 3 between rows 0 and 1, and each row is a track interface.

SUPER FIGURE DATA

A control card is required for each super figure containing its column boundary and row boundary. The series number for this super figure control card is 9, the subseries number is the three-digit super figure number followed by a zero, and the sequence number is 0.

Super figure overlay data consists of five-word sets: (1) initial figure number; (2) column at which to position initial figure; (3) row at which to position initial figure; (4) rotation indicator; and (5) reflection indicator.

The initial figure number must be between 10 and 9999 and indicates the particular basic figure or auxiliary figure being overlaid on the super figure. Note that super figures may not be overlaid on other super figures. The column and row numbers indicate the point on which the origin of the initial figure is to be overlaid. The rotation indicator is the multiple of 90-degrees through which the initial figure is to be clockwise rotated in the frame of reference of the super figure, and must lie between 0 and 3. The reflection indicator is 1 for reflection and 0 for no reflection. Note that this refers to reflection within the frame of reference of the super figure. The series number for this data is 9, and the subseries number is the initial super figure number which consists of a three-digit super figure number followed by a one-digit auxiliary super figure number. The additional overlay sets for each auxiliary super figure modify only those of auxiliary figure 0.

The complete set of card numbers for super figure 24 might be:

902400 super figure control card
902401 super figure overlay sets
902402 super figure overlay sets
902403 super figure overlay sets
902411 additional overlay sets for first auxiliary figure
902412 additional overlay sets for first auxiliary figure
902421 additional overlay sets for second auxiliary figure

Note that super figures must be numbered sequentially from 1 and, for each super figure, the auxiliary super figures (if any) must be numbered sequentially from 1. It is not necessary that every super figure and auxiliary super figure defined actually be used in the final figure overlay.

FINAL FIGURE OVERLAY DATA

Final figure overlay data is specified using card series number 17. The data consists of six-word final figure overlay sets, each consisting of the following information: (1) final figure number; (2) initial figure number (+) or initial super figure number (-); (3) column at which to position initial figure; (4) row at which to position initial figure; (5) rotation indicator; and (6) reflection indicator.

The final figure number may have any value between 1 and 999 consistent with the maximum final figure specified in the control input (see Section 9.1). The second number in a six-word set is the initial figure number or initial super figure number which is to be overlaid on the region of solution. If the number is positive, an initial figure is indicated; if the number is negative, an initial super figure is indicated. In either case the absolute value of the number must be between 10 and 9999. The column and row indicate the point in the region of solution which is to be overlaid by the origin of the initial figure. The rotation number is the multiple of 90-degrees through which the initial figure or initial super figure is to be clockwise rotated; the rotation

number must be between 0 and 3. The reflection indicator is 1 for reflection and 0 for no reflection.. Note that more than one final figure overlay set sextuplet may be present on any card in this series. Cards in this series must be sequential.

As an example, the card

170001, 3, 52, 5, 12, 3, 1

would assign final figure number 3 to auxiliary figure 2 of basic figure 5, position its origin at column 5, row 12 in the region of solution, rotate the figure 3 times 90 degrees (270 degrees) clockwise, and reflect the figure. If the card were instead

170001, 3, -52, 5, 12, 3, 1

the information would be identical except that auxiliary super figure 2 of super figure 5 would be used.

CHANNEL BIAS DATA

For problems which are fine blocked, the channel bias data is input on the 16 series. The data consists of one channel bias number for each final figure overlay set on cards 170001 - 170999. The n-th data item on these cards is added to all channel numbers specified for the initial figure in the n-th sextuplet on cards 170001 - 170999. Thus these cards, if present, must contain exactly the same number of data items as there are sextuplets of final figure overlay data.

If the channel bias data is missing, the bias for each final figure overlay set is determined by the contents of card 160000. This card, which is optional, may contain one item, either zero or one. If zero, each final figure overlay set is assigned a channel bias of zero; if one, the channel biases are 0, C, 2C, 3C, ... for each succeeding final figure overlay set. In the latter case, C is the maximum channel number specified for any initial figure. If this card is missing, zero is assumed.

The following is a tabulation of the cards used to describe a rectangular geometry:

05XXX1 - 05XXX9

Mesh intervals for subseries XXX in expansion format. Data consists of an arbitrary number of sets. Each set is a pair consisting of a floating-point mesh interval value followed by an integer point number. Point numbers must be in strictly increasing order. The mesh subseries number XXX may range from 001 to 999 and need not be sequential.

150000

In fine blocked problems, the default indicator for specification of fine blocked planar regions. The card contains a single item:
0 implies planar regions specified on cards 150001-150999 are to be fine blocked (assumed if card is missing);
1 implies all planar regions except those specified on cards 150001-150999 are to be fine blocked.

150001 - 150999

List of planar regions to be fine blocked if the item on card 150000 is 0 or missing; list of planar regions not to fine block if the item on card 150000 is 1. The list of planar regions is given in the form:

R(1), +-R(2), +-R(3), ..., +-R(N)

with the form R(I), -R(I+1) meaning all of the planar regions from R(I) through R(I+1).

8BBB00

(1) COLUMN BOUNDARY of the basic figure.
(2) ROW BOUNDARY of the basic figure.
(3)-(N) Mesh subseries number for COLUMN INTERVALS.
(N+1) 0 (separator between column and row intervals)
(N+2)-(M) Mesh subseries numbers for ROW INTERVALS.

Control card for basic figure BBB. The value of BBB may range from 001 to 999, and must be sequential. The mesh subseries for the columns and rows are those defined by the 05XXXS series. The total number of mesh spacings assigned to the columns by the set of column subseries numbers must be exactly the column boundary of the basic figure. Exactly row boundary intervals must be assigned to the rows.

8BBB01 - 8BBB09

Planar region overlay sets for basic figure BBB. Each overlay set (quintuplet) is of the form:

(1) PLANAR REGION number
(2) LEFT column
(3) RIGHT column
(4) TOP row
(5) BOTTOM row

Each card may contain any number of overlay sets (quintuplets). Overlay sets will be used in the order in which they appear on the cards. The left and right columns and top and bottom rows must define a nondegenerate rectangle within the basic figure.

8BBBA1 - 8BBBA9

Planar region overlay for auxiliary figure A of basic figure BBB. Format of the data on these cards (quintuplets) is exactly the same as the 8BBB01 - 8BBB09 cards. For a given basic figure there may be up to 9 auxiliary figures and they must be numbered sequentially. Overlay sets for any auxiliary figure modify only those of the parent basic figure.

700000

In fine blocked problems, the default indicator for assignment of channel/track identifiers to basic figures. This card contains a single item:

0 implies each mesh element in the basic figure is given channel number 1 and track number 1 (assumed if card is missing);
1 implies channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the basic figure and each mesh line is a channel/track boundary.

7BBB00

In a fine blocked problem, defines the convention used for labelling columns and rows of basic figure BBB. This card contains a single item:

0 implies channels are delimited by columns, tracks by rows (assumed if card is missing);
1 implies tracks are delimited by columns, channels by rows.

7BBB01 - 7BBB09

Modifications to the default channel/track identifiers for basic figure BBB. The form of the data is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where: C(i) < C(i+1) are column numbers.
R(i) < R(i+1) are row numbers.
Ch(i) > 0 are column identifiers (usually channels).
Tr(i) > 0 are row identifiers (usually tracks).
For Ch(i) and Tr(i), + indicates a single identifier for all columns or rows, - indicates sequential identifiers.

7BBBA1 - 7BBBA9

Channel/track data for auxiliary figure A of basic figure BBB. Format of the data on these cards is exactly the same as on the 7BBB01 - 7BBB09 cards. Channel/track data for auxiliary figures modify only that of the basic figure.

9BBB00

(1) COLUMN BOUNDARY of the super figure.
(2) ROW BOUNDARY of the super figure.

Control card for super figure BBB. Value of BBB may range from 1 to 999 and must be sequential.

9BBB01 - 9BBB09

Super figure overlay sets for super figure BBB. Each overlay set is a quintuplet of the form:

(1) INITIAL FIGURE number.
(2) COLUMN at which to position initial figure origin.
(3) ROW at which to position initial figure origin.
(4) ROTATION indicator.
(5) REFLECTION indicator.

Each card may contain any number of overlay sets (quintuplets). Only basic and auxiliary figures may be used (not other super figures). Rotation indicator is 0, 1, 2, or 3 for 0, 90, 180, or 270 degrees. Reflection indicator is (0/1) for (no/yes).

9BBBA1 - 9BBBA9

Super figure overlay sets for auxiliary super figure A of super figure BBB. Format of the data on these cards (quintuplets) is exactly the same as the 9BBB01 - 9BBB09 cards. For a given super figure there may be up to 9 auxiliary super figures and they must be numbered sequentially. Overlay sets for any auxiliary super figure modify only those of the parent super figure.

170001 - 170999

Final figure overlay sets. Each overlay set is a sextuplet of the form:

(1) FINAL FIGURE number.
(2) INITIAL FIGURE (+) or INITIAL SUPER FIGURE (-)
(3) COLUMN at which to position initial figure origin.
(4) ROW at which to position initial figure origin.
(5) ROTATION indicator.
(6) REFLECTION indicator.

Each card may contain any number of final figure overlay sets (sextuplets). Overlay sets will be used in the order in which they appear on these cards. A positive initial figure number indicates a basic or auxiliary figure while a negative initial figure number refers to an initial super figure. Rotation indicator is 0, 1, 2, or 3 for 0, 90, 180, or 270 degrees. Reflection indicator is (0/1) for (no/yes).

160000

In problems which are fine blocked, the default indicator for channel bias data. The card contains a single item:
0 implies each final figure overlay set is assigned a channel bias of 0 (assumed if this card is missing);
1 implies each successive final figure overlay set is assigned a channel bias of 0, C, 2C, 3C, ... where C is the maximum channel number specified for any initial figure.

160001 - 160999

In problems which are fine blocked, channel bias numbers. There must be one channel bias value for each final figure overlay set (sextuplet) on the 170001 - 170999 cards.

10.2. GEOMETRY INPUT PREPARATION: HEXAGONAL GEOMETRY DATA

This section describes the data used for the transverse planar mesh description in hexagonal geometry. A description of the method of construction and terminology used can be found in Chapter 3.

Data used in the hexagonal geometry construction process is described via card input. If the same geometry is to be used in several problems, the complete geometric description which is constructed may be saved in an output File Manager geometry file. This File Manager geometry file may then be input to succeeding problems eliminating the need for repeatedly constructing the geometry. It should be noted that an input File Manager geometry file contains a complete geometric description, and only the material assignments (composition correspondences) may be changed in a problem which uses this file. Geometry cards may or may not be present when a File Manager geometry file is input; if present, they will be deleted by the program.

The card series used to define a transverse hexagonal geometry mesh are as follows:

05XXXS	Planar mesh interval data
150SSS	Fine block planar region data
8BBBAS	Basic and auxiliary figure data
7BBBAS	Channel/track data
9BBBAS	Super figure data
170SSS	Final figure data
160SSS	Channel bias data

Some of these card series have subseries numbers (XXX or BBBA) whose meanings will be explained below. All of the card series having sequence numbers (S or SSS) must begin with 1 and be used sequentially.

Additional geometry data necessary for the axial description of the grid in 3-D problems can be found in Section 10.4. The fine block planar region data, channel/track data, and channel bias data are used only in problems which are fine blocked. If these cards are present in a problem which is not fine blocked, they will be checked by the program but will not be used.

MESH INTERVAL DATA

Planar mesh interval data is specified in expansion format, each set consisting of a floating point interval value followed by a point number. The series number is 05 and any of the three-digit subseries 001-999 may be used. Each such subseries specifies a sequence of intervals extending from point 0 to an arbitrary termination point. The data might consist of the following cards, for example, defining mesh subseries 3, 17, and 256:

```
050031, 1+1, 1, 5+1, 2

050171, 2+1, 2, 3+1, 3, 1+1, 5

052561, 4+1, 1
```

The mesh sequences described on this series will be used to define the row and column mesh spacings in basic figures.

FINE BLOCK PLANAR REGION DATA

In fine blocked problems the set of planar regions which are to be fine blocked is input on the 150 series. Card 150000 is the default indicator for this series. This card contains a single integer item, zero or one. If zero, then cards 150001-150999 contain the planar regions to be fine blocked; if one, then all planar regions except those on cards 150001-150999 are to be fine blocked. If this card is not present, zero is assumed.

The cards 150001-150999 contain a list of planar region numbers:

R(1), +-R(2), +-R(3), ... , +-R(N)

with the form R(i), -R(i+1) meaning all of the planar regions from R(i) through R(i+1).

BASIC FIGURE DATA

A control card is required for each basic figure. This card contains the column boundary, the row boundary, a set of column interval subseries numbers, a zero separator, and a set of row interval subseries numbers. The series number for this basic figure control card is 8, the subseries number is the three-digit basic figure number BBB followed by a zero, and the sequence number is 0. The control card for basic figure 7 might be:

800700, 6, 9, -17, 256, 0, 3, 17, 3

where the interval subseries numbers refer to those given in the examples on the 05 series above. Note that the mesh intervals being specified are measured along the 60-degree axes of the basic figure. This basic figure has a column boundary of 6 and a row boundary of 9, the column intervals consist of subseries 17 (reversed because it is specified as negative) followed by subseries 256. The row intervals consist of those in subseries 3 followed by those in subseries 17 followed by those in subseries 3. Thus the column intervals are equivalent to a single subseries of the form

1+1, 2, 3+1, 3, 2+1, 5, 4+1, 6

and the row intervals are equivalent to a single subseries of the form

1+1, 1, 5+1, 2, 2+1, 4, 3+1, 5, 1+1, 8, 5+1, 9

The advantage of using multiple subseries is that repeating sequences of intervals need be specified only once. Note that the number of meshes assigned by the column subseries must be exactly equal to the column boundary of the basic figure, and similarly the number of row intervals must be row boundary. Note also that the column and row boundaries may be as small as 1 and as large as desired.

The control card for a transition figure differs from that of a normal basic figure in that it contains a value of -1 for column boundary, followed by the row boundary, a column interval subseries number, a zero separator, a set of subseries numbers for the row mesh spacings on the left side, and a set of subseries numbers for the row mesh spacings on the right side. Note that the column boundary of a transition figure is always one. The control card for transition figure 22 might be:

802200, -1, 7, 256, 0, 3, 17, -17, 3

where the interval subseries refer to the the examples given for the 05 series above. The single column mesh spacing of this transition figure will be 4+1. The row intervals on the left side of the transition figure are equivalent to a single subseries of the form

1+1, 1, 5+1, 2, 2+1, 4, 3+1, 5, 1+1, 7

and the row intervals on the right side of the figure equivalent to the single subseries

1+1, 2, 3+1, 3, 2+1, 5, 1+1, 6, 5+1, 7

Exactly row boundary intervals must be specified on each of the left and right sides of the transition figure. Further, the sum of the intervals on the left side must equal the sum of the intervals on the right side within a tolerance of 0.01 per cent. Note in the example above this sum is 15+2 on each side.

Planar region overlay data for the basic figure consists of five-word sets: (1) planar region number; (2) left column; (3) right column; (4) top row; and (5) bottom row.

The column and row numbers must define a nondegenerate quadrilateral which does not extend outside the basic figure boundaries. The series number for this data is 8, and the subseries number is the initial figure number consisting of the three-digit basic figure number followed by a one-digit auxiliary figure number. A complete overlay is given using auxiliary figure number 0, and then modifications to this overlay are given for each auxiliary figure 1,2, ...

In fine blocked problems a method exists to partially fine block a planar region. If a negative planar region number is specified in any planar region overlay set, then if the planar region was to be fine blocked (from the 150SSS series) it will not be fine blocked for the mesh elements in this overlay set only. Conversely, if the planar region was not to be fine blocked, it will be fine blocked in this overlay only.

The complete set of card numbers used to define basic figure 16 and its two auxiliary figures might be:

801600 basic figure control information
801601 basic figure planar region overlays
801602 basic figure planar region overlays
801611 additional overlays for first auxiliary figure
801621 additional overlays for second auxiliary figure
801622 additional overlays for second auxiliary figure

Note that basic figure must be numbered sequentially from 1, and for each basic figure the auxiliary figures (if any) must also be numbered sequentially from 1. It is not necessary, however, that every basic figure and auxiliary figure defined actually be used in the final figure overlay.

CHANNEL/TRACK DATA

In a fine blocked problem, each mesh element in a basic figure (and auxiliary figure) is assigned a channel and a track identifier through the data on the 7 series. Channel/track data serves to label the mesh elements and delineate the columns and rows of the initial figure which are channel and track boundaries. Normally channels are bounded by columns in the basic figure and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in an initial figure would have the same channel number and all mesh elements between two consecutive rows would have the same track number. This convention may be reversed for any basic figure as described below.

Card 700000 (which is optional) may be used to default the channel/track data in any initial figure for which no explicit channel/track input is present. There may be a single item on this card, either zero or one. If zero, the entire initial figure mesh is assigned a channel number of 1 and a track number of 1; if one, channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the initial figure and each mesh line is made a channel/track boundary. If this card is missing, zero is assumed.

The convention to assign channel numbers to columns and track numbers to rows may be reversed for a basic figure and all of its auxiliary figures by use of the optional card 7BBB00. The single item on this card may be zero or one. If zero, the labels are as normally assigned; if one, the labels are reversed (i.e., channels are attached to rows and tracks to columns). If this card is missing, zero is assumed.

The default channel/track data (defined by card 700000) is assigned to the basic figure (auxiliary figure 0) except for any modifications specified by cards 7BBB01 - 7BBB09. For all auxiliary figures 1 through 9, the channel track data for the basic figure (auxiliary figure 0) is assigned except for any modifications specified by cards 7BBBA1 - 7BBBA9, A=1,2,...9.

The form of the data on cards 7BBBA1 - 7BBBA9 is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where the C(i) < C(i+1) are column numbers, the Ch(i) are the column labels (usually channels), the R(i) < R(i+1) are row numbers, and the Tr(i) are the row labels (usually tracks). All of the Ch(i) and Tr(i) which are to be assigned must be integers greater than zero. If -Ch(i) is specified, the mesh elements bounded by columns C(i-1), C(i-1)+1, C(i-1)+2, ..., C(i) are labelled Ch(i), Ch(i)+1, Ch(i)+2, ... Similarly, if -Tr(i) is specified, the mesh elements bounded by rows R(i-1), R(i-1)+1, R(i-1)+2, ..., R(i) are labelled Tr(i), Tr(i)+1, Tr(i)+2, ... If +Ch(i) is specified, all of the mesh elements bounded by columns C(i-1) to C(i) are labelled Ch(i); if +Tr(i) is specified, all of the mesh elements bounded by rows R(i-1) to R(i) are labelled Tr(i).

The specification:

0, 0, R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

will serve to label only the rows of an initial figure while the specification:

C(0), Ch(1), C(1), Ch(2), ..., Ch(N), C(N)

will serve to identify only columns. In any case, the default values previously described will be used for any non-specified labels.

As an example of the use of this series, the card

700701, 0, 100, 2, -500, 5, 600, 6, 0, 0, -3, 9

assigns the following channel/track data to basic figure 7: channel 100 between columns 0 and 2; channel 500 between columns 2 and 3; channel 501 between columns 3 and 4; channel 502 between columns 4 and 5; and channel 600 between columns 5 and 6. Tracks are numbered sequentially starting with track 3 between rows 0 and 1, and each row is a track interface.

SUPER FIGURE DATA

A control card is required for each super figure containing its column boundary and row boundary. The series number for this super figure control card is 9, the subseries number is the three-digit super figure number followed by a zero, and the sequence number is 0.

Super figure overlay data consists of five-word sets: (1) initial figure number; (2) column at which to position initial figure; (3) row at which to position initial figure; (4) rotation indicator; and (5) reflection indicator.

The initial figure number must be between 10 and 9999 and indicates the particular basic figure or auxiliary figure being overlaid on the super figure. Note that super figures may not be overlaid on other super figures. The column and row numbers indicate the point on which the origin of the initial figure is to be overlaid. The only limitation on origin column and row numbers is that a transition figure may not extend outside super figure boundaries. The rotation indicator is the multiple of 60-degrees through which the initial figure is to be clockwise rotated in the frame of reference of the super figure, and must lie between 0 and 5. The reflection indicator is 1 for reflection and 0 for no reflection. Note that this refers to reflection within the frame of reference of the super figure. The series number for this data is 9, and the subseries number is the initial super figure number which consists of a three-digit super figure number followed by a one-digit auxiliary super figure number. The additional overlay sets for each auxiliary super figure modify only those of auxiliary figure 0.

The complete set of card numbers for super figure 24 might be:

902400 super figure control card
902401 super figure overlay sets
902402 super figure overlay sets
902403 super figure overlay sets
902411 additional overlay sets for first auxiliary figure
902412 additional overlay sets for first auxiliary figure
902421 additional overlay sets for second auxiliary figure

Note that super figures must be numbered sequentially from 1 and, for each super figure, the auxiliary super figures (if any) must be numbered sequentially from 1. It is not necessary that every super figure and auxiliary super figure defined actually be used in the final figure overlay.

FINAL FIGURE OVERLAY DATA

Final figure overlay data is specified using card series number 17. The data consists of six-word final figure overlay sets, each consisting of the following information: (1) final figure number; (2) initial figure number (+) or initial super figure number (-); (3) column at which to position initial figure; (4) row at which to position initial figure; (5) rotation indicator; and (6) reflection indicator.

The final figure number may have any value between 1 and 999 but must be consistent with the maximum final figure number specified in the control input (see Section 9.1). The second number in a six-word set is the initial figure number or initial super figure number which is to be overlaid on the region of solution. If the number is positive, an initial figure is indicated; if the number is negative, an initial super figure is indicated. In either case the absolute value of the number must be between 10 and 9999. The column and row indicate the point in the region of solution which is to be overlaid by the origin of the initial figure. The rotation number is the multiple of 60-degrees through which the initial figure or initial super figure is to be clockwise rotated; the rotation number must be between 0 and 5. The reflection indicator is 1 for reflection and 0 for no reflection. Note that more than one final figure overlay set sextuplet may be present on any card in this series. Cards in this series must be sequential.

As an example, the card

170001, 3, 52, 5, 12, 3, 1

would assign final figure number 3 to auxiliary figure 2 of basic figure 5, position its origin at column 5, row 12 in the region of solution, rotate the figure 3 times 60 degrees (180 degrees) clockwise, and reflect the figure. If the card were instead

170001, 3, -52, 5, 12, 3, 1

the information would be identical except that auxiliary super figure 2 of super figure 5 would be used.

CHANNEL BIAS DATA

For problems which are fine blocked, the channel bias data is input on the 16 series. The data consists of one channel bias number for each final figure overlay set on cards 170001 - 170999. The n-th data item on these cards is added to all channel numbers specified for the initial figure in the n-th sextuplet on cards 170001 - 170999. Thus these cards, if present, must contain exactly the same number of data items as there are sextuplets of final figure overlay data.

If the channel bias data is missing, the bias for each final figure overlay set is determined by the contents of card 160000. This card, which is optional, may contain one item, either zero or one. If zero, each final figure overlay set is assigned a channel bias of zero; if one, the channel biases are 0, C, 2C, 3C, ... for each succeeding final figure overlay set. In the latter case, C is the maximum channel number specified for any initial figure. If this card is missing, zero is assumed.

The following is a tabulation of the cards used to describe a hexagonal geometry:

05XXX1 - 05XXX9

Mesh intervals for subseries XXX in expansion format. Data consists of an arbitrary number of sets. Each set is a pair consisting of a floating-point mesh interval value followed by an integer point number. Point numbers must be in strictly increasing order. The mesh subseries number XXX may range from 001 to 999 and need not be sequential.

150000

In fine blocked problems, the default indicator for specification of fine blocked planar regions. The card contains a single item:
- 0 implies planar regions specified on cards 150001-150999 are to be fine blocked (assumed if card is missing);
- 1 implies all planar regions except those specified on cards 150001-150999 are to be fine blocked.

150001 - 150999

List of planar regions to be fine blocked if the item on card 150000 is 0 or missing; list of planar regions not to fine block if the item on card 150000 is 1. The list of planar regions is given in the form:

R(1), +-R(2), +-R(3), ..., +-R(N)

with the form R(I), -R(I+1) meaning all of the planar regions from R(I) through R(I+1).

8BBB00

(1) COLUMN BOUNDARY of the basic figure.
(2) ROW BOUNDARY of the basic figure.
(3)-(N) Mesh subseries number for COLUMN INTERVALS.
(N+1) 0 (separator between column and row intervals)
(N+2)-(M) Mesh subseries numbers for ROW INTERVALS.

Control card for basic figure BBB. The value of BBB may range from 001 to 999, and must be sequential. The mesh subseries for the columns and rows are those defined by the 05XXXS series.

For a normal basic figure (column boundary > 0), the total number of mesh spacings assigned to the columns by the set of column subseries numbers must be exactly the column boundary of the basic figure. Exactly row boundary intervals must be assigned to the rows in this case.

For a transition figure (column boundary = -1), exactly one mesh interval must be assigned by the column subseries number. Two times row boundary mesh intervals are specified for the rows, the first row boundary of these applying to the left side of the transition figure and the second row boundary applying to the right side.

8BBB01 - 8BBB09

Planar region overlay sets for basic figure BBB. Each overlay set (quintuplet) is of the form:

(1) PLANAR REGION number
(2) LEFT column
(3) RIGHT column
(4) TOP row
(5) BOTTOM row

Each card may contain any number of overlay sets (quintuplets). Overlay sets will be used in the order in which they appear on the cards. The left and right columns and top and bottom rows must define a nondegenerate rectangle within the basic figure.

8BBBA1 - 8BBBA9

Planar region overlay for auxiliary figure A of basic figure BBB. Format of the data on these cards (quintuplets) is exactly the same as the 8BBB01 - 8BBB09 cards. For a given basic figure there may be up to 9 auxiliary figures and they must be numbered sequentially. Overlay sets for any auxiliary figure modify only those of the parent basic figure.

700000

In fine blocked problems, the default indicator for assignment of channel/track identifiers to basic figures. This card contains a single item:

- 0 implies each mesh element in the basic figure is given channel number 1 and track number 1 (assumed if card is missing);
- 1 implies channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the basic figure and each mesh line is a channel/track boundary.

7BBB00

In a fine blocked problem, defines the convention used for labelling columns and rows of basic figure BBB. This card contains a single item:

- 0 implies channels are delimited by columns, tracks by rows (assumed if card is missing);
- 1 implies tracks are delimited by columns, channels by rows.

7BBB01 - 7BBB09

Modifications to the default channel/track identifiers for basic figure BBB. The form of the data is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where: C(i) < C(i+1) are column numbers.
R(i) < R(i+1) are row numbers.
Ch(i) > 0 are column identifiers (usually channels).
Tr(i) > 0 are row identifiers (usually tracks).
For Ch(i) and Tr(i), + indicates a single identifier for all columns or rows, indicates sequential identifiers.

7BBBA1 - 7BBBA9

Channel/track data for auxiliary figure A of basic figure BBB. Format of the data on these cards is exactly the same as on the 7BBB01 - 7BBB09 cards. Channel/track data for auxiliary figures modify only that of the basic figure.

9BBB00

(1) COLUMN BOUNDARY of the super figure.
(2) ROW BOUNDARY of the super figure.

Control card for super figure BBB. Value of BBB may range from 1 to 999 and must be sequential.

9BBB01 - 9BBB09

Super figure overlay sets for super figure BBB. Each overlay set is a quintuplet of the form:

(1) INITIAL FIGURE number.
(2) COLUMN at which to position initial figure origin.
(3) ROW at which to position initial figure origin.
(4) ROTATION indicator.
(5) REFLECTION indicator.

Each card may contain any number of overlay sets (quintuplets). Only basic and auxiliary figures may be used (not other super figures). Rotation indicator is 0, 1, 2, 3, 4, or 5 for 0, 60, 120, 180, 240, or 300 degrees. Reflection indicator is (0/1) for (no/yes).

9BBBA1 - 9BBBA9

Super figure overlay sets for auxiliary super figure A of super figure BBB. Format of the data on these cards (quintuplets) is exactly the same as the 9BBB01 - 9BBB09 cards. For a given super figure there may be up to 9 auxiliary super figures and they must be numbered sequentially. Overlay sets for any auxiliary super figure modify only those of the parent super figure.

170001 - 170999

Final figure overlay sets. Each overlay set is a sextuplet of the form:

(1) FINAL FIGURE number.
(2) INITIAL FIGURE (+) or INITIAL SUPER FIGURE (-)
(3) COLUMN at which to position initial figure origin.
(4) ROW at which to position initial figure origin.
(5) ROTATION indicator.
(6) REFLECTION indicator.

Each card may contain any number of final figure overlay sets (sextuplets). Overlay sets will be used in the order in which they appear on these cards. A positive initial figure number indicates a basic or auxiliary figure while a negative initial figure number refers to an initial super figure. Rotation indicator is 0, 1, 2, 3, 4, or 5 for 0, 60, 120, 180, 240, or 300 degrees. Reflection indicator is (0/1) for (no/yes).

160000

In problems which are fine blocked, the default indicator for channel bias data. The card contains a single item:
0 implies each final figure overlay set is assigned a channel bias of 0 (assumed if this card is missing);
1 implies each successive final figure overlay set is assigned a channel bias of 0, C, 2C, 3C, ... where C is the maximum channel number specified for any initial figure.

160001 - 160999

In problems which are fine blocked, channel bias numbers. There must be one channel bias value for each final figure overlay set (sextuplet) on the 170001 - 170999 cards.

10.3. GEOMETRY INPUT PREPARATION: QUADRILATERAL GEOMETRY DATA

This section describes the data used for the transverse planar mesh description in quadrilateral geometry. A description of the method of construction and terminology used can be found in Chapter 3.

Data used in the quadrilateral geometry description process may be input from either cards or a File Manager figure file (or both). Basic and auxiliary figure building information (if any) is input from cards. Compound figure building sets may be input from either cards or a File Manager figure file. Additionally, complete descriptions of substructures to be used in the construction process, namely file figures, may be input from a File Manager figure file. The program will optionally save a File Manager figure file for any problem in which geometry is constructed. Inputing this file to problems using similar geometries can result in reduction of geometry generation time. File Manager figure files may also be used as a means of communicating with external geometry generators.

If the same geometry is to be used in several problems, the complete geometric description which is constructed may be saved in an output File Manager geometry file. This File Manager geometry file may then be input to succeeding problems eliminating the need for repeatedly constructing the geometry. It should be noted that an input File Manager geometry file contains a complete geometric description, and only the material assignments (composition correspondences) may be changed in a problem which uses the file. Geometry cards may or may not be present when a File Manager geometry file is input; if present, they will be deleted by the program.

The card series used to define a transverse quadrilateral geometry mesh are as follows:

05XXXS	Planar mesh interval data
150SSS	Fine block planar region data
8BBBAS	Basic and auxiliary figure data
7BBBAS	Channel/track data
9CCCSS	Compound figure data

Some of these card series have subseries numbers (XXX, CCC, or BBBA) whose meanings will be explained below. All of the card series having sequence numbers (S, SS, or SSS) must begin with 1 and be used sequentially.

The fine block planar region data and channel/track data are used only in problems which are fine blocked. If these cards are present in a problem which is not fine blocked, they will be checked by the program but will not be used.

MESH INTERVAL DATA

Planar mesh interval data is specified in expansion format, each set consisting of a floating point interval value followed by a point number. The series number is 05 and any of the three-digit subseries 001-999 may be used. Each such subseries specifies a sequence of intervals extending from point 0 to an arbitrary termination point. The data might consist of the following cards, for example, defining mesh subseries 3, 17, and 256:

```
050031, 1+1, 1, 5+1, 2

050171, 2+1, 2, 3+1, 3, 1+1, 5

052561, 4+1, 1
```

The mesh sequences described on this series will be used to define the row and column mesh spacings in basic figures.

FINE BLOCK PLANAR REGION DATA

In fine blocked problems the set of planar regions which are to be fine blocked is input on the 150 series. Card 150000 is the default indicator for this series. This card contains a single integer item, zero or one. If zero, then cards 150001-150999 contain the planar regions to be fine blocked; if one, then all planar regions except those on cards 150001-150999 are to be fine blocked. If this card is not present, zero is assumed.

The cards 150001-150999 contain a list of planar region numbers:

R(1), +-R(2), +-R(3), ... , +-R(N)

with the form R(i), -R(i+1) meaning all of the planar regions from R(i) through R(i+1).

BASIC FIGURE DATA

A control card 8BBB00 is required for each basic figure. This card contains a unique alphanumeric basic figure label (up to 10 characters), the column boundary, the row boundary, a set of column interval subseries numbers, a zero separator, and a set of row interval subseries numbers. The series number for this basic figure control card is 8, the subseries number is a three-digit number BBB followed by a zero, and the sequence number is 0. The same subseries number BBB will be used on all cards containing data pertaining to the particular basic figure and will be referred to as the basic figure number (although the basic figure will be identifed by its alphanumeric label). The basic figure number BBB may vary from 1 to 999 and need not be sequential. The control card for the basic figure named STRUCTURE2 might be:

800700, STRUCTURE2, 6, 9, -17, 256, 0, 3, 17, 3

where the interval subseries numbers refer to those given in the examples on the 05 series above. Note that the mesh intervals specified are measured along the axes of the basic figure (the angle between these axes is the internal angle of the basic figure). This basic figure has a column boundary of 6 and a row boundary of 9, the column intervals consist of subseries 17 (reversed because it is specified as negative) followed by subseries 256. The row intervals consist of those in subseries 3 followed by those in subseries 17 followed by those in subseries 3. Thus the column intervals are equivalent to a single subseries of the form

1+1, 2, 3+1, 3, 2+1, 5, 4+1, 6

and the row intervals are equivalent to a single subseries of the form

1+1, 1, 5+1, 2, 2+1, 4, 3+1, 5, 1+1, 8, 5+1, 9

The advantage of using multiple subseries is that repeating sequences of intervals need be specified only once. Note that the number of meshes assigned by the column subseries must be exactly equal to the column boundary of the basic figure, and similarly the number of row intervals must be row boundary. Note also that the column and row boundaries may be as small as 1 and as large as desired.

Cards 8BBBA0 are control cards for auxiliary figures containing a single item, namely a unique alphanumeric label (up to 10 characters) for the auxiliary figure. The series number is 8, the subseries number is the three-digit basic figure number BBB followed by a one-digit auxiliary figure number (1 to 9, not necessarily sequential), and the sequence number is 0. The same one-digit auxiliary figure number will be used on all card series containing information pertaining to this particular auxiliary figure.

Planar region overlay data for the basic figure consists of five-word sets: (1) planar region number; (2) left column; (3) right column; (4) top row; and (5) bottom row.

The column and row numbers must define a nondegenerate quadrilateral which does not extend outside the basic figure boundaries. Any mesh elements not assigned a planar region number will be considered transparencies. The series number for this data is 8, and the subseries number is the three-digit basic figure number BBB followed by a one-digit auxiliary figure number A (0 to 9). The overlay is given for auxiliary figure number 0, and then modifications to this overlay are given for any auxiliary figure used.

In fine blocked problems a method exists to partially fine block a planar region. If a negative planar region number is specified in any planar region overlay set, then if the planar region was to be fine blocked (from the 150SSS series) it will not be fine blocked for the mesh elements in this overlay set only. Conversely, if the planar region was not to be fine blocked, it will be fine blocked in this overlay only.

The complete set of card numbers used to define a basic figure and its two auxiliary figures using subseries number 16 might be:

801600 basic figure control information
801601 basic figure planar region overlays
801602 basic figure planar region overlays
801610 label for first auxiliary figure
801611 additional overlays for first auxiliary figure
801650 label for second auxiliary figure
801651 additional overlays for second auxiliary figure
801652 additional overlays for second auxiliary figure

Basic figure numbers need not be sequential, nor must auxiliary figure numbers (if any). It is not necessary that every basic figure and auxiliary figure defined actually be used in the building process. It should be noted that if a basic figure is defined having the same label as a file figure contained in an input File Manager figure file, the file figure will be replaced by the basic figure.

Optional card 800000 may be used to define the internal angles at the origin of the basic figures. The angles are specified using expansion format, each set consisting of a floating point angle value in degrees followed by an integer basic figure number. The last angle value specified holds for all higher numbered basic figures (if any). If this card is missing, the internal angles of all basic figures are assumed to be 90 degrees if the geometry type is -1 and 60 degrees if the geometry type is -4.

CHANNEL/TRACK DATA

In a fine blocked problem, each mesh element in a basic figure (and auxiliary figure) is assigned a channel and a track identifier through the data on the 7 series. Channel/track data serves to label the mesh elements and delineate the columns and rows of the initial figure which are channel and track boundaries. Normally channels are bounded by columns in the basic figure and tracks are bounded by rows. That is, all mesh elements between two consecutive columns in an initial figure would have the same channel number and all mesh elements between two consecutive rows would have the same track number. This convention may be reversed for any basic figure as described below.

Card 700000 (which is optional) may be used to default the channel/track data in any initial figure for which no explicit channel/track input is present. There may be one item on this card, either zero or one. If zero, the entire initial figure mesh is assigned a channel number of 1 and a track number of 1; if one, channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the initial figure and each mesh line is made a channel/track boundary. If this card is missing, zero is assumed.

The convention to assign channel numbers to columns and track numbers to rows may be reversed for a basic figure and all of its auxiliary figures by use of the optional card 7BBB00. The single item on this card may be zero or one. If zero, the labels are as normally assigned; if one, the labels are reversed (i.e., channels are attached to rows and tracks to columns). If this card is missing, zero is assumed.

The default channel/track data (defined by card 700000) is assigned to the basic figure (auxiliary figure 0) except for any modifications specified by cards 7BBB01 - 7BBB09. For all auxiliary figures 1 through 9, the channel track data for the basic figure (auxiliary figure 0) is assigned except for any modifications specified by cards 7BBBA1 - 7BBBA9, A=1,2,...9.

The form of the data on cards 7BBBA1 - 7BBBA9 is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where the C(i) < C(i+1) are column numbers, the Ch(i) are the column labels (usually channels), the R(i) < R(i+1) are row numbers, and the Tr(i) are the row labels (usually tracks). All of the Ch(i) and Tr(i) which are to be assigned must be integers greater than zero. If -Ch(i) is specified, the mesh elements bounded by columns C(i-1), C(i-1)+1, C(i-1)+2, ..., C(i) are labelled Ch(i), Ch(i)+1, Ch(i)+2, ... Similarly, if -Tr(i) is specified, the mesh elements bounded by rows R(i-1), R(i-1)+1, R(i-1)+2, ..., R(i) are labelled Tr(i), Tr(i)+1, Tr(i)+2, ... If +Ch(i) is specified, all of the mesh elements bounded by columns C(i-1) to C(i) are labelled Ch(i); if +Tr(i) is specified, all of the mesh elements bounded by rows R(i-1) to R(i) are labelled Tr(i).

The specification:

0, 0, R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

will serve to label only the rows of an initial figure while the specification:

C(0), Ch(1), C(1), Ch(2), ..., Ch(N), C(N)

will serve to identify only columns. In any case, the default values previously described will be used for any non-specified labels.

As an example of the use of this series, the card

700701, 0, 100, 2, -500, 5, 600, 6, 0, 0, -3, 9

assigns the following channel/track data to the basic figure: channel 100 between columns 0 and 2; channel 500 between columns 2 and 3; channel 501 between columns 3 and 4; channel 502 between columns 4 and 5; and channel 600 between columns 5 and 6. Tracks are numbered sequentially starting with track 3 between rows 0 and 1, and each row is a track interface.

COMPOUND FIGURE DATA

Compound figure descriptions may be input to the program in three different forms:

(1) Complete descriptions of compound figures may be input from an optional File Manager figure file; these are called file figures.

(2) Building descriptions of compound figures which are to be constructed by the program may be input from a File Manager figure file.

(3) Building descriptions of compound figures which are to be constructed by the program may be input on cards.

The user may employ any one or a combination of any of the above methods.

If a File Manager figure file is input to the problem, the compound figure generator automatically has access to all of the file figures which it contains. These are identified by alphanumeric label (up to 10 characters), as are all compound figures.

All compound figures which are to be generated by the program require a control card. This card has the form 9CCC00, where the subseries number CCC may vary from 1 to 999 and need not be sequential. The same subseries number CCC will be used on all cards containing data pertaining to this particular compound

figure and will be referred to as the compound figure number (although the compound figure will be identified by its alphanumeric label). The compound figures will be generated in the order determined by this subseries number. The control card may contain either one item or three items. If the card contains one item:

9CCC00, LABEL

where LABEL is the alphanumeric compound figure label (up to 10 characters), then the overlay sets for this figure will be taken from the input File Manager figure file and any overlay sets input on cards 9CCC01-9CCC99 will be appended at the end of those from the file. If the control card contains three items:

9CCC00, LABEL, COLBDY, ROWBDY

namely, the alphanumeric compound figure label, column boundary of the compound figure, and row boundary of the compound figure, then the entire building description will consist of the compound figure overlay sets on cards 9CCC01-9CCC99. In either case, if a file figure with the same label is contained in an input File Manager figure file, the figure will be reconstructed using the appropriate set of building descriptions.

Card input compound figure building descriptions are input on cards 9CCC01-9CCC99, one overlay set per card. Each card input compound figure overlay set is of the form:

9CCCSS, FIGLABEL, I, J, Dx, Dy, FF, CH, Xo, Yo, R2

where these data items are: (1) initial figure label FIGLABEL; (2) column I in the compound figure containing the point overlaid by the origin of the initial figure; (3) row J in the compound figure containing the point overlaid by the origin of the initial figure; (4) row directional index Dx; (5) column directional index Dy; (6) final figure bias FF; (7) channel bias CH; (8) x-coordinate of intial figure position, Xo; (9) y-coordinate of initial figure position, Yo; (10) secondary rotation angle R2.

There may be from one to ten items on any card. The first item must be present in every overlay set; the program will supply default values for each unspecified item beyond the first. Note, however, that in order to specify any particular item, all preceding items in the overlay set must be explicitly stated. That is, when any item is defaulted, all succeeding items in that overlay set must also be defaulted. Thus, for example, to specify a channel bias for any overlay set, values for all of the first six items must be specified on the card (none of the first six may be defaulted).

The alphanumeric initial figure label (up to 10 characters) may designate a basic figure, auxiliary figure, file figure, or previously generated compound figure. The column and row specifies the mesh point (I,J) in the compound figure lattice which is to be overlaid by the origin of the initial figure. The row and column directional indices Dx and Dy are integers from 1 to 8 describing the correspondence between the points in the initial figure and the points in the compound figure which each is to overlay. The directions corresponding to each of the integer values are found in Section 3.6, Figure 3.6.1. Allowable combinations of these indices are shown in Table 3.6.1. The default value for the row directional index is 1; the default value for the column directional index is 3. If one of the directional indices is defaulted, both must be defaulted.

The final figure bias FF is an integer which will be added to the final figure numbers of each mesh element of the initial figure when overlaying the compound figure; the default value of the final figure bias is 0. Although the final figure bias may have any value, the resulting final figure number for each mesh element must always be greater than or equal to 0 and less than or equal to 999. In the solution figure the final figure numbers must be less than the maximum final figure number specified in the control input (see Section 9.1). The channel bias CH is an integer which will be added to each nonzero channel number in the initial figure when overlaying the compound figure; the default value of the channel bias is 0. Although the channel bias may have any value, the resulting channel number in fine blocked regions must always be greater than 0 and less than or equal to 999,999,999.

The floating point x-coordinate and y-coordinate describe the exact spatial location (Xo,Yo) of the origin of the initial figure being laid down. These are specified in a fourth quadrant coordinate system whose axis intersect at an angle equal to the internal angle of the compound figure (see Figure 3.6.4). If Xo is specified, then Yo must be specified. If the coordinates Xo and Yo are not specified in the overlay set, the position of the origin of the initial figure being laid down is defaulted to be the existing spatial position of the mesh point which it overlays (i.e. the position of the point (I,J) specified by items (2) and (3)). Note that the spatial position of this point (I,J) must have been defined by a previous overlay set when Xo and Yo are missing. The one exception is the case in which I = 0 and J = 0; this point is defined to have spatial coordinates (0.0, 0.0) before it has been overlaid by an initial figure.

The secondary angle of rotation R2 is a floating point value input in degrees and assumed to be 0.0 if not specified. Allowable values for this angle are functions of the internal angle of the compound figure and the row directional index Dx, and can be found in Table 3.6.2 of Section 3.6.

For the special case in which an initial figure is to be laid down such that it abuts against two points in the compound figure which have already been defined, the row directional index is specified as negative (-Dx); in this case Xo, Yo, and R2 must not be specified.

Optional card 900000 may be used to define the internal angles at the origin of the compound figures. The angles are specified using expansion format, each set consisting of a floating point angle value in degrees followed by an integer compound figure number. The last angle value specified holds for all higher numbered compound figures (if any). If this card is missing, the internal angles of all compound figures are assumed to be 90 degrees if the geometry type is -1 and 60 degrees if the geometry type is -4.

The region of solution of the problem may be designated by using the 900001 card. This card may contain one item, the label of the initial figure which is to be used as the solution space. If this card is missing, the default label for the initial figure to be used as the solution space is SOLUTION.

The following is a tabulation of the cards used to describe a quadrilateral geometry:

05XXX1 - 05XXX9

Mesh intervals for subseries XXX in expansion format. Data consists of an arbitrary number of sets. Each set is a pair consisting of a floating-point mesh interval value followed by an integer point number. Point numbers must be in strictly increasing order. The mesh subseries number XXX may range from 001 to 999 and need not be sequential.

150000

In fine blocked problems, the default indicator for specification of fine blocked planar regions. The card contains a single item:
0 implies planar regions specified on cards 150001-150999 are to be fine blocked (assumed if card is missing);
1 implies all planar regions except those specified on cards 150001-150999 are to be fine blocked.

150001 - 150999

List of planar regions to be fine blocked if the item on card 150000 is 0 or missing; list of planar regions not to fine block if the item on card 150000 is 1. The list of planar regions is given in the form:

R(1), +-R(2), +-R(3), ..., +-R(N)

with the form R(I), -R(I+1) meaning all of the planar regions from R(I) through R(I+1).

800000

Optional card listing the internal angles of basic figures in expansion format. Data consists of sets of pairs, each pair consisting of a floating point angle in degrees and an integer basic figure number. The basic figure numbers must be in strictly increasing order. The last angle is assumed to apply for any higher numbered basic figures (if any). If the card is missing, the internal angles are assumed to be 90 degrees if geometry type is -1 and 60 degrees if the geometry type is -4.

8BBB00

(1) LABEL of the basic figure.
(2) COLUMN BOUNDARY of the basic figure.
(3) ROW BOUNDARY of the basic figure.
(4)-(N) Mesh subseries numbers for COLUMN INTERVALS.
(N+1) 0 (separator between column and row intervals)
(N+2)-(M) Mesh subseries numbers for ROW INTERVALS.

Control card for basic figure BBB. The value of BBB may range from 001 to 999, and need not be sequential. The label is a unique alphanumeric (up to 10 characters) identifier for the basic figure. The mesh subseries for the columns and rows are those defined by the 05XXXS series. The total number of mesh spacings assigned to the columns by the set of column subseries numbers must be exactly the column boundary of the basic figure. Exactly row boundary intervals must be assigned to the rows.

8BBB01 - 8BBB09

Planar region overlay sets for basic figure BBB. Each overlay set (quintuplet) is of the form:

(1) PLANAR REGION number
(2) LEFT column
(3) RIGHT column
(4) TOP row
(5) BOTTOM row

Each card may contain any number of overlay sets (quintuplets). Overlay sets will be used in the order in which they appear on the cards. The left and right columns and top and bottom rows must define a nondegenerate quadrilateral within the basic figure.

8BBBA0

Control card for auxiliary figure A of basic figure BBB. This card contains one item, a unique alphanumeric label (up to 10 characters) for the auxiliary figure. For a given basic figure, there may be up to 9 auxiliary figures and they need not be numbered sequentially.

8BBBA1 - 8BBBA9

Planar region overlay for auxiliary figure A of basic figure BBB. Format of the data on these cards (quintuplets) is exactly the same as the 8BBB01 - 8BBB09 cards. Overlay sets for any auxiliary figure modify only those of the parent basic figure.

700000

In fine blocked problems, the default indicator for assignment of channel/track identifiers to basic figures. This card contains a single item:
0 implies each mesh element in the basic figure is given channel number 1 and track number 1 (assumed if card is missing);
1 implies channel numbers 1,2,3,... and track numbers 1,2,3,... are assigned to the basic figure and each mesh line is a channel/track boundary.

7BBB00

In a fine blocked problem, defines the convention used for labelling columns and rows of basic figure BBB. This card contains a single item:
0 implies channels are delimited by columns, tracks by rows (assumed if card is missing);
1 implies tracks are delimited by columns, channels by rows.

7BBB01 - 7BBB09

Modifications to the default channel/track identifiers for basic figure BBB. The form of the data is:

C(0), +-Ch(1), C(1), +-Ch(2), ..., +-Ch(N), C(N), 0,
R(0), +-Tr(1), R(1), +-Tr(2), ..., +-Tr(M), R(M)

where: C(i) < C(i+1) are column numbers.
R(i) < R(i+1) are row numbers.
Ch(i) > 0 are column identifiers (usually channels).
Tr(i) > 0 are row identifiers (usually tracks).

For Ch(i) and Tr(i), + indicates a single identifier for all columns or rows, and - indicates sequential identifiers.

7BBBA1 - 7BBBA9

Channel/track data for auxiliary figure A of basic figure BBB. Format of the data on these cards is exactly the same as on the 7BBB01 - 7BBB09 cards. Channel/track data for auxiliary figures modify only that of the basic figure.

900000

Optional card listing the internal angles of compound figures in expansion format. Data consists of sets of pairs, each pair consisting of a floating point angle in degrees and an integer compound figure number. The compound figure numbers must be in strictly increasing order. The last angle is assumed to apply for any higher numbered compound figures (if any). If the card is missing, the internal angles are assumed to be 90 degrees if geometry type is -1 and 60 degrees if the geometry type is -4.

900001

Optional card designating the region of solution of the problem. This card may contain one item, the alphanumeric label of the initial figure which is to be used as the solution space. If this card is missing, the default label for the initial figure to be used as the solution space is SOLUTION.

9CCC00

This card is a control card required for each compound figure which is to be generated. CCC may range from 1 to 999 and need not be sequential; compound figures are generated in the order determined by CCC. If the card contains one item:

(1) LABEL of the compound figure.

then overlay sets for the compound figure identified by the label will be taken from an input File Manager figure file and any overlay sets input on cards 9CCC01-9CCC99 will be appended to these. If the card contains three items:

(1) LABEL for the compound figure.
(2) COLUMN BOUNDARY of the compound figure.
(3) ROW BOUNDARY of the compound figure.

then overlay sets for the compound figure identified by the label will consist only of those on cards 9CCC01-9CCC99.

In either case, if a file figure having the same label has been input, the figure will be reconstructed using the building description.

9CCC01 - 9CCC99

Compound figure overlay sets for compound figure CCC. Each card contains one overlay set, and each overlay set may contain from one to ten items as follows:

	Default Value
(1) INITIAL FIGURE label	-
(2) COLUMN overlaid by the initial figure origin	0
(3) ROW overlaid by the initial figure origin	0
(4) ROW DIRECTIONAL INDEX Dx	1
(5) COLUMN DIRECTIONAL INDEX Dy	3
(6) FINAL FIGURE bias	0
(7) CHANNEL bias	0
(8) x-coordinate Xo	[existing position]
(9) y-coordinate Yo	[existing position]
(10) SECONDARY ROTATION ANGLE R2	0.0

Default values are used for any unspecified items. When any item in an overlay set is defaulted, all of the items in the overlay set which follow it must be defaulted.

The initial figure is specified by an alphanumeric label (up to 10 characters). The row and column directional indices are integers between 1 and 8. If one directional index is defaulted, both must be defaulted. If the row directional index is negative, an abutting overlay is designated. The x-coordinate, y-coordinate, and secondary angle of rotation are floating point values. The angle is specified in degrees. When the x-coordinate and y-coordinate are not specified, the existing location of the point (I,J) in the compound figure is used as the default. The x-coordinate and y-coordinate must be specified if the origin is outside the boundary of the compound figure. In the first overlay set Xo and Yo must be specified unless I=0 and J=0.

10.4. GEOMETRY INPUT PREPARATION: AXIAL GEOMETRY DATA

This section describes the data used for the axial geometric description in all three-dimensional problems. If a File Manager geometry file is input to the problem, all of the data will be taken from the file instead of from the card input described here.

Axial mesh interval data is required in three-dimensional problems. This data is input on card series 070SSS, where the sequence numbers SSS must begin with 001 and be used sequentially. The data is specified in expansion format, each set consisting of a floating point mesh interval value followed by an axial point number. The termination point must be the plane boundary of the problem.

Gross plane boundaries may optionally be input on card series 060SSS, where SSS is a sequence number which must begin with 001 and must be used sequentially. The axial planes which are gross plane boundaries are specified in increasing order, and the last value must be the plane boundary of the problem. If this series is used, there must be at least two gross plane boundaries specified. Although plane 0 is a gross plane boundary, it must not be specified on these cards. If card series 060SSS is missing, the gross plane boundaries will be the PPP from the 03PPP1 - 03PPP9 cards (see Section 10.5).

In problems which are fine blocked, fine plane boundaries are optionally input on card series 061SSS, where SSS is the sequence number which must begin with 001 and be used sequentially. The axial planes which are fine plane boundaries are specified in increasing order, and the last value must be the plane boundary of the problem. All planes which are gross plane boundaries must also be fine plane boundaries. If card series 061SSS is missing, the contents of optional card 061000 determines the fine plane boundaries. Card 061000 contains a single item, either zero or one. If zero, the fine plane boundaries will be set equal to the gross plane boundaries; if one, every plane will be a fine plane boundary. If card 061000 is missing, zero is assumed.

The following is a summary of the cards used to describe the axial geometry in three-dimesional problems:

070001 - 070999

Axial mesh intervals in expansion format. Each set is a pair consisting of a floating-point mesh interval value followed by an integer axial point number. Point numbers must be in strictly increasing order, with the last point number equal to the plane boundary of the problem.

060001 - 060999

These cards may optionally be used to define gross plane boundaries. The axial points which are gross plane boundaries are listed in increasing order, and the last plane must be equal to the plane boundary of the problem. If missing, the gross plane boundaries will be the planes for which the cards 03PPP1-03PPP9 are present.

061000

In fine blocked problems, the default indicator for specification of fine block planes if cards 061001-061999 are missing. The card contains a single item:

0 implies that the fine plane boundaries are equal to the gross plane boundaries (assumed if the card is missing);
1 implies that every axial point is a fine plane boundary.

061001 - 061999

In fine blocked problems, these cards may optionally be used to define fine plane boundaries. The axial points which are fine plane boundaries are listed in increasing order, and the last axial point must be equal to the plane boundary of the problem. The list must include all planes which are gross plane boundaries (not including plane 0). If missing, the fine plane boundaries will be determined by the 061000 card.

10.5. GEOMETRY INPUT PREPARATION: COMPOSITION-CONFIGURATION DATA

Composition correspondence data may be input in several ways. The user specifies whether the compositions will correspond to final figures or planar regions on the control input card 010001. On this card the correspondence may further be specified as one-to-one, indicating that composition N will correspond to planar region (or final figure) N. Alternatively, composition correspondence data may be input on cards or from an input File Manager geometry file. If a File Manager geometry file is input, composition correspondence cards may be present (whether they are to be used or not); if not used these cards will be deleted by the program.

Card input composition correspondence data is specified using card series 03 and may be used only if the composition correspondence has not been designated one-to-one. The cards are of the form 03PPPS, where PPP is the subseries number and S is the sequence number which starts with 1 and must be sequential. The data on the cards consists of triplets of the form N(i), C(j), N(k) which assign composition C(j) to planar regions (or final figures) N(i) to N(k) inclusive. Each card may contain any number of triplets. The triplets are processed sequentially, and any triplet may change an assignment established by a previous triplet. For example, if compositions are to be assigned to planar regions, then the set of triplets:

2, 1, 5, 1, 3, 1, 3, 2, 4

assigns composition 2 to planar regions 3 and 4, composition 3 to planar region 1, and composition 1 to planar regions 2 and 5. An edit of the composition correspondences is supplied when geometry is generated and a geometry input edit is requested.

For 1-D and 2-D problems, subseries 000 (cards 030001-030009) defines the composition correspondences in the first configuration (identified as configuration 0); in problems not using multiple configurations, this will be the only set of composition correspondences. In problems using multiple configurations, subseries PPP (cards 03PPP1-03PPP9) are required for each configuration PPP at which the composition correspondences change. The triplets in such a subseries need only describe the modifications to the correspondences in the previous configuration. Thus the input for the first configuration must assign a composition to every planar region (or final figure), while the input for succeeding configurations need only describe the changes to the correspondences of the previous configuration. Any configuration not explicitly specified is identical to the previous configuration; thus if CCC is the maximum configuration number specified (on cards 03CCCS), then the total number of configurations is CCC+1.

In 3-D problems, subseries 000 (cards 030001-030009) defines the composition correspondences for the first plane. Note that every planar region (or final figure) must be assigned a composition. Subseries PPP (cards 03PPP1-03PPP9) are required for each axial plane PPP at which the composition correspondences change. The triplets in subseries PPP need only describe the modifications to the correspondences of the previous plane. If the optional cards 060SSS have been used to define gross plane boundaries (see Section 10.4), then the planes PPP at which the composition correspondences may change are restricted to those gross plane boundaries. If cards 060SSS are missing, then the planes for which cards 03PPPS are present will define the gross plane boundaries.

Card 030000 is an optional card used to qualify the composition correspondence data in certain instances. If present, card 030000 contains one or two items. The first item specifies whether composition correspondence data is to be taken from card input or from an input File Manager geometry file; the second item specifies the configuration to be used. CARD 030000 IS DELETED FROM CASE TO CASE. The use of this card is described below.

A File Manager geometry file contains the composition correspondence data from the problem in which it was created. When such a file is input, the user may specify that either the composition correspondence data contained in the file be used, or that composition correspondence data input on cards be used. The first item on card 030000 is either zero or one. If zero, then the composition correspondence data contained in the input File Manager geometry file will be used; if one, then the card input composition correspondence data

will be used. If the card is missing, zero is assumed. Note that this item is meaningful only when a File Manager geometry file is input.

When a File Manager geometry file is input and the first item on card 030000 is one (implying card input be used), an error will result if cards 030001-039999 are missing. However, the composition correspondences contained in the input File Manager geometry file will be edited if a geometry input edit has been requested.

The second item on card 030000 specifies which configuration is to be used. This item must be an integer between 0 and the maximum configuration. If this item is missing and a File Manager geometry file has been input, the last configuration used in the problem in which the file was created will be used. If this item is missing and a File Manager geometry file has not been input, zero is assumed. This configuration is used for concentration placement or replacement.

It should be noted that, in some instances, the configuration may be later changed by certain options. In 1-D multiple configuration search problems, the user may optionally specify in which configuration the search is to begin (card 010052). In problems using subcases, the user may optionally choose a different configuration by subcase (cards 204SSS).

NOTE

It is emphasized that initial concentration placement or replacement is performed according to the configuration implied by the contents of card 030000 regardless of the other optional initial configuration specifications.

The following is a tabulation of the cards used for composition and configuration data:

030000

Optional card containing one or two items:

(1) COMPDATA
(2) CONFIG

The first item COMPDATA is meaningful only when a File Manager geometry file has been input. The two possible values for this item are:

0 which implies that the composition correspondences contained in the input File Manager geometry file are to be used (assumed if the card is missing);

1 which implies that card input composition correspondences are to be used.

The second item CONFIG specifies which configuration is to be used. This item must be an integer between 0 and the maximum configuration number. If this item is missing and a File manager geometry file has been input, the configuration from the file is used; otherwise, if this item is missing, 0 is assumed.

THIS CARD IS DELETED FROM CASE TO CASE.

030001 - 030009

Composition correspondences for the first configuration if 1-D or 2-D; composition correspondences for plane 0 if 3-D. Data consists of triplets of the form:

N(i), C(j), N(k)

which assigns composition C(j) to planar regions (or final figures) N(i) to N(k) inclusive. Each card may contain any number of triplets. Triplets are processed sequentially, and any set may change a correspondence established by a preceding set. This assignment must be complete; that is, every planar region (or final figure) must be assigned a composition number by the data on these cards.

03PPP1 - 03PPP9

The data (triplets) on these cards has the same form as the composition correspondence data on cards 030001-030009.

In 1-D and 2-D problems, these cards contain the modifications at configuration PPP to the composition correspondences of the previous configuration. Each configuration number (less than the maximum PPP used) for which no modifications are input will be identical to the configuration which precedes it.

In 3-D problems, these cards contain the modifications at plane PPP to the composition correspondences of the previous plane. These planes must be gross plane boundaries.

10.6. GEOMETRY INPUT PREPARATION: MISCELLANEOUS GEOMETRY DATA

The use of the geometry-related data described in this section is optional. Some of the options are restricted to certain geometry types as noted.

Planar Region Areas

The use of input planar region areas is optional and may be used in all geometries. The user may input this data as one method to check his geometric laydown. If this data is present, the input values of the areas of planar regions are compared to the areas calculated by the program in the process of geometry generation. If the input and calculated areas differ by more than 1 per cent in any planar region, an error results and all of the calculated areas are printed. Note that planar region areas are always edited when the geometry is generated and a geometry input edit is requested. Planar region areas are specified in expansion format using card series 1800SS, where the number SS may vary from 01 to 99 sequentially. Each pair consists of a floating point area value (in the same units as the input mesh intervals) followed by a fixed point planar region number, and the last planar region number must equal the largest planar region as specified in the control input.

Picture Edits - Rectangular and Hexagonal Geometry

Printed picture edits are optionally available in rectangular and hexagonal geometry. These edits are produced only for the solution space of the problem; they may be based on any of the geometric identifiers. The picture edits are printed in a unitized 90-degree mesh in rectangular geometry and a unitized 60-degree mesh (chevron) in hexagonal geometry. If the picture produced requires more than one page of printed output, edits in both geometries are constructed such that the full picture may be easily assembled from the separate pages of output.

All mesh elements are labelled with two-character labels. One- or two-digit labels will appear unaltered; three-digit identifers are labelled with a two-character code (a conversion table is supplied with the edit). The low order three digits of identifiers greater than three digits will be printed in the two-character code.

Picture edits are requested on the optional 010009 card. This card may contain up to 5 items, each of which is zero for no picture or one to request a picture. The five requests in order are for: final figure, planar region, channel, track, and hexagonal transformation. Zero is assumed for all missing fields. This card is deleted from case to case.

Optional cards 01009S may be used to specify particular subfields in any of the requested picture edits. The sequence number S determines the type of picture edit being specified as follows:

S = 1 for final figures.
S = 2 for planar regions.
S = 3 for channels.
S = 4 for tracks.
S = 5 for hexagonal transformation.

Each card may contain up to ten triplets, each triplet specifying one printed picture. Each triplet consists of:

TITLE, DIGIT1, DIGIT2

where TITLE is an alphanumeric title (up to 10 characters) for the picture and DIGIT1 is the first and DIGIT2 is the second digit (numbered from right to left) defining the subfield to be used. Each subfield must contain one to three digits. Note that the appropriate edit must have been requested on the 010009 card for the appropriate requests on the 01009S cards to be utilized.

For the final figure or planar region (whichever corresponds to compositions) picture edit request, a composition picture edit will be produced if DIGIT1 and DIGIT2 are specified as negative. For 1-D and 2-D problems, this composition edit is based on the current configuration; for 3-D problems, the edit is based on plane 0.

Plots and Picture Edits - Quadrilateral Geometry

Plots and printed picture edits are optionally available in quadrilateral geometry. Both may be produced not only for the solution space of the problem, but also for any of the substructures (compound figures, basic figures, auxiliary figures, file figures) used in the generation of the geomtery. The user may obtain plots or printed pictures based on: (1) geometric identifiers, (2) combinations of geometric identifiers, or (3) row and column mesh lines of a figure. To obtain either plots or printed picture edits, figures must be generated or a File Manager figure file must have been input. Plots and printed picture edits differ somewhat in form and content as is explained below.

Picture edits are printed in a 90-degree unitized mesh; horizontal, vertical, or diagonal interfaces in either direction will be indicated. If the picture produced requires more than one page of printed output, the edit is constructed such that the full picture may be easily assembled from the separate pages of output. Printed pictures always depict a grid of points with (C+1) columns and (R+1) rows where C is the column boundary and R is the row boundary of the figure being edited. However, defined (non-transparent) points will be printed as a plus sign; transparent points will be printed as a period. Mesh elements will be labelled when the printed picture is based on a single geometric identifier; pictures based on multiple identifiers or mesh lines will not be labelled. The user may specify that a subfield of the geometric identifier be used as the printed label and for determination of interfaces. For example, if a channel picture is requested, the user may specify that the labels appearing on the printed picture be the fourth and fifth digits of the channel identifier and interfaces be determined by changes in these digits. If any of the requested labels is greater than three digits, only the low order three digits will be printed but interfaces are determined based on the entire subfield specified. Geometric identifiers which are zero are printed as zero; transparent mesh elements are blank. Maximum figure size which may be printed is 1000 rows by 1000 columns.

Plots are produced in true mesh; mesh elements are not labelled. In plots based on geometric identifiers, the lines drawn connect defined points along the interfaces determined by the identifier. Plots of mesh lines connect all defined points along a row or column as well as showing any diagonal interfaces. A reference coordinate system is provided with each plot. It sould be noted that the plots are produced in the fourth quadrant to appear in their proper orientation, and thus the y-coordinate values will appear as negative.

Both plot and printed picture edit reqnests are input on the 0102SS cards, where the sequence number SS may vary from 01 to 99 and need not be sequential. Each card in this series contains a single request for either a plot or a printed picture. The format of these cards is as follows:

0102SS, OPTION, FIELD, FIGLABEL, TITLE1, TITLE2, DIGIT1, DIGIT2

where:

(1) OPTION is either the alphanumeric word PRINT for printed pictures or the alphanumeric word PLOT for plots.

(2) FIELD is one of the following alphanumeric words designating the basis for interfaces in the edit:

FIGURES for final figures.
REGIONS for planar regions.
CHANNELS for channels.
TRACKS for tracks.
COMPS for compositions.
FIG/REG for final figures and planar regions.
CHAN/TRACK for channels and tracks.

INTERFACES for final figures, planar regions, channels, and tracks.
MESH for row and column mesh lines and diagonal interfaces.
TWIST for hexagonal angle transformations.

In the fields based on multiple geometric identifiers, a change in any of the indicated identifiers will create an interface in the plot or printed picture.

(3) FIGLABEL is the alphanumeric label of the substructure (basic figure, auxiliary figure, compound figure, file figure) to be printed or plotted.

(4)-(5) TITLE1 and TITLE2 are two alphanumeric words (up to 10 characters each) which are used to title the plot or printed picture. These items are optional. If they are missing, item (2) will be used as the title. If they are present, item (2) is always printed ahead of this title.

(6)-(7) DIGIT1 is the first and DIGIT2 is the second decimal digit (numbered from right to left) defining the subfield to be used for labelling printed pictures and for determining interfaces in both plots and printed pictures. If these are missing, the whole field will be used. These descriptors are ignored for multiple field pictures or plots. Each digit must be greater than 0 and less than or equal to 15.

Items (1) through (3) must always be present in plot and picture requests; items (4) through (7) will be defaulted as indicated if they are missing.

Distortion Indicators - Quadrilateral Geometry

In quadrilateral geometry the user may optionally request that the program calculate measures of the distortion or irregularity of the solution space grid. Severe distortions of the mesh lines comprising the lattice may result in increasing the difficulty of the iterative solution of the problem. The program will compute several different measures of the mesh distortion, each providing a particular indication of the extent and manner that the solution grid varies from a constant mesh, parallel line lattice. The complexity of the analysis of the grid to be performed is specified by the user.

Distortion indicators are requested on the optional 010200 card. This card contains a single integer +-N, where the value of N designates the level of distortion measure to be calculated as follows:

N = 1 for coupling distances and coupling ratios.
N = 2 for mesh quadrilateral distortion.
N = 3 for angles and angle ratios.
N = 4 for triangle area ratios.

Specifying any value of N will also include all measures corresponding to values less than N. If N is positive, the maximum, minimum, and average values of each indicator will be printed together with a histogram indicating the distribution of the values of each indicator between its maximum and minimum. If N is negative, the histogram will be omitted. Definitions of the various distortion indicators are given below.

A coupling distance is the distance from a mesh point to any of its (up to eight) neighboring mesh points to which it is coupled in the difference equation sense. The coupling ratio is computed for each mesh point, and is the ratio of the maximum coupling distance at the mesh point to the minimum coupling distance at that point. Mesh quadrilateral distortion is computed for each mesh quadrilateral, and is the square of the distance between the midpoints of the two diagonals of the mesh quadrilateral divided by the area of the quadrilateral. The angles are those measured between consecutive coupling lines from a point to neighboring points to which it is coupled. The angle ratio is computed at each mesh point, and is the ratio of the maximum angle between couplings to the minimum angle between couplings for that mesh point. The triagle area ratio is computed at each mesh point, and is the ratio of the area

of the largest triangular mesh element to the area of the smallest triangular mesh element surrounding a mesh point (i.e., of all triangles having a vertex at that mesh point).

A tabular summary of the optional cards described in this section is as follows:

180001 - 180099

Input planar region areas in expansion format. Each pair consists of a floating point area value (in the same units as the input mesh intervals), followed by a fixed point planar region number. Each planar region must be assigned an area.

010009

Printed picture edit request for rectangular and hexagonal geometry. This card contains up to five indicators (0/1 = no/yes) designating printed pictures for: (1) final figures, (2) planar regions, (3) channels, (4) tracks, and (5) hexagonal angle transformations. This card is deleted from case to case.

010009S

Card used for optionally specifying subfields in requested picture edits. Values of S correspond to the following pictures:

S=1 for final figures.
S=2 for planar regions.
S=3 for channels.
S=4 for tracks.
S=5 for hexagonal angle transformation.

Data consists of up to ten triplets. Each triplet consists of an alphanumeric title (up to 10 characters) for the edit, followed by the first and last digits (counted from right to left) describing the subfield. Each subfield must be from one to three digits. A picture edit for this type of edit must have been requested on the 010009 card.

For the planar region or final figure picture (whichever corresponds to compositions), if the digits are specified as negative, a composition picture edit will be produced.

010200

Card for requesting distortion indicators in quadrilateral geometry. This card contains a single item +-N designating the level of distortion measure to be calculated:

N=1 for coupling distances and ratios.
N=2 for mesh quadrilateral distortion.
N=3 for angles and angle ratios.
N=4 for triangle area ratios.

If +N is specified a histogram of the distribution of the indicators will be included; if -N is specified the histogram is omitted.

010201 - 010299

These cards contain requests for plots or printed picture edits in quadrilateral geometry. Each card contains one request for a plot or printed picture. Each request contains from three to seven items as follows:

(1) Option is either PRINT or PLOT.
(2) Field is one of FIGURES, REGIONS, CHANNELS, TRACKS, COMPS, FIG/REG, CHAN/TRACK, INTERFACES, MESH, or TWIST.
(3) Label of figure to be printed or plotted.

(4) First title word (up to 10 characters).
(5) Second title word (up to 10 characters).
(6) First decimal digit defining subfield to be used.
(7) Second decimal digit defining subfield to be used.

The first five items are alphanumeric; the last two items are integers. The first three items must be present on all cards; the last four items may be defaulted. If items (4) and (5) are missing, the title of the edit will be item (2). If items (6) and (7) are missing, the entire field will be used. If any item is defaulted, all succeeding items on that card must be defaulted.

These cards need not be sequential.

11.1. HARMONY INPUT PREPARATION: NUCLIDE IDENTIFICATION DATA

Three types of nuclide labels may be input to the program: (1) a numeric identification, (2) the atomic weight associated with each nuclide, and (3) an alphanumeric identification associated with each nuclide. These three sets of labels are specified as follows:

```
300001 - 300299 : numeric nuclide identifications
       300300 : Avogadro constant (optional)
300301 - 300499 : nuclide atomic weights (optional)
300501 - 300599 : alphanumeric nuclide identifications
```

If a problem is depletable, the numeric and alphanumeric identifications are required. Further, if this data is in error the remainder of the HARMONY input data is not checked for errors because much of the checking involves the use of these id's. Details of each of these card series follows.

Depletable problems require the following cards:

Numeric Nuclide ID's

300SSS, ID(1), ID(2), ...

ID(i) is a numeric nuclide identification. These cards must contain a list of numeric nuclide identifications (id's) if the problem is depletable. Each must be unique, non - zero, and less than 65536 in absolute value. "Input id" or "nuclide id" always refers to this list. If a nuclide is to be fine block depletable, the appropriate id must be negative. If the problem is not being fine blocked, such negative id's are set positive with no error assumed; such a process allows a fine block depleted problem to be continued without fine blocking with no significant alteration of the input data. The SSS sequence numbers are 001, 002, ... , 299.

The following card is optional:

Avogadro Constant

300300, AVOGAD

AVOGAD is the Avogadro constant. This optional card may contain one floating point value to override the default value of the Avogadro constant. The built-in default value for this constant is .602252+24 and is used only for optional editing of nuclide loadings in kilograms.

The following cards are optional:

Atomic Weights

300SSS, WEIGHT(1), WEIGHT(2), ...

WEIGHT(i) is the atomic weight of a nuclide. These optional cards may contain floating point quantities which are the atomic weights of the nuclides. If present, these cards must contain exactly the same number of items as are present on the numeric nuclide identification cards. These atomic weights are assumed to be given in the same order as the numeric nuclide id's. The default value for these quantities is 1.0 for each nuclide; they are used only for optional

editing of nuclide loadings in kilograms. The SSS sequence numbers are 301, 302, ... , 499.

Depletable problems require the following cards:

Alphanumeric Nuclide ID's

300SSS, NAME(1), NAME(2), ...

NAME(i) is an alphanumeric nuclide identification. These cards must contain a list of alphanumeric nuclide identifications (id's) if the problem is depletable. Such id's are used by the program to label nuclide data. Each alphanumeric label is from one to ten characters; they are assumed to be given in the same order as the numeric nuclide id's. The SSS sequence numbers are 501, 502, ... , 599.

11.2. HARMONY INPUT PREPARATION: NUCLIDE CHAIN DATA

Nuclide chains are described by giving, for each chain, a control card specifying the number of nuclides in the chain, the chain type (depletion or fission product), and the maximum subinterval length for the chain. Then, for each nuclide in the chain, the id, form (linearization indicator), and decay factor are given; these are followed by triplets giving the coupling type, id of nuclide coupled to, and the fraction of such coupling to be applied. By specifying the type of coupling allowed to each nuclide in each chain, the chain definition cards identify the depletion equations to be solved for each nuclide. It is anticipated that once these cards are prepared for a particular chain, they will not change from problem to problem except, possibly, as required to handle the special case of depletion at zero power (see Section 4.8).

Once the chain descriptions have been established, there must be a mechanism for determining which nuclides will appear together in a composition. This is done in two steps by (1) giving several lists of chains and then by (2) associating one of these chain lists with each depleting composition.

A chain list is merely a list of chain numbers of those chains which are to be grouped together. Each chain list is checked for erroneous duplication of nuclides and for proper linearization of complicated chains. A list of permissible nuclides can then be prepared for each chain list.

Through the chain list assignment, each composition is given a chain list number. Thus, a list of permissable nuclides is assigned to each composition. Any mention of a nuclide in a composition, such as initial concentration, microscopic cross section table, or interpolating table, is checked against the list of nuclides assigned to that composition. A special chain list number of zero must be assigned to all non - depleting compositions.

The second consequence of the chain list is that it defines the order in which the depletion equations are solved. This relates to the problem of calculating the fission yield in the fission product chains (see Section 4.9). A third consequence of the chain list is that it determines the number of subintervals (the number of times the chains will be solved during a time step) in each composition.

The following is a brief summary of the input cards used to specify chain data:

```
          3cc000 : chain cc control card
3ccnn1 - 3ccnn9 : description of nn-th nuclide in chain cc
09LL01 - 09LL99 : chain list LL definition
090001 - 090099 : chain list assignment to compositions
```

A more detailed description of this data is given below.

For each chain cc = 01, 02, ... ,99:

Chain Control

3cc000, NUCLIDES, TYPE, MAXDT

NUCLIDES is the number of nuclides in chain cc; must be positive and no greater than 15.

TYPE is 1 if a depletion chain (no direct yield term), 2 if a fission product chain.

MAXDT is the maximum subinterval length (hours) to be used for this chain; for practical reasons, .00001 is the smallest value allowed. This value is floating point.

For each nuclide nn = 01, 02, ... ,15 in chain cc = 01, 02, ... (the nn indicates the order in which the nuclides occur in the chain):

Nuclide Parameters

3ccnn1, ID(nn), FORM, DECAY

ID(nn) is the numeric id of the nn-th nuclide in the chain.
FORM is 0 if the nuclide appears only in this chain in a chain list. If the nuclide appears in more than one chain in a chain list: FORM is 0 if this is the first appearance in the chain cc (see figures in Section 4.7); FORM is -1 if this is a duplication of an appearance in a previous chain; and FORM is +1 if this is a partial contribution to a previous appearance of the nuclide.
DECAY is the decay constant for the nuclide in units of 1/seconds. This value is floating point.

For each coupling to nuclide nn in chain cc:

Couplings

3ccnnS, COUPLING(j), ID(j), FRACTION(j)

COUPLING(j) indicates the type of coupling from nuclide ID(j) to this nuclide ID(nn).
ID(j) is the numeric ID of the nuclide coupled to.
FRACTION(j) is the fraction of the coupling from nuclide ID(j). This is a floating point value between and including 0.0 and 1.0.

If nn = 01, the first nuclide in the chain, then COUPLING(j) = 1, 2, or 3 is not allowed; COUPLING(j) = 4 means the third term is deleted in Equation 4.7.1 (i.e. dN/dt = Y or dN/dt = 0), and in this case set ID(j) = ID(nn), FRACTION(j) = 0.0, and NUCLIDES = 1; COUPLING(j) = 5 is allowed if TYPE = 2 (see below). Unless the special equation given by COUPLING(j) = 4 is desired, no coupling card is allowed for nn = 01 in a depletion chain.

If nn is greater than 01, one triplet with COUPLING(j) = 1, 2, or 3 is required and these specify decay, capture, or decay plus capture respectively and in this case ID(j) = ID(nn-1). FRACTION(j) is a floating point quantity which must be positive and is the term "alpha" in Equation 4.7.1. COUPLING(j) = 4 is not allowed, and COUPLING(j) = 5 is allowed if TYPE = 2.

For any nn, if TYPE = 2, use COUPLING(j) = 5 to specify yield term for fission products. In this case, ID(j) is the numeric id of a fissile nuclide, and FRACTION(j) is the fractional yield of nuclide ID(nn) from fissile nuclide ID(j). Several such triplets are allowed. If the special equation dN/dt = Y is desired, these triplets follow the [4, ID(nn), 0.0] triplet.

Note that S = 2, 3, ... , 9; supply as many triplets per card as desired and then sequence additional cards using the S in the card number.

For each chain list LL = 01, 02, ... ,99:

Chain List Definition

09LLSS, CHAIN(1), CHAIN(2), ...

CHAIN(i) is the chain number of the i-th chain in chain list LL. SS is a

sequence number 01, 02, ... ,99 for each LL. The chains in each list must be consistent as described in Section 4.9. The order in which the chains are listed determines the order in which they are to be solved.

Chain list to composition assignment data:

Chain List Assignment

0900SS, C-LIST(1), COMP(1), C-LIST(2), COMP(2), ...

C-LIST(i) is one of the lists LL given by the 09LLSS cards, or zero (which represents a non - depletable composition).
COMP(i) is a composition number; they must be in strictly increasing order and the last such number listed must be MAXCMP (see Section 9.1). This form of data input is called "sequential expansion" (see Section 8.2).

SS is sequential from 01, ... , 99.

11.3. HARMONY INPUT PREPARATION: NUCLIDE CONCENTRATION DATA

Card input concentrations are required to be present even if an input File Manager concentration file is used. The reason for this is that such card input is used for replacement data and for mask tables in which the independent variable is a fraction value.

Sets of concentration values and associated nuclide id's are specified along with lists of compositions to which such sets are to be assigned. In addition, the ability exists to specify that the concentrations in a set of compositions be some user supplied factor times the concentrations in another composition.

The initial nuclide concentrations must be included for each depletable composition. They are required to be consistent with the chain list per composition in that no concentrations may be given for non - depletable compositions and values may be given only for permissible nuclides that have been assigned to a depletable composition. This establishes the requirement that each nuclide for which an initial concentration is given appear in at least one chain description which in turn appears in a chain list. Initial concentrations which are not specified by the user are assigned a default value of zero.

Briefly, the cards used in supplying initial concentrations are as follows:

```
          10XXX0 : list of composition numbers
10XXX1 - 10XXX9 : list of (id, concentration value) pairs
14CCC1 - 14CCC9 : assigns modified concentrations
```

A more detailed description of these cards is given below.

After all 10XXXS and 14CCCS cards have been processed, each depletable composition must have been assigned a concentration (even if zero) for at least one nuclide. In any composition, nuclides for which no concentration values have been input are automatically assigned a concentration of zero.

For any XXX from 001 to 999:

Composition List

10XXX0, C(1), +-C(2), +-C(3), ...

C(i) is a composition number. This list of compositions will be assigned the nuclide concentrations contained on cards 10XXXS. The form C(i), -C(i+1) implies composition numbers C(i), C(i)+1, C(i)+2, ... , C(i+1).

For any XXX from 001 to 999:

Nuclide Concentrations

10XXXS, ID(1), N(1), ID(2), N(2), ...

ID(i) is a numeric nuclide id.
N(i) is a floating point number density representing the concentration (per barn-cm) of nuclide ID(i).

For each XXX present, use sequence numbers 1, 2, ... , 9 if required. Such concentration values are assigned to the compositions listed on card 10XXX0. If card 10XXX0 is not present, the concentration values are assigned to the single composition XXX. The 10XXX0 and 10XXXS cards are processed in order for XXX = 001, 002, ..., 999 but any XXX may be missing. Note that this implies a

kind of overlay of the data if the composition lists overlap.

Optionally, for each composition CCC:

Nuclide Concentration Factors

14CCCS, FACTOR, C(1), +-C(2), +-C(3), ...

FACTOR is a floating point constant which is used to multiply the concentrations from composition CCC and apply them to the compositions listed for all nuclides not already assigned a value in those compositions.

C(i) is a composition number. The form C(i), -C(i+1) implies composition numbers C(i), C(i)+1, C(i)+2, ... , C(i+1).

For each composition CCC use sequence numbers 1, 2, ... , 9 if required. This card data is processed AFTER the 10XXXS card data but cannot overlay any concentration input specified on those cards. That is, this data can be used to define only concentrations which have not been specified on cards 10XXXS or on a previous 14CCCS card.

If an error is detected in any nuclide concentration input, a card input concentration edit by composition is performed even if not requested.

11.4. HARMONY INPUT PREPARATION: CONCENTRATION REPLACEMENT DATA

To replace non-uniform nuclide concentrations with uniform concentrations, a list of compositions must be given. This action will cause all nuclides in such compositons to be replaced with card input nuclide concentrations. If selected nuclides only are to be replaced, a list of such nuclides must be given in addition to the list of compositions. The following cards are used in the replacement process:

010101 - 010109 : composition list (optional)
010171 - 010179 : nuclide list (optional)

The program has no explicit "switch" which causes replacement to be done; it is simply the presence of these list specifications which cause the program to perform the replacement process. To protect against accidental replacement, these cards are automatically deleted from case to case. Replacement can also be performed from sub-case to sub-case. Details of each of these card series follows.

For S = 1, 2, ... , 9:

Composition List

01010S, C(1), +-C(2), +-C(3), ...

C(i) is a composition number. The form C(i), -C(i+1) implies composition numbers C(i), C(i)+1, C(i)+2, ... , C(i+1). These compositions are those for which nuclide concentration replacement is to be done. These cards are optional and are deleted from case to case.

For S = 1, 2, ... , 9:

Nuclide List

01017S, ID(1), ID(2), ...

ID(i) is a numeric nuclide identification. These id's identify nuclides whose concentrations are to be replaced by card input nuclide concentrations in compositions specified on cards 01010S. These cards are optional and are deleted from case to case.

11.5. HARMONY INPUT PREPARATION: CROSS SECTION DATA

The specification of the collection of cross section tables to be used in each composition is done in two steps. First a basic table set, which is simply a collection of tables, is assigned to each composition. Then optionally, through the table overlay input, tables from other table sets may be borrowed for use in a composition either to add to the list of tables or to replace a table already assigned for use in that composition. The desired effect of these additions and deletions is to reduce the total number of tables in use in a particular problem to avoid exceeding the storage available in the problem. When the total number of tables is small there is probably no need for the table overlay input. Another use of the overlay is to correct certain tables in a table set produced by an auxiliary program. That is, the table set containing an error is assigned to the composition and the erroneous table is replaced by one from cards by the overlay.

Table sets may be provided to the program via an input File Manager table set file, table set card input, or both.

A table set supplied on cards includes a numeric and optional alphanumeric ID, and may contain a MASTER MACRO table, MASTER MICRO tables, and MASK-FUNCTION (INTERPOLATING) table references. FUNCTION tables and MASK tables are specified separately and then referenced to become part of a table set. A type of "borrowing" is available through OVERLAY data which allows tables from different table sets to be added to a composition or to replace a like table in a composition. Finally, table sets are assigned to compositions via table set assignment cards.

Briefly, the card data used to specify table set information consists of the following:

```
010181 - 010189 : list of non-counting nuclide ID's
110001 - 110099 : table set assignment to compositions
111001 - 111099 : MASTER MACRO table overlay
112g01 - 112g99 : MASTER MICRO table overlay, group g
113g01 - 113g99 : INTERPOLATING MACRO table overlay, group g
114g01 - 114g99 : INTERPOLATING MICRO table overlay, group g
115g01 - 115g99 : INTERPOLATING G table overlay, group g
          12mm00 : MASK mm table control
12mmj1 - 12mmj9 : MASK mm table values for dimension j=1,2,3
12mm91 - 12mm99 : MASK mm off-diagonal indices
          13fff0 : FUNCTION fff table control
13fff1 - 13fff9 : FUNCTION fff table values
          4tt000 : numeric table set ID
          4tt001 : alphanumeric table set ID
          4ttg00 : MASTER MACRO table, group g part
4ttg01 - 4ttg99 : MASTER MICRO table, group g
4tt601 - 4tt699 : MASK-FUNCTION table assignment
```

Details of each of these card series follows.

The following cards are optional:

Non-Counting Nuclides

010185, ID(1), ID(2), ...

ID(i) is a numeric nuclide identification. Nuclides mentioned in this list do not contribute directly to the calculated macroscopic cross sections but may be used as independent variables in interpolations. This capability to ignore a nuclide when calculating macroscopic cross sections is most useful for dummy nuclides such as counters which may require a non-zero microscopic cross section in order to "deplete" properly.

These cards are sequenced S = 1, 2, ..., 9.

The following cards are required in every problem:

Table Set Assignment to Compositions

1100SS, T(1), C(1), T(2), C(2), ...

T(i) is a numeric table set ID.
C(i) is a composition number. This data is in sequential expansion format so that table set T(i) is assigned to compositions C(i-1) through C(i) with C(0) understood to be zero. These composition numbers must be in strictly increasing order with the last value equal to MAXCMP (see Section 9.1).

These cards are sequenced SS = 01, 02, ... , 99.

The following cards are optional:

MASTER MACRO Table Overlay

1110SS, T, C(1), -C(2), C(3), -C(4), ...

T is a numeric table set ID. The MASTER MACRO table from this table set is to be overlayed in the specified compositions.
C(i) is a composition number. The identified MASTER MACRO table will be overlayed in compositions C(1) through C(2), compositions C(3) through C(4), etc. The composition numbers must be specified as plus - minus pairs even if C(i) = C(i+1). The composition numbers in absolute value must be in non - decreasing order.

If the table set ID is zero, the identified table is to be deleted from the specifed compositions. These cards are sequenced SS = 01, 02, ... , 99. Each card represents one overlay. Do NOT continue onto a second card with a single overlay, and do NOT begin a second overlay on a single card.

The following cards are optional:

MASTER MICRO Table Overlay

112gSS, T, ID(1), ... , ID(n), C(1), -C(2), C(3), -C(4), ...

T is a numeric table set ID. The MASTER MICRO tables in group g for the identified nuclides from this table set are to be overlayed in the specified compositions.
ID(i) is a numeric nuclide ID and identifies a MASTER MICRO table for such a nuclide in group g.
C(i) is a composition number. The identified MASTER MICRO tables will be overlayed in compositions C(1) through C(2), compositions C(3) through C(4), etc. The composition numbers must be specified as plus - minus pairs even if C(i) = C(i+1). The composition numbers in absolute value must be in non - decreasing order.

If the table set ID is zero, the identified tables are to be deleted from the specifed compositions. These cards are sequenced SS = 01, 02, ... , 99 for each group g. Each card represents one overlay. Do NOT continue onto a second card with a single overlay, and do NOT begin a second overlay on a single card.

The following cards are optional:

INTERPOLATING MACRO Table Overlay

113gSS, T, t, C(1), -C(2), C(3), -C(4), ...

T is a numeric table set ID. The INTERPOLATING MACRO table with type t from this table set is to be overlayed in the specified compositions.
t is the type of cross section (see Table 11.5.1).
C(i) is a composition number. The identified INTERPOLATING MACRO table will be overlayed in compositions C(1) through C(2), compositions C(3) through C(4), etc. The composition numbers must be specified as plus - minus pairs even if C(i) = C(i+1). The composition numbers in absolute value must be in non - decreasing order.

If the table set ID is zero, the identified table is to be deleted from the specifed compositions. These cards are sequenced SS = 01, 02, ... , 99 for each group g. Each card represents one overlay. Do NOT continue onto a second card with a single overlay, and do NOT begin a second overlay on a single card.

The following cards are optional:

INTERPOLATING MICRO Table Overlay

114gSS, T, t, ID(1), ... , ID(n), C(1), -C(2), C(3), -C(4), ...

T is a numeric table set ID. The INTERPOLATING MICRO tables with type t in group g for the identified nuclides from this table set are to be overlayed in the specified compositions.
t is the type of cross section (see Table 11.5.1).
ID(i) is a numeric nuclide ID and identifies an INTERPOLATING MICRO table with type t for such a nuclide in group g.
C(i) is a composition number. The identified INTERPOLATING MICRO tables will be overlayed in compositions C(1) through C(2), compositions C(3) through C(4), etc. The composition numbers must be specified as plus - minus pairs even if C(i) = C(i+1). The composition numbers in absolute value must be in non - decreasing order.

If the table set ID is zero, the identified tables are to be deleted from the specifed compositions. These cards are sequenced SS = 01, 02, ... , 99 for each group g. Each card represents one overlay. Do NOT continue onto a second card with a single overlay, and do NOT begin a second overlay on a single card.

The following cards are optional:

INTERPOLATING SELF SHIELDING Table Overlay

115gSS, T, t, ID(1), ... , ID(n), C(1), -C(2), C(3), -C(4), ...

T is a numeric table set ID. The INTERPOLATING SELF SHIELDING (C) tables with type t in group g for the identified nuclides from this table set are to be overlayed in the specified compositions.
t is the type of self shielding (see Table 11.5.1).
ID(i) is a numeric nuclide ID and identifies an INTERPOLATING SELF SHIELDING table with type t for such a nuclide in group g.
C(i) is a composition number. The identified INTERPOLATING SELF SHIELDING tables will be overlayed in compositions C(1) through C(2), compositions C(3) through C(4), etc. The composition numbers must be specified as plus - minus pairs even if C(i) = C(i+1). The composition numbers in absolute value must be in non - decreasing

order.

If the table set ID is zero, the identified tables are to be deleted from the specifed compositions. These cards are sequenced SS = 01, 02, ... , 99 for each group g. Each card represents one overlay. Do NOT continue onto a second card with a single overlay, and do NOT begin a second overlay on a single card.

The following card is optional:

MASK Table Control

12mm00, DIM, ND, NOD

DIM is the dimensionality of mask mm; that is, there are DIM independent variables in the mask. This must be 1, 2, or 3.
ND is the number of diagonal entries, necessarily positive.
NOD is the number of off diagonal entries. This number may be zero or positive.

The mm is the mask number and can take on any value 01, 02, ... , 99, not necessarily sequential.

The following cards are optional:

MASK Diagonal Values

12mmJS, ID, N/F, N(1), N(2), ... , N(ND)

ID is the numeric nuclide ID of the J-th independent variable.
N/F is the indicator of whether the number density itself is to be used as the independent variable (N/F=0) or the fraction remaining is to be used as the independent variable (N/F=1).
N(i) is the i-th value of the J-th independent variable. This value is floating point. For J=1, the primary independent variable is being described, and these entries must be in strictly decreasing order.

For each J=1,...,DIM for each mask mm, sequence cards with S=1,...,9. For S greater than 1, omit ID and N/F. The J=1,2,3 determines the order of matrix designation in the 12mm9S cards.

The mm is the mask number and can take on any value 01, 02, ... , 99, not necessarily sequential.

The following cards are optional:

MASK Off Diagonal Indices

12mm9S, I(1), J(1), ... , I(NOD), J(NOD) $ 2-D mask

12mm9S, I(1), J(1), K(1), ... , I(NOD), J(NOD), K(NOD) $ 3-D mask

I(i) is the index or position of the J=1 independent variable specified on cards 12mm1S which is to be used as the value of the J=1 independent variable for the i-th off-diagonal value.
J(i) is the index or position of the J=2 independent variable specified on cards 12mm2S which is to be used as the value of the J=2 independent variable for the i-th off-diagonal value.
K(i) is the index or position of the J=3 independent variable specified on cards 12mm3S which is to be used as the value of the J=3

independent variable for the i-th off-diagonal value.

This data is to be included if and only if NOD is non-zero.

The mm is the mask number and can take on any value 01, 02, ... , 99, not necessarily sequential. These cards are sequenced S = 1, 2, ... , 9 for each mask mm.

Each pair in a 2-D mask and each triplet in a 3-D mask must represent a "proper" entry (see Section 4.5). This implies that, for a 2-D mask, I(i)=J(i) is not true for any i=1,...,NOD; for a 3-D mask, I(i)=J(i)=K(i) is not true for any i=1,...,NOD.

Visualize a two - dimensional mask as a matrix of elements with the diagonals of the mask appearing as the diagonal of the matrix with the j=1 variable appearing as the row (I) label and the j=2 variable as the column (J) label. Then off-diagonal entries can be located by giving the row number followed by the column number of the matrix position of the entry. Each off-diagonal entry will be described by a doublet if the table is two - dimensional or a triplet if the table is three - dimensional. That is, for the n-th off-diagonal entry give the location first for the j=1 variable, then for the j=2 variable, then for the j=3 variable. For j=1, the numbers must be nondecreasing; i.e., I(n) must be greater than or equal to I(n-1) for n=2,...,NOD. All of the off-diagonal entries corresponding to the first value of the j=1 variable must be given first, then all of the off-diagonal entries corresponding to the second value of the j=1 variable, etc.

For example, consider a 2-D mask represented by the following figure where x's indicate the entries used and o's indicate positions not used. The main independent variable is labelled 235 and uses N(t)/N(0); the second independent variable is labelled 238 and uses N(t).

		238 (j=2)			
		.02	.05	.03	.01
235 (j=1)	1.0	x	x	o	x
	0.8	o	x	o	o
	0.6	o	o	x	o
	0.4	o	x	o	x

The sample mask shown may be specified with card input as follows:

```
12mm00, 2, 4, 3 $ 2-D, 4 diagonals, 3 off diagonals
12mm11, 235, 1, 1+1, 8+0, 6+0 $ j=1 diagonal values
12mm12, 4+0 $ j=1 diagonal values cont'd
12mm21, 238, 0, 2-1, 5-1, 3-1, 1-1 $ j=2 diagonal values
12mm91, 1, 2, 1, 4, 4, 2 $ off diagonal indices
```

or, the last card could be:

```
12mm91, 1, 4, 1, 2, 4, 2 $ alternate off diagonal indices
```

The following cards are optional:

FUNCTION Table Control

13fff0, k, ID, t, g, o, f, i(1), t(1), i(2), t(2), ...

k is the general type of quantity represented as follows:
k=3 means MACRO,
k=4 means MICRO,
k=5 means SELF SHIELDING.
ID is the numeric nuclide ID, zero if k=3.
t is the type of cross section (see Table 11.5.1).
g is the group number.
o is the order of interpolation (1,2,3,4, or 5).
f is 0 if the function itself is to be interpolated, f is 1 if the inverse of the function is to be interpolated.
i(n), t(n) are (id, type) pairs. When k=5 ONLY, the function table can be used to represent SELF SHIELDING for several different (id, type) combinations for the same group. In this case, the additional pairs of values of nuclide ID i and type t are listed following f as shown above.

The fff is the function table number and can take on any value 001, 002, ... , 999, not necessarily sequential.

The following cards are optional:

FUNCTION Diagonal Values

13fffS, F(1), F(2), ... , F(ND)

F(i) is the i-th function value (dependent variable) for the diagonal entries of the table. This value is floating point. Note that ND must match up with the mask given for the table and the function values must be input in the same order as the diagonal mask entries.

These cards are sequenced 1, 2, ... , 9 for each table fff. The fff is the function table number and can take on any value 001, 002, ... , 999, not necessarily sequential.

The following cards are optional:

FUNCTION Off Diagonal Values

13ffffs, F(1), F(2), ... , F(NOD)

F(j) is the j-th function value (dependent variable) for the off diagonal entries of the table. This value is floating point. Note that NOD must match up with the mask given for the table and the function values must be input in the same order as the off diagonal mask entries.

This data is to be included if and only if NOD is non-zero.

For each table fff, continue the sequence numbering s=S+1,...,9 where S is the last sequence number used to describe the diagonal entries. The fff is the function table number and can take on any value 001, 002, ... , 999, not necessarily sequential.

Note that when f=1 on cards 13fff0, all F(i) and F(j) must be nonzero. It is further assumed that when the inverse of the cross section is interpolated that

the cross section values, not the inverse values, are available in the table. The program automatically provides the inverses in this case.

The following cards are required:

Table Set Numeric Identification

4tt000, T

T is the numeric table set ID of the table set data with subseries number tt. T must be greater than zero and less than 65535.

The tt in the card number differentiates the table set input. That is, all data associated with a single table set has the same subseries tt. The value of tt can take on any value of 01, 02, ... , 99, not necessarily sequential.

The following cards are optional:

Table Set Alphanumeric Identification

4tt001, TSNAME

TSNAME is the optional alphanumeric name of the table set data with subseries number tt. Any number of alphanumeric words may appear on this card but only the first four words (40 characters) are used. This name is used only in the optional editing of HARMONY input data to identify the table sets used.

The following cards are optional:

MASTER MACRO Table Values

4ttg00, D, A, R, F, K

D is the diffusion constant for group g in the MASTER MACRO table for the table set with subseries number tt. If the table set is assigned to a depletable composition, this entry is assumed to be the macroscopic transport cross section (SIGMA TR) instead. This value is floating point.
A is the macroscopic absorption cross section for group g (SIGMA A). This value is floating point.
R is the macroscopic removal cross section for group g (SIGMA R). This value is floating point.
F is the macroscopic source fission cross section for group g (NU SIGMA F). This value is floating point.
K is the macroscopic power fission cross section for group g (KAPPA SIGMA F). This value is floating point.

If g is one of two thermal groups, the order of this data is: D(1), D(2), SIGMA(1), SIGMA(2), F, K, REM (the term which multiplies the epithermal R to obtain an effective removal cross section), all floating point. Again, if the table set is assigned to a depletable composition, the D(1) and D(2) are assumed to be SIGMA TR(1), and SIGMA TR(2) respectively.

If the fission cross sections (F,K) are zero, they may be omitted but they must either be present or omitted from each group for a given table set. That is, EITHER each group must contain the fission cross sections OR all groups must not contain the fission cross sections.

If any one group g is present, all groups must be present.

Note that macroscopic KAPPA SIGMA F are not included in the power renormalization calculations during depletion (see Section 4.7).

The following cards are optional:

MASTER MICRO Table Values

4ttgSS, i, tr, a, r, f, nu, kappa

- i is the numeric nuclide ID which identifies the nuclide associated with this MASTER MICRO table in group g for the table set with subseries number tt.
- tr is the microscopic transport cross section for nuclide i in group g. This value is floating point.
- a is the microscopic absorption cross section for nuclide i in group g. This value is floating point.
- r is the microscopic removal cross section for nuclide i in group g. This value is floating point.
- f is the microscopic fission cross section for nuclide i in group g. This value is floating point.
- nu is the average number of neutrons produced per fission for nuclide i in group g. This value is floating point.
- kappa is the energy released per fission (watt-sec/fission) for nuclide i in group g. This value is floating point.

If g is one of two thermal groups, the order of this data after the ID is: tr(1), tr(2), a(1), a(2), f, nu, kappa, all floating point.

For these tables, the various groups g need not be consistent in the inclusion or omission of the fission terms (f,nu,kappa). That is, they may be included or omitted in any group independent of whether they are included in other groups.

Not all groups need be present.

Each card contains one table for one group g. The cards are sequenced for each group with SS = 01, 02, ... , 99.

The following cards are optional:

MASK-FUNCTION Table Assignment

4tt6SS, mm, fff(1), fff(2), ...

- mm is a mask number associated with function tables fff(i) to be included in the table set with subseries number tt.
- fff(i) is a function table to be associated with mask mm and included in the table set with subseries number tt.

Each card in the sequence SS = 01, 02, ... , 99 contains one mask and several function table numbers.

The specification of the function table itself indicates the cross section which is to be interpolated in this table set.

TABLE 11.5.1

INTERPOLATING TABLE "TYPES"

Macroscopic (Σ_o), Microscopic (σ), Self Shielding (G)

Type (t)	Fast groups or 1 thermal group			First of 2 thermal groups			Second of 2 thermal groups		
1	Σ^{tr}	σ^{tr}	G^{tr}	$\Sigma^{tr,1}_{G-1}$	σ^{tr}_{22}	G^{tr}_{22}	$\Sigma^{tr,1}_{G}$	σ^{tr}_{11}	G^{tr}_{11}
2	Σ^{a}	σ^{a}	G^{a}	$\Sigma^{tr,2}_{G-1}$	σ^{tr}_{21}	G^{tr}_{21}	$\Sigma^{tr,2}_{G}$	σ^{tr}_{12}	G^{tr}_{12}
3	Σ^{R}	σ^{R}	G^{R}	Σ^{1}_{G-1}	σ_{22}	G_{22}	Σ^{1}_{G}	σ_{11}	G_{11}
4	$\nu\Sigma^{f}$	σ^{f}	G^{f}	Σ^{2}_{G-1}	σ_{21}	G_{21}	Σ^{2}_{G}	σ_{12}	G_{12}
5	$\kappa\Sigma^{f}$	ν	-	$\nu\Sigma^{f}_{G-1}$	σ^{f}_{G-1}	G^{f}_{G-1}	$\nu\Sigma^{f}_{G}$	σ^{f}_{G}	G^{f}_{G}
6	B^2	κ	-	$\kappa\Sigma^{f}_{G-1}$	ν_{G-1}	-	$\kappa\Sigma^{f}_{G}$	ν_{G}	-
7	-	-	-	R_{G-1}	κ_{G-1}	-	R_{G}	κ_{G}	-
8	-	-	-	B^2_{G-1}	-	-	B^2_{G}	-	-

a. For depletion, $\sigma^{a}_{G-1} = \sigma_{21}$ and $\sigma^{a}_{G} = \sigma_{11}$.

b. Note the equivalence between two different forms for 2 thermal groups.

c. $\Sigma^{t}_{g} = \Sigma^{t}_{o,g} + \sum_{i} N_i G^{t}_{i,g} \sigma^{t}_{i,g}$

11.6. HARMONY INPUT PREPARATION: BUCKLING DATA

Buckling values are optional in all problems. They may be specified separately for each group or they may be specified as group independent. Buckling values are input in expansion format by composition. The card series used is 08 and the subseries number is the group number. Subseries zero may be used to specify values for all groups in which group - dependent values are not provided. There need not be a subseries for each group but there must be a complete set of values for each subseries present. The cards used for buckling input are as follows:

080001 - 080099 : buckling values for all groups (optional)
08g001 - 08g099 : buckling values for group g (optional)

A more detailed description of this card data is given below.

For SS = 01, 02, ... , 99:

Buckling Values

08g0SS, BUCLNG(1), C(1), BUCLNG(2), C(2), ...

BUCLNG(i) is a floating point number representing a buckling value. For g = 0, this buckling value is assigned to all groups in compositions C(i-1)+1 through C(i). For g not 0, this buckling value is assigned to group g in compositions C(i-1)+1 through C(i) and the buckling values input on cards 0800SS, if any, are ignored in group g.

C(i) is a composition number. These numbers must be in strictly increasing order with the last value equal to MAXCMP (see Section 9.1).

11.7. HARMONY INPUT PREPARATION: AREA RATIO DATA

Area ratio values are optional in all problems. They may be specified in two different ways: (1) by composition; or (2) by final figure (or planar region, whichever corresponds to compositions) and by gross plane (or configuration). In the first form, area ratio values are input in expansion format by composition. The card series used is 02 and there is no subseries number. The data defaults to unity for each composition. In the second form, area ratio values are input in overlay format by figure (or region). The subseries number is the point plane number. If this second form is present, the area ratios for plane zero must be completely described for all figures (or regions); then later subseries give the changes in area ratios at the various planes. These changes can only occur at gross plane boundaries in three dimensional problems.

Area ratio data is optional and if both types of input are present the second form is used. The cards used for area ratio input are as follows:

020001 - 020099 : area ratios by composition (optional)
19ppp1 - 19ppp9 : area ratios by figure (region) at plane (configuration) ppp (optional)

A more detailed description of this card data is given below.

For SS = 01, 02, ... , 99:

Area Ratios by Composition

0200SS, ARATIO(i), C(1), ARATIO(2), C(2), ...

ARATIO(i) is a floating point number representing an area ratio value. This value is assigned to compositions C(i-1)+1 through C(i).
C(i) is a composition number. These numbers must be in strictly increasing order with the last value equal to MAXCMP (see Section 9.1).

For S = 1, 2, ... , 9:

Area Ratios by Figure (or Region)

19pppS, R(1), ARATIO(1), R(2), R(3), ARATIO(2), R(4), ...

ARATIO(i) is a floating point number representing an area ratio value. This value is assigned to figures (or regions) R(2*i-1) through R(2*i) beginning at point plane (or configuration) ppp.
R(i) is a figure (or region) number. Within a triplet [R(2*i-1), ARATIO(i), R(2*i)], the number R(2*i-1) must not be greater than R(2*i).

At plane or configuration zero (ppp=0), all figures (or regions) must be assigned a value; values at any other ppp simply modify the values given for the previous ppp and need not be complete.

11.8. HARMONY INPUT PREPARATION: FLUX ENHANCEMENT DATA

The depletion portion of the program allows for a time variation of the flux between the subintervals. Multiplicative factors, possibly group and composition dependent, are applied to the flux to accomplish the desired result. These factors are applied to the input-power normalized flux as follows: the composition dependent factor raised to the n-1st power multiplies the appropriate group of flux. Here, n is the subinterval number counted through the entire depletion time interval T(0) to T(1). That is, the subinterval number n continues while depleting from T(0) to T(1) even if thermal flux renormalizations are done. If these factors are applied to fuel compositions and thermal flux renormalizations are being done, the flux used in the calculation of the fast and thermal contributions to the power integrals needed to obtain the new thermal - flux normalization is the flux as modified by these factors raised to the m-th power, where m is the number of subintervals performed up to that point in time. Note that, in general, the number of subintervals is a function of composition.

Flux enhancement factors are optional in all depletable problems. These factors are input in expansion format by composition. The card series used is 02 and the subseries number is the group number. There need not be a subseries for each group but there must be a complete set of values for each subseries present. The default values for these factors for missing subseries is unity. The cards used for flux enhancement factor input are as follows:

02g001 - 02g099 : flux factors for group g (optional)

A more detailed description of this card data is given below.

For SS = 01, 02, ... , 99:

Flux Enhancement Factors

02g0SS, FACTOR(1), C(1), FACTOR(2), C(2), ...

FACTOR(i) is a floating point number representing a flux enhancement factor value. This factor is assigned to group g in compositions C(i-1)+1 through C(i).

C(i) is a composition number. These numbers must be in strictly increasing order with the last value equal to MAXCMP (see Section 9.1).

12.1. EDIT REQUEST INPUT PREPARATION: INPUT PROCESSING EDIT DATA

For every case of input, the following are always edited during input processing:

(a) CARDFILE cards in the order they are encountered;

(b) Card data from card files in the order they are processed;

(c) Card input data for the current case;

(d) A one page summary of important problem parameters; and,

(e) In synthesis cases, the trial function descriptions.

All other editing of input data which can occur during input processing (except, of course, error commenting) is optional. There are five major sections of optional input editing which can be requested:

1. Geometry data,

2. Concentration data,

3. Harmony input data,

4. Integration edit definitions, and

5. Geometry pictures.

These edits, as well as all other optional edits in the program, are defaulted "off"; that is, they are not done unless specifically requested. In addition, such edit requests are deleted from case to case and thus must be requested explicitly in each case if desired.

The geometry picture edit input is described in detail in Section 10.6 and will not be given here. The edit of items (1) through (4) as well a fifth item pertaining to editing of calculated macroscopic cross sections are all specified on a single card 010010. The macro edit option is not an input processing edit but is included here since that option resides on the same card as the input processing edits. Details of the content of this card follows.

Input Edit Control

010010, GEOMED, CONCED, HARMED, EDSTED, MACRED

GEOMED is the indicator of whether or not to edit the processed geometry card input data. A value of 0 means no; a value of 1 means yes.

CONCED is the indicator of whether or not to edit the processed nuclide concentration card input data. These concentration values are edited by composition. A value of 0 means no; a value of 1 means yes.

HARMED is the indicator of whether or not to edit the processed HARMONY input data. A value of 0 means no; a value of 1 means yes. In addition, a value of -1 will produce a much shortened edit which omits the detailed table usage edit.

EDSTED is the indicator of whether or not to edit the processed input which describes the planar and axial edit set integration space. A value of 0 means no; a value of 1 means yes.

MACRED is the indicator of whether or not to edit the macroscopic cross sections calculated in this case. A value of 0 means no; a value of 1 means yes. These cross sections are edited over integration edit sets and the printed values are volume weighted averages.

This card is optional and if omitted all options are assumed to be zero (no editing). From one to five items may be present. All trailing items omitted are assumed to be zero. This card is deleted from case to case.

12.2. EDIT REQUEST INPUT PREPARATION: INTEGRAL EDIT DATA

Flux integrals and edits resulting from combinations of flux - weighted macroscopic cross section integrals are automatically edited by the program. All other integration editing is optional and must be explicitly requested via card input data.

The volume weighted macroscopic cross sections may be optionally edited by edit set and plane grouping. The request for this edit is on card 010010 and is described in Section 12.1.

Named collections of nuclide reaction rates and atom counts may be optionally edited. Such collections are specified on cards 0101X0 and each consists of the name to be associated with the collection followed by a set of alphanumeric nuclide identifications. The name of a "previously" defined collection can be included with the set of nuclide identifications in the definition of a "later" collection. The value of X specifies the type of data as follows: (a) X = 1 means nuclide power; (b) X = 2 means nuclide absorption rate; (c) X = 3 means nuclide fission rate; and (d) X = 4 means nuclide atom counts (integrated concentrations). Such collections are edited as name - value pairs. The data in these collections is integrated over the entire solution space. For X = 9, named constants can be defined to be used in the algebraic combination edits.

Arbitrary algebraic combinations of the collection data and specified constants can be optionally edited. Such combinations are specified on cards 010191, ... , 010199 and each consists of the name to be associated with the result of the operation, the first operand, the operator, and the second operand. The operands are either a collection name, the name of a defined constant, or the name of a "previous" result. The possible operators are +, -, *, /, and ** meaning add, subtract, multiply, divide, and exponentiate respectively. Such results are edited as name - value pairs.

Nuclide power fractions, absorption rates, fission rates, average concentrations, and loadings may optionally be edited by edit set and plane grouping. Cards 0101X1 - 0101X9 are used to list the numeric nuclide identifications of the nuclides to be edited. The value of X specifies the type of data as follows: (a) X = 1 means power fractions; (b) X = 2 means absorption rates; (c) X = 3 means fission rates; and (d) X = 4 means average concentrations and/or loadings. In addition, average concentrations and loadings may be edited utilizing axial edits.

With one exception, all integral data is edited for specified combinations of final figures and planar regions (edit sets) along with combinations of gross planes or sets of individual planes (plane groupings and axial edits respectively). The one exception is the edit of arbitrary collections of nuclide data and combinations of these collections. Such data is integrated over all solution space.

Edit integral space is specified using series number 01. Subseries 100 - 499 are used for edit set definitions (radial integration extent), subseries 500 - 599 are used for plane grouping definitions (axial integration extent), and subseries 600 - 699 are used for axial edit definitions.

The data for each edit set subseries is of the form:

$$F(1), \pm F(2), \pm F(3), \ldots, \pm F(m)$$
$$, 0 ,$$
$$R(1), \pm R(2), \pm R(3), \ldots, \pm R(n)$$

where F(i) is a final figure number, R(j) is a planar region number, and the zero is used to separate a collection of planar region numbers from a collection of final figure numbers. A negative figure number designates all figures from the previous figure number through the negative figure number, and similarly for a negative region number. For both the figures and the regions, the numbers must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive. As an example, the sequence:

3, 5, -7, 0 , 2, -4, 9

specifies figure numbers 3, 5, 6, and 7 and region numbers 2, 3, 4, and 9.

The subseries are separated into four ranges: 100 - 199, 200 - 299, 300 - 399, and 400 - 499. Any (but not all) of the ranges may be omitted and the first missing subseries in each range terminates the range. Each subseries specifies a different combination of the data as follows. Each of subseries 100 - 199 specifies a single edit set. In each of subseries 200 - 299, the figure numbers are expanded to remove negative signs and an edit set of the form:

F(i), 0 , R(1), +-R(2), +-R(3), ..., +-R(n)

is constructed for each figure number F(i). Similarly, in each of subseries 300 - 399, the region numbers are expanded and an edit set of the form:

F(1), +-F(2), +-F(3), ..., +-F(m), 0 , R(j)

is constructed for each region number R(j). Finally, in each of subseries 400 - 499, both the figure and region numbers are expanded and an edit set of the form:

F(i), 0 , R(j)

is constructed for each figure - region pair F(i), R(j).

At least one plane grouping subseries OR one axial edit subseries is required in three - dimensional problems and the subseries numbers present must be sequential. Plane grouping data is input on subseries 500 - 599. The data for each plane grouping subseries specifies a single plane grouping and is of the form:

P(1), -P(2), P(3), -P(4), ..., P(n-1), -P(n)

The plane numbers in a subseries must be strictly increasing in absolute value and occur in plus - minus pairs, each pair designating the axial region between the two planes. For example, the sequence:

0, -3, 5, -8

specifies a plane grouping consisting of planes 0 - 3 together with planes 5 - 8. Only plane zero and the gross plane boundaries are permitted to be plane grouping boundaries.

Various quantities may be edited via axial edit sets. These quantities include average flux, average power, average concentrations, and the results of thermal feedback including fuel temperature, moderator temperature, moderator density, vapor fraction, and heat flux. Axial edit data is input on subseries 600 - 699. The data for each axial edit subseries specifies a single axial edit and is of the form:

KEYWORD, PRINT, P1, P2, E(1), +-E(2), +-E(3), ...

where KEYWORD is an alphanumeric key word specifying the quantity to be edited, PRINT is the indicator of whether to print or printer - plot the data, P1 and P2 are axial point numbers specifying the axial extent of the edit and must be gross plane boundaries, and the E(i) are edit set numbers where a negative number designates all edit sets from the previous edit set number through the negative edit set number. The edit set numbers must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive.

An option is available which permits a significant reduction in the volume of integral output, particularly in three - dimensional problems. This is accomplished by including in the input a card 011000 containing up to nine numbers.

The first pair of numbers refers to the volume - weighted macroscopic data edits, the second pair refers to the integration edits (flux integrals and flux - weighted macroscopic data), the third pair refers to the nuclide rate edits (power fractions, absorption rates, and fission rates), and the fourth pair refers to the average nuclide concentration and loading edits as well as the

integration editing performed during xenon and thermal feedback calculations.

Each of these pairs consists of the last edit set and the last plane grouping for which the corresponding integrals are to be printed. Either number (or both numbers) in a pair may be input as zero to request that printing not be done for any edit set or plane grouping.

The ninth item refers to axial edits. This item is the last axial edit to print or printer - plot and may be zero to request that no axial edits be printed.

If printing is not done but an edit integral File Manager output file is to be written, all integrals requested ARE computed so that the file can be written properly.

A summary of the input data used to specify integral edits is as follows:

```
          010010 : volume weighted macro edit (see Section 12.1)
          010110 : nuclide power collections
010111 - 010119 : nuclide power fraction edits
          010120 : nuclide absorption rate collections
010121 - 010129 : nuclide absorption rate edits
          010130 : nuclide fission rate collections
010131 - 010139 : nuclide fission rate edits
          010140 : nuclide atom count collections
010141 - 010149 : nuclide concentration, loading edits
          010190 : definition of constants
010191 - 010199 : combination edit definitions
          011000 : printing limit definitions
011XX1 - 011XX9 : each XX an edit set
012XX1 - 012XX9 : for each XX, each figure with all regions an edit set
013XX1 - 013XX9 : for each XX, each region with all figures an edit set
014XX1 - 014XX9 : for each XX, each figure - region pair an edit set
015XX1 - 015XX9 : each XX a plane grouping
016XX1 - 016XX9 : each XX an axial edit
```

Details of each of these card series follows.

Nuclide Collections

0101X0, C(1), N(1), N(2), ... , N(j), (), C(2), N(j+1), ...

C(i) is the name associated with the collection of nuclides listed up to the next blank item. This name is alphanumeric, from one to ten characters. This defines an integral over all problem space of a quantity summed over all nuclides listed in the collection. There are four types of collections and the quantity defined depends on the value of X as follows:

a. X = 1 is the sum over groups of the nuclide power;
b. X = 2 is the sum over groups of the nuclide absorption rate;
c. X = 3 is the sum over groups of the nuclide fission rate;
d. X = 4 is the nuclide concentration.

N(i) is the alphanumeric name of a nuclide or the name of an already defined collection of the same type.

Multiple collections are defined on this card by the mechanism of separating each collection with a blank word (open then closed parentheses). The final blank word is optional.

This data is integrated over the entire solution space at the beginning of the depletion interval and then edited by name and value.

These collection names may be used in specifying edits of algebraic combinations of collections specified on cards 01019S.

Nuclide Integral Edits

0101XS, ID(1), ID(2), ID(3), ...

ID(i) is the numeric ID of a nuclide for which integration and editing is to be performed. The type of quantity to be edited depends on the value of X as follows:

a. X = 1 is the nuclide power fraction (total and by group);
b. X = 2 is the nuclide absorption rate (total and by group);
c. X = 3 is the nuclide fission rate (total and by group);
d. X = 4 is the nuclide concentration and/or loading.

The dénominator in the power fraction quantities is not necessarily the total power; it is simply the sum of the power for the nuclides listed on the 01011S cards.

For X = 4, if the nuclide ID is positive a concentration edit is performed; if the nuclide ID is negative a loading edit (in kilograms) is done.

For X = 1, 2, and 3, this data is integrated by edit set and plane grouping at the beginning of the depletion interval.

For X = 4, this data is integrated by edit set and plane grouping at the end of the depletion interval. In addition, this edit set data may be edited for sets of individual gross planes by appropriate axial edit specifications.

For each X that is present, the S = 1, 2, ... , 9 sequentially.

Definition of Constants

010190, NAME(1), CONS(1), NAME(2), CONS(2), ...

NAME(i) is the name of the following constant. This name is alphanumeric, from one to ten characters.
CONS(i) is a floating point constant.

These named constants may be used in specifying edits of algebraic combinations of collections specified on cards 01019S.

Algebraic Combination Definitions

01019S, RES(1), C(1), (OP), C(2), RES(2), C(3), (OP), C(4), ...

RES(i) is the name associated with the result of the specified operation. This name is alphanumeric, from one to ten characters.
C(i) is the name of an operand which is one of: (a) a collection specified on cards 0101X0, (b) the name of a constant specified on card 010190, or (c) the name of an already evaluated result.
OP is an alphanumeric symbol which specifies the operation to be performed between operand C(i) and C(i+1). This symbol must be one of +, -, *, /, or ** meaning add, subtract, multiply, divide, or exponentiate respectively.

The operation symbol OP should be enclosed in parenthesis to avoid confusion as to the proper type of input data. For example, addition between operands named ABC and XYZ should be specified as:

ABC, (+), XYZ

and division of ABC by XYZ should be specified as:

ABC, (/), XYZ

In a divide operation, if the divisor is zero the result is set to zero. In an exponentiate operation, if the base is negative or the result would be "too large" the result is set to zero.

The S = 1, 2, ... , 9 sequentially.

Integral Data Printing Limits

011000, E1, P1, E2, P2, E3, P3, E4, P4, AX

- E1 is the last edit set to print if volume - weighted macroscopic data is edited.
- P1 is the last plane grouping to print if volume - weighted macroscopic data is edited.
- E2 is the last edit set to print for flux integrals and flux weighted macroscopic data.
- P2 is the last plane grouping to print for flux integrals and flux weighted macroscopic data.
- E3 is the last edit set to print if nuclide rate data (power fractions, absorption rates, and fission rates) is edited.
- P3 is the last plane grouping to print if nuclide rate data (power fractions, absorption rates, and fission rates) is edited.
- E4 is the last edit set to print if concentration and loading data is edited. This also limits editing during xenon and thermal feedbacks if they are being done.
- P4 is the last plane grouping to print if concentration and loading data is edited. This also limits editing during xenon and thermal feedbacks if they are being done.
- AX is the last axial edit to print or printer plot.

Data pertaining to plane grouping and/or axial edit printing limitations is ignored if the problem is not three - dimensional.

This card is optional and there may be from one to nine items present. All trailing omitted items default to the full editing.

Edit Set Definitions

01XXXS, F(1), +-F(2), ... , 0 , R(1), +-R(2), ...

- F(i) is a final figure number. The form F(i), -F(i+1) implies final figure numbers F(i), F(i)+1, F(i)+2, ... , F(i+1). The F(i) must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive.
- R(i) is a planar region number. The form R(i), -R(i+1) implies planar region numbers R(i), R(i)+1, R(i)+2, ... , R(i+1). The R(i) must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive.

The list of final figure numbers must be separated from the list of planar region numbers by a zero.

The meaning of this data varies with the subseries number XXX which is divided into four ranges as follows:

XXX = 100 - 199 : Each XXX is an edit set.

XXX = 200 - 299 : For each XXX, each figure with all regions is an edit set.

XXX = 300 - 399 : For each XXX, each region with all figures is an edit set.

XXX = 400 - 499 : For each XXX, each figure - region pair is an edit set.

Any, but not all, of the subseries may be omitted. The edit sets are numbered as follows: the first ones are those defined using the 100 - 199 subseries (if any), followed by those defined using the 200 - 299 subseries (if any), followed by those defined using the 300 - 399 subseries (if any), and finally those defined using the 400 - 499 subseries (if any). In any given range X00 - X99, the subseries number must be X00, X01, ... , X99 sequentially.

The number of edit sets printed for various types of integrated data may be limited to something less than the number of edit sets defined by use of the 011000 card. In general, edit sets containing identically zero data or missing from the geometry description are not printed.

The S = 1, 2, ... , 9 sequentially for each XXX.

Plane Grouping Definitions

015XXS, P(1), -P(2), P(3), -P(4), ...

P(i) is an axial point number specifying the axial limit of integration for plane grouping XX. The P(i) must be strictly increasing in absolute value and occur in plus - minus pairs, each pair designating the axial region between the two planes. Only zero and the gross plane boundaries are permitted to be plane grouping boundaries.

The number of plane groupings printed for various types of integrated data may be limited to something less than the number of plane groupings defined by use of the 011000 card. In general, edit sets containing identically zero data or missing from the geometry description are not printed.

The XX = 00, 01, 02, ... , 99 sequentially. Each XX specifies one plane grouping and, for each XX used, S = 1, 2, ... ,9.

Axial Edit Definition

016XXS, KEYWORD, PRINT, P1, P2, E(1), +-E(2), ...

KEYWORD is the alphanumeric key word which specifies the quantity to be edited. This keyword may be one of the following:

a. An alphanumeric nuclide ID for concentration and/or loading;
b. "POWER" for the average power;
c. "FLUXg" for group g of the average flux;
d. "FUEL-TEMP" for the fuel temperature;
e. "MOD-TEMP" for the moderator temperature;
f. "MOD-DENS" for the moderator density;
g. "VAP-FRACT" for the vapor fraction;
h. "HEAT-FLUX" for the heat flux.

PRINT is the indicator of whether to print or printer - plot the data. If PRINT is 0, the data is printed. If PRINT is 1, this specifies a printer - plot with ten edit sets per plot. If PRINT is negative with magnitude one to ten, this specifies a printer - plot and the magnitude indicates the number of edits sets to present on a single plot.

P1 is an axial point number which is the lowest numbered plane defining the axial extent of the edit. This number must either be zero or a gross plane boundary.

P2 is an axial point number which is the highest numbered plane defining the axial extent of the edit. This number must be a gross

plane boundary. P2 must be greater than P1.

E(i) is an edit set number. The edit set numbers must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive. The form E(i), -E(i+1) designates edit set numbers E(i), E(i)+1, E(i)+2, ... , E(i+1).

If KEYWORD is some alphanumeric nuclide ID, then the axial edit specification will result in an edit only if that nuclide is designated as an average concentration or loading edit nuclide on cards 01014S. This requirement results from the fact that axial edits simply represent a different way to display otherwise available data and such data must have been generated via the appropriate option selection. The same comment applies to the thermal feedback quantities. That is, an edit of thermal data must be specified on card 010036 (see Section 15.5). The power and flux integrals ARE always available since flux integrals and flux - weighted macroscopic cross section integrals are automatically computed by the program and are not optional.

WARNING: The KEYWORD is not checked in the input so that if it is not one of the allowable key words the axial edit is simply ignored.

The number of axial edits printed for various types of integrated data may be limited to something less than the number of axial edits defined by use of the 011000 card. In general, edit sets containing identically zero data or missing from the geometry description are not printed.

The XX = 00, 01, 02, ... , 99 sequentially. Each XX specifies one axial edit and, for each XX used, S = 1, 2, ... ,9.

12.3. EDIT REQUEST INPUT PREPARATION: POINTWISE EDIT DATA

All pointwise editing is done over two specified regions of the mesh, the first for flux and the second for power. These regions are defined as a box containing some contiguous set of columns, rows, and planes. Editing of each pointwise quantity is optional, including the flux in each group, the total thermal flux in a two - thermal group problem, the partition power, and the average or peak point power along with the relative maxima of either of these.

The gross and/or fine block power may be edited meshwise in addition to the pointwise editing. This option is more properly included in Section 12.4 but is included here because the option is chosen by input on the same card as the pointwise power edit option. The cards used to specify pointwise editing are as follows:

010005 - pointwise flux edit region, options
010006 - pointwise/mesh power edit region, options

Details of each of these cards follows.

Pointwise Flux, Mixing Coefficient Edit Control

010005, C1, C2, R1, R2, P1, P2, G1, G2, ... , GG, T

C1 is the lowest point column to edit.
C2 is the highest point column to edit.
R1 is the lowest point row to edit.
R2 is the highest point row to edit.
P1 is the lowest point plane to edit.
P2 is the highest point plane to edit.
G1 is the group 1 pointwise flux edit indicator.
G2 is the group 2 pointwise flux edit indicator.
. .
. .
GG is the last group pointwise flux edit indicator.
T is the total thermal flux edit indicator.

This card is used to request pointwise flux edits. This card is optional and if omitted all options are assumed to be zero (no editing). From one to 6+GROUPS (7+GROUPS in a two thermal group problem) items may be present. All trailing items omitted are assumed to be zero. This card is deleted from case to case.

The first six values (C1 through P2) describe the edit region (first and last columns, first and last rows, first and last planes) and the remaining values (G1 through GG) are the edit indicators for each group (0 = no edit, 1, 2, or 3 = do an edit).

An edit indicator (T) of the same type may be included at the end of the card for the total thermal flux in a two-thermal group problem.

In a synthesis problem, only the first and last planes are significant when used to describe the edit limits for axial mixing coefficients and fractional flux printer/plots. Again in a synthesis problem, the edit indicators may have three different non-zero values to request combinations of pointwise flux edits and mixing coefficient edits. In this case, a value of 1 will obtain mixing coefficients; a value of 2 will obtain pointwise flux; and a value of 3 will obtain both.

CAUTION

In a synthesis problem, the pointwise flux is usually not generated since very large problem sizes can be accomodated if such flux is not required. However, if the pointwise flux is chosen to be edited, or the partition power or pointwise power is chosen to be edited, or if the

pointwise flux or partition power is to be written as a File Manager file, then the pointwise flux IS generated. For very large synthesis problems, this may not be possible due to limitations in disk storage capacity.

If the problem is not synthesis, any one of the values 1, 2, or 3 will obtain a pointwise flux edit so that this card does not have to be redone in switching back and forth between explicit and synthesis problems.

This card is deleted from case to case.

Mesh, Point Power Edit Control

010006, C1, C2, R1, R2, P1, P2, POINT, PART, MESH

C1 is the lowest point column to edit.
C2 is the highest point column to edit.
R1 is the lowest point row to edit.
R2 is the highest point row to edit.
P1 is the lowest point plane to edit.
P2 is the highest point plane to edit.
POINT is the pointwise power edit indicator.
PART is the partition power edit indicator.
MESH is the mesh power edit indicator.

This card is used to request pointwise and meshwise (block) power edits. The card is optional and if omitted all options are assumed to be zero (no editing). From one to nine items may be present. All trailing items omitted are assumed to be zero. This card is deleted from case to case.

The first six numbers (C1 through P2) describe the power edit region. These items are, respectively, first and last columns, first and last rows, and first and last planes.

POINT is the pointwise power edit indicator. There are seven possible values of POINT:

IF POINT is 0, no pointwise power edit is done.
If POINT is 1, an edit of the pointwise average power is done.
If POINT is 2, an edit of the pointwise peak power is done.
If POINT is 3, a pointwise average and relative maximum edit is done (if -3, the relative maximum is not done).
If POINT is 4, a pointwise peak and relative maximum edit is done (if -4, the relative maximum is not done).

PART is the partition power edit indicator. PART may have three different values:

If PART is 0, no edit is done.
If PART is 1, an edit is done in floating point format.
If PART is 2, an edit is done in fixed point format.

MESH is the mesh power edit indicator. The block power is edited by expanding the gross or fine block power and printing by mesh element. This block power edit by mesh is not available in quadrilateral geometry (it is turned off if requested). For one - dimensional problems only, if the value of P2 (last plane) is negative, block power is printer-plotted as well as printed.

In addition, whenever MESH is any non-zero value, an edit of the maximum block power value for each block plane is also edited where the entire radial space is scanned for the designated planes. If MESH is negative, only this maximum edit is done. The value of MESH determines whether gross block or fine block power is to be edited:

If MESH is 0, no editing is done.
If MESH is 1, fine block power is edited.
If MESH is 2, gross block power is edited.
If MESH is 3, both gross and fine block power are edited.

If fine blocking is not being done and MESH is non-zero, the value of MESH is automatically set to 2 (gross block edit only).

This card is deleted from case to case.

12.4. EDIT REQUEST INPUT PREPARATION: MESHWISE EDIT DATA

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. Any of this data may be edited for each mesh element in non - quadrilateral geometry problems. Since, in general, a block is larger than a single mesh element, this edit smears the data into the appropriate mesh elements so that the data can be printed in a regular grid pattern. There are two different types of mesh edits and, in the case of one - dimensional problems, a third type of mesh edit.

The first type of mesh edit simply prints a value for each mesh element. Recall that in hexagonal geometry, these mesh elements are triangles. The region to be edited is specified separately for nuclide concentrations; this specification is input on card 010007 and consists of the first and last columns, the first and last rows, and the first and last planes to edit. If this card is missing, the entire problem space is the default space. The nuclides to be edited in this fashion are input on cards 010151 - 010159 for concentrations before the depletion and on cards 010161 - 010169 for concentrations after the depletion. The list is a set of numeric nuclide ID's, a positive value indicating gross block values and a negative value indicating fine block values.

For the average power, the edit region specified for pointwise power edits is used. The same card is used to specify the average power edit option (card 010006, see Section 12.3).

Another type of mesh edit, called a display edit, is very compact since it does not print a value for each mesh element but instead prints a single character for each mesh element. This character represents a "range" of values between a minimum and maximum. A table is included with each item edited giving the characters and the associated ranges. Each item may be edited over a separate specified edit region. Such data is input on cards 020101 - 020199 for power, cards 020201 - 020299 for concentrations before depletion, and cards 020301 - 020399 for concentrations after depletion. The form for each of these cards is: the identification of the item to be edited, number of increments to use, minimum value to consider, maximum value to consider, short/long print form, then the region to edit (first and last columns, first and last rows, and first and last planes).

A third type of edit is available for one - dimensional problems. In this option, the data may be printer - plotted as well as printed.

A summary of the card input required to specify mesh edits is as follows:

```
          010006 : power by mesh element (see Section 12.3)
          010007 : edit region for concentrations by mesh element
010151 - 010159 : nuclide ID's, edit concentrations before depletion
010161 - 010169 : nuclide ID's, edit concentrations after depletion
020101 - 020199 : power display edit definitions
020201 - 020299 : display edit definitions, concentrations before depletion
020301 - 020399 : display edit definitions, concentrations after depletion
```

Details of each of these card series follows.

Spatial Concentration Edit Space Definition

010007, C1, C2, R1, R2, P1, P2

C1 is the lowest point column to edit.
C2 is the highest point column to edit.
R1 is the lowest point row to edit.
R2 is the highest point row to edit.
P1 is the lowest point plane to edit.
P2 is the highest point plane to edit.

This card is used to define the space to edit block - concentrations meshwise.

The card is optional and if omitted the default edit space is the entire problem space.

The six numbers (C1 - P2) describe the three - dimensional region used for meshwise concentration edits and are, in order, first and last columns, first and last rows, and first and last planes. This card does not request any editing but must be used in conjunction with the 01015S and 01016S cards which define nuclides to edit before and after depletion respectively. These edits are ignored (deleted) in quadrilateral geometry.

For one - dimensional problems only, if P2 is negative, the concentrations are printer - plotted as well as printed.

This card is deleted from case to case.

Nuclide Mesh Edit

0101XS, ID(1), ID(2), ID(3), ...

ID(i) is the numeric ID of a nuclide for which mesh editing of the block concentration is to be performed. The value of X determines when the concentrations are to be edited as follows:

a. X = 5 is for concentrations before depletion;
b. X = 6 is for concentrations after the depletion interval.

If the ID is positive, an edit of gross block concentrations is done; if the ID is negative, an edit of fine block concentrations is done. If fine blocking is not being done, the program sets all of these ID's positive unconditionally.

These edits are ignored (no error) in quadrilateral geometry.

These cards are deleted from case to case.

020XSS, ID, INCR, MIN, MAX, PRINT, C1, C2, R1, R2, P1, P2

ID is either 1 (for power) or the numeric nuclide identification to edit depending on the value of X as follows:

a. X = 1 means power;
b. X = 2 means concentration before depletion;
c. X = 3 means concentration after the depletion interval.

INCR is the number of intervals to use for categorizing the data. This value must be positive and no greater than 36. The characters used for increasing values of the categorized data are the digits 0 through 9 followed by the letters A through Z in that order. Thus, if INCR were 10 then only the digits 0 through 9 would be used to display the data and only 10 intervals of data would be categorized.

MIN is the minimum data value to consider. If MIN is zero, the program will pre-scan the data and automatically determine the minimum non-zero value. This item is floating point.

MAX is the maximum data value to consider. If MAX is zero, the program will pre-scan the data and automatically determine the maximum non-zero value. This item is floating point.

PRINT is an indicator of whether to print the display values and frequency chart or just the frequency chart. A value of 0 will cause only the chart to be printed; a value of 1 will cause the display values as well as the frequency chart to be printed.

C1 is the lowest point column to edit.
C2 is the highest point column to edit.
R1 is the lowest point row to edit.
R2 is the highest point row to edit.
P1 is the lowest point plane to edit.
P2 is the highest point plane to edit.

Each optional card represents one edit request and may contain from 1 to 11 data items. The last ten items default to:

36, 0.0, 0.0, 0, 0, COLBDY, 0, ROWBDY, 0, PLNBDY

where COLBDY, ROWBDY, and PLNBDY are the maximum problem columns, rows, and planes respectively. These default values imply that if an edit request contained only one item (the ID), an edit would be obtained with the following characteristics: the interval between the program determined minimum and maximum values would be broken up into 36 intervals and a frequency chart only would be printed representing data scanned over the entire problem space.

The minimum and maximum values and their locations are always printed with the frequency chart.

For each X present, the SS = 01, 02, ... , 99 sequentially.

These cards are deleted from case to case.

12.5. EDIT REQUEST INPUT PREPARATION: BLOCKWISE EDIT DATA

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. This block data may be edited directly. Such an edit is much more compact than a mesh edit since there is no expansion of the data over all mesh elements associated with a block and there is no imposed mesh grid structure. However, since block identification by block number is difficult to decipher, this type of edit utilizes a user defined structure in the various geometry labels associated with each block to identify the printed data. For gross block data, final figures and planar regions as well as axial plane limits are used to identify the data of interest. For fine block data, channels and tracks as well as axial plane limits are used to identify the data of interest.

These types of edit are called HIERARCHICAL edits because the user defines an ordered set of structures and this set represents a hierarchy of levels of structures. The user creates this structure by defining disjoint fields in the existing geometry labels (final figure and planar region or channel and track). Each field is defined as a set of contiguous decimal digits in the geometry labels. A name is assigned to each set of digits; that is, to each field. These names are then used to identify the output data. These definitions are hierarchical; that is, they have an order and this order determines the order of the data printed. To select an edit, a particular value of each field is selected, from the first (highest) level down to the last specific level desired. The program will then obtain the data associated with the specified field values and print ALL sub-structures included.

Multiple hierarchies may be defined in the same problem. For each quantity edited, the maximum and minimum values and their "location" (given by defined labels as noted previously) are printed. In the scan for maximum and minimum values, zero values are ignored. An option exists to scan a defined structure and print only such maximum and minimum values and their location.

Of course, this edit system depends on the user to include some structure in the various geometry labels.

In these edits, sub-structures which contain nothing but zero data values are not printed. At the lowest level, data values are printed across a line and leading zero values are skipped.

Cards 0103H0 are used to define the H-th hierarchy. The data on these cards consists of an indicator of gross or fine block data to edit, number of levels in the first field (figure or channel), then triplets of the form [sub-field name, first decimal digit, and last decimal digit]. Cards 0103H1 - 0103H9 are used to specify edits in hierarchy H. The data on these cards consists of an identification of the data, a short/long print form indicator, format indicator, first plane, last plane, then in the order of the sub-field definitions (on card 0103H0) give the desired (numeric) level values of interest.

A summary of the input data used to request optional blockwise edits is as follows:

0103H0 : hierarchy H definition
0103H1 - 0103H9 : edit definitions for hierarchy H

Details of each of these cards follows.

Hierarchy Definition

0103H0, GF, LEVELS1, NAME(1), D1(1), D2(1), NAME(2), D1(2), D2(2), ...

GF is the indicator of gross or fine block data. GF = 0 implies gross block data, GF = 1 implies fine block data.
LEVELS1 is the number of levels in the first field (final figure number for gross blocks, channel number for fine blocks).
NAME(i) is the name of the i-th sub-field being defined by the following digits. This item is alphanumeric, from one to ten characters.
D1(i) is the first decimal digit in the i-th sub-field counting from right to left.
D2(i) is the last decimal digit in the i-th sub-field counting from right to left.

Up to ten hierarchies may be defined using H = 0, 1, ... , 9 not necessarily sequentially.

Blockwise Edit Requests

0103HS, ID, PRINT, FORM, P1, P2, LEV(1), LEV(2), ...

ID is the identification of the data to be edited as follows:

a. If ID is zero, block average power is edited;
b. If ID is negative, this is the numeric nuclide identification of a nuclide whose concentration before depletion is to be edited;
c. If ID is positive, this is the numeric nuclide identification of a nuclide whose concentration after the depletion interval is to be edited.

PRINT is an indicator of whether the entire edit is to be printed or just the minimum and maximum values and their locations are to be printed. If PRINT = 0, only the minimum and maximum edit is done; if PRINT = 1, the entire edit is done.
FORM is an indicator of the form of the data values printed. If FORM = 0, the data is printed in a more compact fixed point form (suitable for editing power values or any quantity which is normalized to be near unity); if FORM = 1, the data is printed in a floating point form.
P1 is the lowest point plane to edit.
P2 is the highest point plane to edit.
LEV(i) is the (numeric) level of interest in the i-th sub-field. These must be given in the same order as the sub-field definitions on cards 0103H0.

Each card represents one edit.

There must be 5 + X data values on each card where X is greater than zero and not greater than the number of sub-fields defined on cards 0103H0. That is, there must be at least one sub-field value given and there cannot be more sub-fields given than are defined on cards 0103H0.

Neither the H = 0, 1, ... , 9 nor the S = 1, 2, ... , 9 need be sequential.

These cards are deleted from case to case.

13.1. SUB-CASE INPUT PREPARATION: SUB-CASE DATA

There are eleven possible input quantities per sub-case. These items are input on card series 2xxSSS where SSS = 001, 002, ... , 999 sequentially. Each subseries xx = 01, 02, ... , 11 specifies data of one kind for all sub-cases. All sub-case input cards are deleted from case to case. The number of data items in the first subseries (01) determines the number of sub-cases defined. All other sub-case data cards (subseries 02, 03, ... , 11) are optional but if any subseries is present, it must contain exactly the same number of items as exists on subseries 01. In all optional data a default value is defined and consistency checks are made as described below for each item.

Sub-case data for any option is meaningless if that particular option was not specified in the parent case. For example, if a 1-D search problem specified zero for the search criterion (item 2 on card 010051) implying no search, a search request on card series 204SSS is ignored. That is, a search can be "turned off" and then "turned on" again in various sub-cases if the parent case specified a search. But if no such search was specified, the search can never be "turned on" in a sub-case. These same comments apply to thermal and xenon feedbacks. In a similar manner, sub-case replacement cannot be done if the appropriate replacement data is not present in the parent case.

NOTE

Since sub-case restarts are possible, all comments in this section about the "first" sub-case actually pertain to the first sub-case executed. Also, if a special path (item 1 non-zero on card 010000) has been specified in the parent case, only the first sub-case is performed for the particular path chosen.

Sub-Case Identifications

201SSS, IDENT(1), IDENT(2), ...

IDENT(i) is an alphanumeric quantity representing the SUB-CASE IDENTIFICATION for the i-th sub-case. Each of these alphanumeric quantities consists of from one to ten characters. For each sub-case, this item is used to identify the output of the sub-case and is inserted into columns 71 through 80 of the title on the printed output.

The SSS = 001, 002, ... , 999 sequentially.

Depletion Time Intervals

202SSS, DELTA(1), DELTA(2), ...

DELTA(i) is a floating point quantity representing the DEPLETION TIME INTERVAL for the i-th sub-case. The units of each value is hours. The default value is zero and these items must be zero if item 3 on card 010008 (DELTMX, the maximum time interval between thermal flux renormalizations) is zero. For each sub-case, thermal flux renormalizations are performed correctly assuming DELTMX on card 010008 holds for all sub-cases. Item 2 on card 010008 (T(1)) is not used to define the first depletion interval; instead sub-case data from this subseries will be used.

NOTE

If for the first sub-case: (a) the depletion time interval is non-zero, (b) the effective power level is non-zero, and (c) a deplete - before - spatial calculation will be done, the program requirements noted in Section 9.1 as to the need for an integrated flux File Manager input file must be satisfied.

In the first sub-case calculation, T(0) is obtained from the first item on card 010008. For all subsequent sub-cases, the cumulative EFPH (Effective Full Power Hours) is added to the first T(0) to yield a current value. If the time interval is specified as negative, the absolute value is used for the depletion interval and the cumulative ELAPSED time is used to update T(0) from sub-case to sub-case.

The SSS = 001, 002, ... , 999 sequentially.

Power Fractions

203SSS, PF(1), PF(2), ...

PF(i) is a floating point quantity representing the POWER FRACTION for the i-th sub-case. The default value for each sub-case is 1.0. Each power fraction must have a value between 0.0 and 1.0 inclusive. Item 4 on card 010008 (POWER) is assumed to represent full power.

The SSS = 001, 002, ... , 999 sequentially.

Control Search Indicators

204SSS, CSIND(1), CSIND(2), ...

CSIND(i) is a fixed point quantity representing the CONTROL SEARCH INDICATOR for the i-th sub-case. If any poison search or a 2-D or 3-D control search has been requested in the parent case, this item represents the maximum number of search tries per sub-case. Each item must be nonnegative. A value of zero, which is the default value, implies no search. An initial move in the first sub-case is allowed. If a 1-D multi-configuration search has been requested in the parent case, these indicators have three possible meanings. If the indicator is negative, the absolute value is used as the configuration and no search is performed; if the indicator is zero, the configuration from the previous sub-case (or parent case) is used as the starting configuration for a search; if the indicator is positive, the value is used as the beginning configuration for a search. Note that except in the first sub-case, configuration zero cannot be chosen as a specific configuration number. To overcome this restriction, simply construct configuration one to be identical to configuration zero. In any event, if depletion is specified to occur before the spatial calculation, the correct (possibly perturbed) geometry is used for that depletion regardless of the choice of this indicator.

The SSS = 001, 002, ... , 999 sequentially.

Control Search Eigenvalues

205SSS, CEIGEN(1), CEIGEN(2), ...

CEIGEN(i) is a floating point quantity representing the CONTROL SEARCH EIGENVALUE for the i-th sub-case. The default value is that search eigenvalue specified on card 010031 for a poison search or a 2-D or 3-D control search; on card 010051 for a 1-D multi-configuration search.

The SSS = 001, 002, ... , 999 sequentially.

Thermal Feedback Indicators

206SSS, TIND(1), TIND(2), ...

TIND(i) is a fixed point quantity representing the MAXIMUM NUMBER OF THERMAL FEEDBACK TRIES for the i-th sub-case. The default value is zero (no feedback). This data is meaningful only if thermal feedback was specified in the parent case.

The SSS = 001, 002, ... , 999 sequentially.

Xenon Feedback Indicators

207SSS, XIND(1), XIND(2), ...

XIND(i) is a fixed point quantity representing the MAXIMUM NUMBER OF XENON FEEDBACK TRIES for the i-th sub-case. The default value is zero (no feedback). This data is meaningful only if xenon feedback was specified in the parent case.

The SSS = 001, 002, ... , 999 sequentially.

Concentration Replacement Indicators

208SSS, REPL(1), REPL(2), ...

REPL(i) is a fixed point quantity representing the CONCENTRATION REPLACEMENT INDICATOR for the i-th sub-case. Each value is either zero (default value) meaning no replacement, or is one meaning to do replacement. This data is allowed to be non-zero only if concentration replacement data is present in the parent case.

The SSS = 001, 002, ... , 999 sequentially.

Depletion Path Indicators

209SSS, DPATH(1), DPATH(2), ...

DPATH(i) is a fixed point quantity representing the DEPLETION PATH INDICATOR for the i-th sub-case. The default value is item 5 on card 010008 (DEPTIM). Each indicator may assume the value of minus one, zero, or

plus one to indicate that depletion is not to occur, that depletion is to occur before the spatial calculation, or that depletion is to occur after the spatial calculation respectively. Of course, the problem must be depletable for these values to be allowed.

The SSS = 001, 002, ... , 999 sequentially.

Output File Version Number Increments

210SSS, VINCR(1), VINCR(2), ...

VINCR(i) is a fixed point quantity representing the OUTPUT FILE VERSION NUMBER INCREMENT for the i-th sub-case. Default values are 0, 1, 2, 3, ... for successive sub-cases. These increments operate on the non-zero parent case version numbers, not on previous sub-case values. If card 010022 (output file version numbers) is not input in the next case, the output version numbers for the next case are the output version numbers of the last sub-case executed plus one. These increments may be negative, zero, or positive but cannot cause a non-zero (parent case) version number to become zero, negative, or greater than 999.

The SSS = 001, 002, ... , 999 sequentially.

Flat/Previous Flux Guess Indicators

211SSS, FGUESS(1), FGUESS(2), ...

FGUESS(i) is a fixed point quantity representing the POINTWISE FLUX - GUESS INDICATOR for the i-th sub-case. The default value is one (use flux from the previous sub-case). The allowable values are zero (flat) or one (previous). A flat flux guess is one for which unity is used for every group and every point except that a value of zero is used for every group at the points on zero flux boundaries.

The SSS = 001, 002, ... , 999 sequentially.

First and Last Sub-Cases to Execute

200000, FIRST, LAST

FIRST is the first sub-case to execute.
LAST is the last sub-case to execute

If sub-cases have been specified, this optional card may be input containing either one or two values. The default values for these are FIRST = 1 and LAST = the number of sub-cases.

FIRST may be used to continue a job which failed for some reason before all sub-cases were completed. This allows a problem to be restarted without re-sequencing all of the sub-case data cards; all that is required is to specify FIRST correctly, and input the appropriate File Manager files (tablesets, flux, concentrations, geometry, ...).

NOTE

Do not use both this 200000 card restart capability and that on card 010000 (see Section 9.1) since a contradiction can occur. The sub-case restart on card 010000 is more automatic and is preferred; for example, the correct input and output File Manager files are automatically determined by the program without user intervention other than including the desired first sub-case on card 010000. However, both types of restart automatically determine the correct value for T(0) for a depletable problem.

The second value (LAST) may be utilized to: (a) input all desired sub-case data, (b) get it checked by the program, but (c) not run all sub-cases.

There may be none, one, or two values on this card and it also is deleted from case to case. Of course FIRST must be strictly positive and less than or equal to LAST; in turn, LAST must be no greater than the number of sub-cases input as determined by cards 201SSS.

14.1. SYNTHESIS INPUT PREPARATION: SYNTHESIS DATA

All synthesis input data appears on the 600000 series of cards. If the problem type is not synthesis (item 1 on card 010001 is not 5), all of these cards are automatically deleted from that case but carry over into the next case. This feature is a convenience to allow the generation of two-dimensional trial functions using an input deck which describes the three - dimensional synthesis problem.

Either two - dimensional flux solutions or individual planes from a three - dimensional flux solution serve as the "trial functions" for three - dimensional synthesis solutions. These flux solutions must have been generated previously and saved as File Manager pointwise flux files. All trial functions are identified by [version number, synonym] pairs in a manner identical to all other File Manager files input or output by the program. When the program saves such files, all groups of pointwise flux are saved in one File Manager file. However, trial functions for individual groups can be extracted from such files and not all groups need be used.

The following is a summary of the card input for a synthesis problem, both required and optional.

```
          600000 : synthesis residual computation, edit
          600001 : number of trial functions in each group
          600002 : trial function zone boundaries
          600003 : weight, trial function position deletion
          600110 : three-dimensional flux file ID
600111 - 600119 : trial function slicing planes
6ZZ001 - 6ZZ009 : trial function ID's, all groups, zone ZZ
6ZZg01 - 6ZZg09 : trial function ID's, group g, zone ZZ
6ZZg11 - 6ZZg19 : trial function mapping, group g, zone ZZ
660001 - 660999 : difference function definitions
```

A more detailed description of this data is given below.

Synthesis Residuals

600000, RESID

RESID is the synthesis residual indicator. This card is used to request the computation and editing of both relative and absolute synthesis residuals for each axial point and group. The card is optional and may contain one fixed point quantity, either zero (default, no residuals) or one (do residuals).

NOTE

This option automatically creates a special "tent" function as position one in the trial function description but deletes the function use in the spatial calculation.

This card is deleted from case to case.

Trial Functions per Group

600001, K(1), K(2), ... , K(GROUPS)

K(g) is the number of trial function in group g in each zone. This card is required in a synthesis problem and there must be the same number of items on this card as the number of groups in the problem. Each K(g) must be greater than zero and less than sixteen. The number of trial functions may vary from group to group, but this data holds for all zones.

Trial Function Zone Boundaries

600002, BDY(1), BDY(2), ...

BDY(i) is an axial point plane number. This card is used to specify the trial function zone boundaries. The card is required in a synthesis problem and specifies the zone boundaries by giving the highest numbered axial mesh point in a zone. The zone boundary actually occurs halfway between the specified point and the next higher numbered point. A gross plane may contain at most one trial function zone boundary. The last zone boundary must equal plane boundary (PLNBDY, see Section 9.1). There must be at least one but less than sixteen such boundaries defined in strictly increasing order. The boundary at axial point zero is understood and must not be included.

Trial - Weight Function Deletion

600003, NOWT, NOTR

NOWT designates the position of a function which is to be used as a trial function but not as a weight function.
NOTR designates the position of a function which is to be used as a weight function but not as a trial function.

This card may be used to specify two trial function positions. The card is optional but if present it must contain two items. These positions hold for all groups and all zones.

Three Dimensional Flux File ID

600II0, V3D, S3D, S2D

V3D is the version number of a three dimension flux file, some of the planes of which are to be used as trial functions. Each version number must be greater than zero and less than 1000.
S3D is the alphanumeric synonym of a three dimension flux file, one to ten characters.
S2D is the "synonym" to be used for all trial functions extracted from the planes of the three dimensional flux file. This item is alphanumeric, one to ten characters.

This card input in conjunction with the next cards (described below) may optionally be used to describe some or all of the synthesis trial functions as the planes of a three - dimensional (3-D) pointwise flux file. For any II=01,02,...49, each card specifies the File Manager identification of a 3-D

pointwise flux file to be used for trial function extraction and the "synonym" to be associated with such trial functions. These cards are optional and there may be one, two, or three items present. If either or both of the synonyms are omitted or have a blank value, the default synonym used is POINTFLUX.

Slicing Planes from 3-D File

600IIS, PLANE(1), VERS(1), PLANE(2), VERS(2), ...

PLANE(i) is the i-th plane to be extracted as a trial function from the 3-D file identified on card 600II0.
VERS(i) is the "version number" to be associated with the trial function extracted from axial point PLANE(i).

For any of II=01,02,...49 for which card 600II0 is present, these cards specify [point plane number, version number] pairs giving the plane numbers to be extracted from the 3-D file and associating them with version numbers. These version numbers along with the "synonym" S2D (see card 600II0) are then used in the trial function description.

The value of S = 1, 2, ... , 9 sequentially.

Trial Function Identifications, all Groups

6ZZ00S, VERS(1), SYN(1), VERS(2), SYN(2), ...

VERS(i) is the version number of the trial function in position i for all groups in zone ZZ.
SYN(i) is the synonym of the trial function in position i for all groups in zone ZZ. This value is alphanumeric, one to ten characters.

These cards specify the [version number, synonym] pairs which are the File Manager identifications for trial functions to be used in all groups in zone ZZ. Successive pairs define identifications for successive trial function positions in zone ZZ.

Each subseries ZZ is optional. However, if M is the maximum number of trial functions in any group, there must be M pairs given for each zone ZZ which is input. If for some group K(g) is less than M, only the first K(g) trial functions defined by these trial function identifications will be used for that group. That is, the required trial functions will be obtained from the first K(g) trial functions (for each group g in zone ZZ) specified by this data. Any or all of this data may be overlaid by use of cards 6ZZg01 - 6ZZg09.

The version numbers are fixed point and the synonyms are one to ten character alphanumeric. If a synonym has a blank value, the default synonym used is POINTFLUX. If the [version number, synonym] pair is [0,UNITY], a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied by the program.

The value of S = 1, 2, ... , 9 sequentially.

Trial Function Identifications, Group g

6ZZg0S, VERS(1), SYN(1), VERS(2), SYN(2), ...

VERS(i) is the version number of the trial function in position i for group g in zone ZZ.
SYN(i) is the synonym of the trial function in position i for group g in zone ZZ. This value is alphanumeric, one to ten characters.

These cards specify the [version number, synonym] pairs which are the File Manager identifications for trial functions to be used in group g in zone ZZ. Successive pairs define identifications for successive trial function positions in zone ZZ. Each subseries ZZ is optional. However, there must be K(g) pairs given for group g for each zone ZZ which is input. These cards, if present, are used to selectively overlay the input data specified by cards 6ZZ001 - 6ZZ009. That is, data specified for group g using cards 6ZZ001 - 6ZZ009 will be replaced by the data items from cards 6ZZg01 - 6ZZg09.

The version numbers are fixed point and the synonyms are one to ten character alphanumeric. If a synonym has a blank value, the default synonym used is POINTFLUX. If the [version number, synonym] pair is [0,UNITY], a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied by the program.

Either set of cards 6ZZ001 - 6ZZ009 or 6ZZg01 - 6ZZg09 may be omitted and the other set used to completely define the trial function identifications, or they may be used in any combination. In either case, each identified File Manager pointwise flux file must (1) contain at least as many groups as exist in the synthesis problem, and (2) have the same transverse planar dimensions (columns and rows) as the three - dimensional synthesis problem.

The value of S = 1, 2, ... , 9 sequentially.

Trial Function Mapping

6ZZg1S, G(1), G(2), ...

G(i) is the group number in the trial function File Manager file for the i-th position in zone ZZ which is to be used in the problem solution group g.

These cards specify a mapping of the group numbers of the trial functions as used in the synthesis problem INTO the group numbers of the trial function fluxes (those from the File Manager pointwise flux files). For example, the trial function used in the second group may be from the first group in trial function position 1, from the second group in trial function position 2, and from the fourth group in trial function position 3. Then assuming there are three trial functions for group 2, we have the items on card series 6ZZ211 as 1,2,4.

These cards are optional. However, there must be K(g) values given for group g for each zone ZZ which is input. If the data is missing, the group correspondence of the trial function fluxes with the synthesis calculation is assumed to be one - to - one.

The value of S = 1, 2, ... , 9 sequentially.

Difference Function Definitions

660SSS, VERS(1), SYN(1), VERS(2), SYN(2), VERS(3), SYN(3)

VERS(1) is the "version number" of a trial function which is to be created as the difference of two other functions.
SYN(1) is the "synonym" of a trial function which is to be created as the difference of two other functions. This value is alphanumeric, one to ten characters.
VERS(2) is the version number of the first trial function used in creating the difference function.
SYN(2) is the synonym of the first trial function used in creating the difference function. This value is alphanumeric, one to ten characters.
VERS(3) is the version number of the second trial function used in creating the difference function.
SYN(3) is the synonym of the second trial function used in creating the difference function. This value is alphanumeric, one to ten characters.

These cards may be used to specify difference functions. The cards are optional and the SSS may be any of 001 to 999, not necessarily sequential. If present, each card must contain three [version number, synonym] pairs which are the File Manager identifications for trial functions. The third trial function identified is to be subtracted from the second to form a difference function. This difference function is used in all required groups as that trial function identified first on this card and somewhere on the trial function description cards (6ZZ001 - 6ZZ009 and/or 6ZZg01 - 6ZZg09).

The version numbers are fixed point and the synonyms are one to ten character alphanumeric. If a synonym has a blank value, the default synonym used is POINTFLUX. If the [version number, synonym] pair is [0,UNITY], a flat trial function (1.0 everywhere except 0.0 on zero flux boundaries) is automatically supplied by the program.

15.1. FEEDBACK INPUT PREPARATION: ONE-DIMENSIONAL SEARCH DATA

To specify a one - dimensional multi - configuration search, the problem must be one - dimensional of course. The mesh spacings in the area which is "moved", that is, on either side of a movable boundary, must be constant. In addition, the composition correspondence may be to final figure or planar region but may not, in either case, be one-to-one.

One card, containing either three or four data items, is required to select the multi - configuration capability. The card number is 010051 and the data items include the desired eigenvalue, the desired accuracy of the converged eigenvalue, and data which specifies "which way is up" for reference purposes. In addition, two optional cards are available. One of the cards, numbered 010052, can be used to specify the initial configuration; the other optional card, numbered 010053, can be used to limit the search in that the total number of search tries can be specified as well as the maximum number of points that can be "moved" in any one search try.

A summary of the card input available for this search is as follows:

010051 : search specification
010052 : optional initial configuration
010053 : optional search limitations

Details of each of these cards is given below.

One-Dimensional Search Specification

010051, EIG, EPSC, UPDOWN, REFER

EIG is the desired eigenvalue. This value is floating point.

EPSC is the desired "closeness" of the computed eigenvalue. This value is floating point. The search is terminated when the computed eigenvalue is within EPSC of the desired eigenvalue EIG. If EPSC is zero, no search is performed. If EPSC is negative, the absolute value is used and if the desired eigenvalue is not obtainable, the program merely terminates the search as though it had converged and proceeds with the remainder of the computation process. If EPSC is positive and the desired eigenvalue is not obtainable, the problem is immediately aborted.

UPDOWN is an indicator of "which way is up". A value of 1 means point zero is the top; a value of 0 means point zero is the bottom of the core.

REFER is an optional reference point number. This point is used to calculate and edit the distances of moving boundaries during the search. If this value is missing, the bottom (see UPDOWN) is used as the reference point. It is required that REFER is non-negative and not greater than the column boundary.

There may be three or four values on this card.

Initial Configuration

010052, INITIAL

INITIAL is the initial configuration to begin the search. The value of INITIAL must be non-negative and no greater than the largest configuration specified (see Section 10.5).

If this card is present and a File Manager input geometry file is present, the original (unperturbed) geometry description is used along with the specified initial configuration number to obtain the actual input geometry description. If this card is not present and a geometry file is not input, configuration zero

is chosen as the initial configuration. If this card is not present and a File Manager input geometry file is present, the actual input geometry description is obtained by using the perturbed geometry from the file along with the configuration number obtained from the file.

NOTE

See Section 10.5 on caution in the specification of "initial configuration" since there are three separate methods of providing such input data.

To specify multiple configurations, see Section 10.5. However, if movable boundaries are to be present for a configuration, additional information must be provided. To specify a "movable" boundary, simply set the composition number negative. The highest numbered point in that composition assignment is then a movable boundary. One restriction occurs in specifying movable boundaries: the composition assigned to the last mesh interval (at the column boundary) cannot be "movable". Multiple movable boundaries can be placed in a single configuration.

This card is optional and is allowed to be present only if a multi - configuration search has been specified.

This card is deleted from case to case.

Search Limitations

010053, TRYS, MAXMOV

TRYS is the maximum number of search tries to do. If this many tries are actually performed, the search is terminated as though it had converged normally. If this card is missing, the default value used is 1000.

MAXMOV is the maximum number of points that a movable boundary is allowed to move on any single search try. If this card is missing, the default value used is the column boundary.

This card is optional and is allowed to be present only if a multi - configuration search has been specified.

15.2. FEEDBACK INPUT PREPARATION: TWO-DIMENSIONAL SEARCH DATA

The two - dimensional movable fuel or control rod search is available only in two - dimensional cylindrical (R-Z) geometry. The axial mesh ("Z" direction) must be constant in the positions through which the control element is moved.

This search option requires that three, or possibly four, cards be present, and a fifth data card is optional. The first of the required cards, numbered 010031, contains three data items consisting of the desired eigenvalue, the accuracy desired in the computed eigenvalue, and the accuracy of the computed eigenvalue during search tries. The second required card, numbered 010032, contains information which limits the search and provides reference data. This data consists of the maximum number of search tries, the maximum move of the control element on any single search try, the axial limits within which the control element is allowed to move, and a reference point. The third of the required cards, numbered 010033, contains a variable number of data items describing the radial and optionally the axial extent of the control element. This data consists of left and right pairs of radial (column) point numbers. Each pair delineates a part of the control element. The fourth card, numbered 010034, is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file. The data on this card consists of the top and bottom definitions of the control element, and a guess for the initial worth of the element in delta eigenvalue per delta centimeter. A fifth optional card, numbered 010035, may be used to initially move the control element. The two items on this card are the position desired, followed by an indication of whether this is an exact move or an incremental move to an existing mesh position.

A summary of these cards is as follows:

010031 : desired eigenvalue, "closeness" specifications
010032 : search limitations, reference position
010033 : radial (and, optionally the axial) extent of control element
010034 : axial extent of control element, worth
010035 : optional initial move

Details of each of these cards is given below.

Two-Dimensional Search Specification

010031, EIG, EPSC, EPSS

EIG is the desired eigenvalue. This value is floating point.
EPSC is the desired "closeness" of the computed eigenvalue to the desired eigenvalue. The search is terminated when the computed eigenvalue is within EPSC of the desired eigenvalue EIG. If EPSC is zero, the search will terminate when the control element has been moved to the discrete (axial) mesh position associated with the computed eigenvalue closest to EIG. This value is floating point.
EPSS is the desired convergence of the flux iterations before a new search calculation is performed. This value is floating point.

Search Limitations

010032, TRYS, MAXMOV, MINBOT, MAXTOP, REFER

TRYS is the maximum number of search tries to do (zero for no search). The search will be terminated after this many tries, but the program will go back through another recalculation of the flux and eigenvalue based on the current position in order to converge the solution to the specified problem parameter (card 010003, see

Section 9.1). The search will be terminated normally as though it had converged but with an appropriate comment.

MAXMOV is the maximum number of (axial) points that the control element will be allowed to move on any single search try. This value must be positive.

MINBOT is the minimum axial point number to which the BOTTOM (highest numbered point in the control element) will be allowed to move.

MAXTOP is the maximum axial point number to which the TOP (lowest numbered point in the control element) will be allowed to move.

REFER is a reference (axial) point number. The reference position is used as the zero position of the BOTTOM of the control element. This value is used to calculate and edit the distances from this reference point to the BOTTOM of the control element. For example, if the axial mesh increment is X centimeters, and if the current position of the BOTTOM of the control element is (axial) point B, then the indicated positon of the control element will be X*(REFER-B). Note that downward (towards increasing axial mesh point numbers) from the zero point gives a negative position indication.

Radial (and Axial) Extent of Control Element

010033, L(1), R(1), L(2), R(2), ... , 0, T(1), B(1), L(k), R(k), L(k+1), R(k+1) ... , 0, T(2), B(2), ...

L(i) is a column number describing the left side of a portion of the radial extent of the control element. This number must be non-negative and less than the column boundary. If column zero is to be the left boundary of a portion of one of the control elements, the pair [0,R(i)] must be the first pair listed in the radial definition of that element.

R(i) is a column number describing the right side of a portion of the radial extent of the control element. This number must be greater than L(i) and no greater than the column boundary. A set of [L(i),R(i)] pairs up to the next zero defines the radial extent of a portion of the control element.

T(j) is the top of the j-th portion of the control element being defined by the immediately preceding set of [L(i),R(i)] pairs. This is the lowest numbered axial point in the control element portion.

B(j) is the bottom of the j-th portion of the control element being defined by the immediately preceding set of [L(i),R(i)] pairs. This is the highest numbered axial point in the control element portion.

The [L(i),R(i)] pairs are separated from their associated [T(j),B(j)] pair by a zero. This zero and the T(j) and B(j) may be missing if there is only one TOP and BOTTOM for all control element portions. In this case, T(1) and B(1) are defaulted to TOP and BOTTOM respectively from card 010034.

The columns included in all of the [L(i),R(i)] pairs must be unique. That is, none of the radial extent portions can overlap.

Axial Extent of Control Element, Worth

010034, TOP, BOTTOM, WORTH

TOP is the axial point number which is the top of the control element. This is the lowest numbered axial point number in the control element. TOP must be less than or equal to T(j) for all j (see card 010033).

BOTTOM is the axial point number which is the bottom of the control element. This is the highest numbered axial point number in the control element. BOTTOM must be greater than or equal to B(j) for

all J (see card 010033).

WORTH is an estimate of the initial value for the change in eigenvalue due to a one centimeter change in axial position. The sign convention for WORTH is as follows: if WORTH is positive, a move downward (towards increasing axial point number) decreases the eigenvalue; if WORTH is negative, a move downward increases the eigenvalue. This value is floating point and must not be zero.

If a two - dimensional control search has been specified, this card is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file; in this case, the T(J) and B(J) data on card 010033 also overrides the like data from the geometry file.

This card is deleted from case to case.

Initial Move Specification

010035, MOVE, EXACT

MOVE is a desired initial position. The program will move the bottom of the control element to this position (relative to REFER) before performing a spatial calculation. This value is floating point.

EXACT is an indication of how precise the initial move is required to be. If EXACT is negative, no initial move is performed; if EXACT is zero, a move is performed such that the bottom of the control element is at the (axial) mesh point nearest the desired position; if EXACT is positive, a move is performed such that the bottom of the control element is exactly at the desired position and the search is turned off (no search is done).

Note that the position indicated by MOVE is described as a distance from the point REFER to the point BOTTOM; this distance is always in CENTIMETERS regardless of the input units of the geometry, and can be either positive or negative; also, MAXMOV is ignored for this initial move.

The edited output during the search contains references to "incremental" moves. An incremental move is simply a move which is an exact multiple of the axial mesh increment. Thus, the prior statements about "nearest" mesh imply an incremental move to some axial mesh point.

This card is deleted from case to case.

15.3. FEEDBACK INPUT PREPARATION: THREE-DIMENSIONAL SEARCH DATA

Two different types of three - dimensional control searches are available in the program: a three - dimensional movable fuel or control rod search, and a fast rod - search available in three - dimensional synthesis problems. Each of these searches is mutually exclusive and so the input required for each type of control search will be described separately.

THREE-DIMENSIONAL MOVABLE FUEL or CONTROL ROD SEARCH

The three - dimensional movable fuel or control rod search is available in both three - dimensional explicit and synthesis problems. The axial ("Z" direction) mesh, the number of axial meshes per gross plane, the number of meshes per fine plane (if any), and the number of fine planes (if any) per gross plane must be constant in the positions through which the control element is moved.

This search option requires that three, or possibly four, cards be present, and a fifth data card is optional. The first of the required cards, numbered 010031, contains three data items consisting of the desired eigenvalue, the accuracy desired in the computed eigenvalue, and the accuracy of the computed eigenvalue during search tries. The second required card, numbered 010032, contains information which limits the search and provides reference data. This data consists of the maximum number of search tries, the maximum move of the control element on any single search try, the axial limits within which the control element is allowed to move, and a reference point. The third of the required cards, numbered 010033, contains a variable number of data items describing the transverse planar and optionally the axial extent of the control element. This data consists of final figure numbers or planar region numbers (whichever correspond to compositions) and, optionally, the axial extent of each portion of the control element. The fourth card, numbered 010034, is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file. The data on this card consists of the top and bottom definitions of the control element, and a guess for the initial worth of the element in delta eigenvalue per delta centimeter. A fifth optional card, numbered 010035, may be used to initially move the control element. The two items on this card are the position desired, followed by an indication of how the move is to be done.

A summary of these cards is as follows:

```
010031 : desired eigenvalue, "closeness" specifications
010032 : search limitations, reference position
010033 : transverse planar (and, optionally the axial) extent of
         control element
010034 : axial extent of control element, worth
010035 : optional initial move
```

Details of each of these cards is given below.

Three-Dimensional Movable Fuel Search Specification

010031, EIG, EPSC, EPSS

EIG is the desired eigenvalue. This value is floating point.
EPSC is the desired "closeness" of the computed eigenvalue to the desired eigenvalue. For this search, only zero is allowed for this item. The search will terminate when the control element has been moved to the discrete (axial) mesh position associated with the computed eigenvalue closest to EIG. The "nearest mesh" in this case is the nearest gross plane boundary. This value is floating point.
EPSS is the desired convergence of the flux iterations before a new

search calculation is performed. This value is floating point.

Search Limitations

010032, TRYS, MAXMOV, MINBOT, MAXTOP, REFER

TRYS is the maximum number of search tries to do (zero for no search). The search will be terminated after this many tries, but the program will go back through another recalculation of the flux and eigenvalue based on the current position in order to converge the solution to the specified problem parameter (card 010003, see Section 9.1). The search will be terminated normally as though it had converged but with an appropriate comment.

MAXMOV is the maximum number of (axial) points that the control element will be allowed to move on any single search try. This value must be at least as large as the number of axial mesh intervals per gross plane in the control element. This value must be positive.

MINBOT is the minimum axial point number to which the BOTTOM (highest numbered point in the control element) will be allowed to move. This value must be a gross plane boundary.

MAXTOP is the maximum axial point number to which the TOP (lowest numbered point in the control element) will be allowed to move. This value must either be zero or a gross plane boundary.

REFER is a reference (axial) point number. The reference position is used as the zero position of the BOTTOM of the control element. This value is used to calculate and edit the distances from this reference point to the BOTTOM of the control element. For example, if the axial mesh increment is X centimeters, and if the current position of the BOTTOM of the control element is (axial) point B, then the indicated positon of the control element will be X*(REFER-B). Since each portion of the control element may have a different top and bottom, a single value is needed to define the location of the element. Therefore, all references to the BOTTOM position in this section refer to the input value on card 010034 as modified during the search or as obtained from a File Manager geometry input file. Note that downward (towards increasing axial mesh point numbers) from the zero point gives a negative position indication.

Transverse (and Axial) Extent of Control Element

010033, R(1), R(2), ... , 0, T(1), B(1), R(k), R(k+1), ... , 0, T(2), B(2), ...

R(i) is a final figure number or planar region number, whichever corresponds to compositions. This set of R(i) defines the transverse extent of a portion of the control element. The R(i) within a portion (up to the next zero) must be in increasing order of absolute value. The form R(i), -R(i+1) may be used to specify numbers R(i), R(i)+1, R(i)+2, ... , R(i+1).

T(j) is the top of the j-th portion of the control element being defined by the immediately preceding set of R(i). This is the lowest numbered axial point in the control element portion. This value must be a gross plane boundary.

B(j) is the bottom of the j-th portion of the control element being defined by the immediately preceding set of R(i). This is the highest numbered axial point in the control element portion. This value must be a gross plane boundary.

The R(i) are separated from the [T(j),B(j)] pairs by a zero. This zero and the T(j) and B(j) may be missing if there is only one TOP and BOTTOM for all control element portions. In this case, T(1) and B(1) are defaulted to TOP and BOTTOM respectively from card 010034.

The R(i), as well as all the numbers implied from the form R(i), -R(i+1), must be unique.

Axial Extent of Control Element, Worth

010034, TOP, BOTTOM, WORTH

TOP is the axial point number which is the top of the control element. This is the lowest numbered axial point number in the control element. TOP must be less than or equal to T(j) for all j (see card 010033). In addition, TOP must be either zero or a gross plane boundary.

BOTTOM is the axial point number which is the bottom of the control element. This is the highest numbered axial point number in the control elelemt. BOTTOM must be greater than or equal to B(j) for all j (see card 010033). In addition, BOTTOM must be a gross plane boundary.

WORTH is an estimate of the initial value for the change in eigenvalue due to a one centimeter change in axial position. The sign convention for WORTH is as follows: if WORTH is positive, a move downward (towards increasing axial point number) decreases the eigenvalue; if WORTH is negative, a move downward increases the eigenvalue. This value is floating point and must not be zero.

If a three - dimensional control search has been specified, this card is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file; in this case, the T(j) and B(j) data on card 010033 also overrides the like data from the geometry file.

This card is deleted from case to case.

Initial Move Specification

010035, MOVE, EXACT

MOVE is a desired initial position. The program will move the BOTTOM of the control element to this position (relative to REFER) before performing a spatial calculation. This value is floating point.

EXACT is an indication of how precise the initial move is required to be. If EXACT is negative, no initial move is performed; if EXACT is zero, a move is performed such that the bottom of the control element is at the gross plane boundary nearest the desired position.

Note that the position indicated by MOVE is described as a distance from the point REFER to the point BOTTOM; this distance is always in CENTIMETERS regardless of the input units of the geometry, and can be either positive or negative; also, MAXMOV is ignored for this initial move.

The edited output during the search contains references to "incremental" moves. An incremental move is simply a move which is an exact multiple of the axial height of a gross plane. Thus, the prior statements about "nearest" mesh imply an incremental move to some mesh point which is a gross plane boundary.

This card is deleted from case to case.

THREE-DIMENSIONAL SYNTHESIS FAST ROD-SEARCH

The three - dimensional fast rod-search is available only for three - dimensional synthesis problems. The axial ("Z" direction) mesh, the number of axial meshes per gross plane, the number of meshes per fine plane (if any), and the number of fine planes (if any) per gross plane must be constant in the positions through which the control element is moved.

This search option requires that three, or possibly four, cards be present, and a fifth data card is optional. The first of the required cards, numbered 010031, contains three data items consisting of the desired eigenvalue, the accuracy desired in the computed eigenvalue, and the accuracy of the computed eigenvalue during search tries. The second required card, numbered 010032, contains information which limits the search and provides reference data. This data consists of the maximum number of search tries, the maximum move of the control element on any single search try, the axial limits within which the control element is allowed to move, and a reference point. The third of the required cards, numbered 010033, contains a variable number of data items describing the transverse planar and optionally the axial extent of the control element. This data consists of final figure numbers or planar region numbers (whichever correspond to compositions) and, optionally, the axial extent of the control element. The fourth card, numbered 010034, is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file. The data on this card consists of the top and bottom definitions of the control element, and a guess for the initial worth of the element in delta eigenvalue per delta centimeter. A fifth optional card, numbered 010035, may be used to initially move the control element. The two items on this card are the position desired, followed by an indication of how the move is to be done.

A summary of these cards is as follows:

010031 : desired eigenvalue, "closeness" specifications
010032 : search limitations, reference position
010033 : transverse planar (and, optionally the axial) extent of control element
010034 : axial extent of control element, worth
010035 : optional initial move

Details of each of these cards is given below.

Three-Dimensional Fast Rod Search Specification

010031, EIG, EPSC, EPSS

EIG is the desired eigenvalue. This value is floating point.
EPSC is the desired "closeness" of the computed eigenvalue to the desired eigenvalue. The search is terminated when the computed eigenvalue is within EPSC of the desired eigenvalue EIG. If EPSC is negative, the search will terminate when the control element has been moved to the discrete (axial) mesh position associated with the computed eigenvalue closest to EIG. The "nearest mesh" in this case is the nearest gross plane boundary. This value is floating point and must be non-zero.
EPSS is the desired convergence of the flux iterations before a new search calculation is performed. This value is floating point.

Search Limitations

010032, TRYS, MAXMOV, MINBOT, MAXTOP, REFER

TRYS is the maximum number of search tries to do (zero for no search). The search will be terminated after this many tries, but the program will go back through another recalculation of the flux and eigenvalue based on the current position in order to converge the solution to the specified problem parameter (card 010003, see Section 9.1). The search will be terminated normally as though it had converged but with an appropriate comment.

MAXMOV is the maximum number of (axial) points that the control element will be allowed to move on any single search try. This value must be at least as large as the number of axial mesh intervals per gross plane in the control element. This value must be positive.

MINBOT is the minimum axial point number to which the BOTTOM (highest numbered point in the control element) will be allowed to move. This value must be a gross plane boundary. Since this number must be positive, the sign of MINBOT is used to indicate where the rod vs. non-rod interface is located: if MINBOT is positive, the interface is assumed to be at the axial point specified as TOP; if MINBOT is negative, the interface is assumed to be at the axial point specified as BOTTOM. In either case, the magnitude of MINBOT is used in the search logic.

MAXTOP is the maximum axial point number to which the TOP (lowest numbered point in the control element) will be allowed to move. This value must either be zero or a gross plane boundary.

REFER is a reference (axial) point number. The reference position is used as the zero position of the BOTTOM of the control element. This value is used to calculate and edit the distances from this reference point to the BOTTOM of the control element. For example, if the axial mesh increment is X centimeters, and if the current position of the BOTTOM of the control element is (axial) point B, then the indicated positon of the control element will be X*(REFER-B). Note that downward (towards increasing axial mesh point numbers) from the zero point gives a negative position indication.

Transverse (and Axial) Extent of Control Element

010033, R(1), R(2), ... , 0 , T(1), B(1)

R(i) is a final figure number or planar region number, whichever corresponds to compositions. This set of R(i) defines the transverse extent of the control element. The R(i) must be in increasing order of absolute value. The form R(i), -R(i+1) may be used to specify numbers R(i), R(i)+1, R(i)+2, ... , R(i+1).

T(1) is the top of the control element. This is the lowest numbered axial point in the control element. This value must either be zero or a gross plane boundary.

B(1) is the bottom of the control element. This is the highest numbered axial point in the control element. This value must be a gross plane boundary.

The R(i) are separated from the [T(1),B(1)] pair by a zero. This zero and T(1) and B(1) may be missing. In this case, T(1) and B(1) are defaulted to TOP and BOTTOM respectively from card 010034.

Axial Extent of Control Element, Worth

010034, TOP, BOTTOM, WORTH

TOP is the axial point number which is the top of the control element. This is the lowest numbered axial point number in the control element. TOP must be equal to T(1) if it is supplied (see card 010033). In addition, TOP must be either zero or a gross plane boundary.

BOTTOM is the axial point number which is the bottom of the control element. This is the highest numbered axial point number in the control elelemt. BOTTOM must be equal to B(1) if it is supplied (see card 010033). In addition, BOTTOM must be a gross plane boundary.

WORTH is an estimate of the initial value for the change in eigenvalue due to a one centimeter change in axial position. The sign convention for WORTH is as follows: if WORTH is positive, a move downward (towards increasing axial point number) decreases the eigenvalue; if WORTH is negative, a move downward increases the eigenvalue. This value is floating point and must not be zero.

If a three - dimensional control search has been specified, this card is required if a File Manager input geometry file is not present. If such a file is present and this card is also present, the card data overrides the like data from the geometry file; in this case, the T(j) and B(j) data on card 010033 also overrides the like data from the geometry file.

This card is deleted from case to case.

Initial Move Specification

010035, MOVE, EXACT

MOVE is a desired initial position. The program will move the BOTTOM of the control element to this position (relative to REFER) before performing a spatial calculation. This value is floating point.

EXACT is an indication of how precise the initial move is required to be. If EXACT is negative, no initial move is performed; if EXACT is zero, a move is performed such that the bottom of the control element is at the gross plane boundary nearest the desired position. If EXACT is positive, a move is performed such that the bottom of the control element is exactly at the desired position and the search is turned off (no search is done).

Note that the position indicated by MOVE is described as a distance from the point REFER to the point BOTTOM; this distance is always in CENTIMETERS regardless of the input units of the geometry, and can be either positive or negative; also, MAXMOV is ignored for this initial move.

The edited output during the search contains references to "incremental" moves. An incremental move is simply a move which is an exact multiple of the axial height of a gross plane. Thus, the prior statements about "nearest" mesh imply an incremental move to some mesh point which is a gross plane boundary.

This card is deleted from case to case.

15.4. FEEDBACK INPUT PREPARATION: POISON SEARCH DATA

The poison search is selected by including one card, numbered 010031, containing six data items. The data on this card includes a specification of the desired eigenvalue, the accuracy required in the computed eigenvalue, a guess for the initial worth due to a fractional change in the specified concentration, the maximum number of search tries, and the identification of the control nuclide.

Since this search attempts to vary the reactivity by fractionally adjusting the concentration of a specified nuclide, the problem must be depletable. However, any geometry type or dimensionality may utilize this search. One important restriction is that the problem geometry may not contain multiple configurations.

Details of the card input for this search are given below.

Poison Search Specification

010031, EIG, EPSC, EPSS, WORTH, TRYS, ID

- EIG is the desired eigenvalue. This value is floating point.
- EPSC is the desired "closeness" of the computed eigenvalue to the desired eigenvalue. The search is terminated when the computed eigenvalue is within EPSC of the desired eigenvalue EIG. This value is floating point.
- EPSS is the desired convergence of the flux iterations before a new poison calculation is performed. This value is floating point.
- WORTH is the initial guess for a worth value. This quantity should be an initial estimate of the change in eigenvalue that will be obtained by a unit change in fraction value. This value is floating point and must not be zero.
- TRYS is the maximum number of poison search tries to do (zero for no search). The poison search will be terminated after this many tries, but the program will go back through another recalculation of cross sections and flux based on the last poison calculation. The search will then be terminated normally as though it had converged but with an appropriate comment.
- ID is the numeric identification of the nuclide whose concentration is to be varied in an attempt to obtain the desired eigenvalue.

The program uses an initial fraction value of 1.0 to begin the search. The latest WORTH value computed is used in the "next" search try and the last such value is saved in a geometry file if such a File Manager output file is written. If a File Manager input geometry file is present, the value of the WORTH from that file is used and the card input value of the WORTH is ignored unless a "slice" problem (see card 010000, Section 9.1) is being run in which case the card input value of the WORTH is always used.

15.5. FEEDBACK INPUT PREPARATION: THERMAL FEEDBACK DATA

The thermal feedback option is available in any depletable problem which exhibits the axial dimension explicitly. The allowable geometries are thus one - dimensional slab, two - dimensional cylindrical, and any three - dimensional problem (explicit or synthesis). The "concentrations" of pseudo-nuclides representing moderator density, moderator temperature, and fuel temperature in each gross block are updated every feedback try until the change in one of the concentrations from one try to the next is less than some input specified value or the specified maximum number of feedback calculations has been completed. If fuel rod clad shrinkage calculations are being done, the "concentrations" of pseudo-nuclides representing the maximum fuel centerline temperature over lifetime, the clad inner radius, and the clad stress are updated on the last feedback try; that is, they are updated after the feedback has converged or the specified maximum number of feedback calculations has been completed.

The presence of one card, numbered 010036, specifies the thermal feedback option in the program and requires that all other thermal input data be present. The specification card contains nine items including the numeric nuclide identifications for the "nuclide" which is to be converged, the "nuclides" representing moderator density, moderator temperature, fuel temperature, and accumulated fissions, as well as an edit indicator and two "closeness" criteria for use in the feedback process. In addition, if fuel rod clad shrinkage calculations are desired, an optional three additional pseudo-nuclide numeric identifications representing the maximum fuel centerline temperature over lifetime, the clad inner radius, and the clad stress must be included.

If the card selecting thermal feedback is present, most of the remaining input data described in this section must be present. If the card selecting thermal feedback is present and specifies that fuel rod clad shrinkage calculations are to be done, all of the remaining input data described in this section must be present. Some of the data is in "expansion" format. For example, the description might include the statement that certain cards contain triplets of data in expansion format by composition. This is simply a shorthand form to take advantage of the fact that such data may be the same for several consecutive compositions. The general form for such data is:

V(1), C(1), V(2), C(2), ...

where V(i) stands for a vector of some arbitrary (fixed) length, and C(i) is a value of the space over which the expansion is to be done (compositions, for example). The C(i) must be strictly increasing in order, and the last such value must be equal to the largest possible value of the expansion space. For example, suppose a triplet of floating point values is to be input in expansion format by composition and that the maximum composition number is twenty. Then the input data:

1.0, 2.0, 3.0, 5, -1.0, -2.0, -3.0, 20

would imply the following: the first parameter in the triplet would have a value of 1.0 in compositions 1 through 5 and the value -1.0 in compositions 6 through 20; similarly, the second parameter in the triplet would have a value of 2.0 in compositions 1 through 5 and the value -2.0 in compositions 6 through 20; and finally, the third parameter in the triplet would have a value of 3.0 in compositions 1 through 5 and the value -3.0 in compositions 6 through 20.

Card series 50 is used for all thermal data. Equivalence symbols for this data are given in Tables 15.5.1 - 15.5.2 which show the relationship between the names used in this description and those used in Reference 14. These tables also contain sample values for some of the parameters associated with a particular vapor fraction correlation suggested in Reference 14. Briefly, thermal data consists of the following.

Cards 500001 - 500009 are used to supply sixteen miscellaneous thermal parameters. If fuel rod clad shrinkage calculations are being done, fourteen additional miscellaneous parameters must be included.

Cards 500011 - 500014 contain from one to six polynomial coefficients on each card. Each set of coefficients is used to evaluate a different correlation parameter.

Cards 510001 - 510099 contain triplets of data in expansion format by track. In each triplet are the fraction of flow in the track, a multiplier appearing in the turbulent mixing calculation, and the inlet temperature.

Cards 520001 - 520099 contain sextuplets of data in expansion format by composition. In each sextuplet are the heat transfer area per unit nuclear design volume, the flow area in the axial direction per unit nuclear design area, the volume of coolant per unit nuclear design volume, the volume of fuel meat per unit nuclear design volume, the flow area in the transverse direction per unit nuclear design area, and the wetted perimeter per unit nuclear design area for flow in the axial direction.

Cards 530001 - 530099 contain quintuplets of data in expansion format by composition. In each quintuplet are the fuel cladding outside radius, the clad inside radius, the fuel element outside radius, the fuel element inside radius, and a fuel type indicator.

Cards 540001 - 540099 contain pairs of data in expansion format by composition. In each pair are the table number identifying an interpolating table for gap conductance, and a table number identifying an interpolating table for fuel meat conductivity.

Cards 550X01 - 550X99 contain reference data in expansion format by composition. The value of X in the card number determines the type of reference data: X = 1 is hydrogen density, X = 2 is moderator temperature, and X = 3 is fuel temperature.

Cards 56RRX1 - 56RRX9 define an interpolating table numbered RR for gap conductance. The value of X in the card number determines which of the variables is given: X = 1 is the first independent variable (heat flux), X = 2 is the second independent variable (accumulated fissions), and X = 3 is the dependent variable (gap conductance).

Cards 57TTX1 - 57TTX9 define an interpolating table numbered TT for fuel meat conductivity. The value of X in the card number determines which of the variables is given: X = 1 is the first independent variable (fuel temperature), X = 2 is the second independent variable (accumulated fissions), and X = 3 is the dependent variable (fuel meat conductivity).

Cards 580001 - 580099 are optional and contain composition dependent parameters used for fuel rod clad shrinkage calculations.

Cards 580101 - 580199 are optional and contain composition dependent parameters used for fuel rod clad shrinkage calculations.

Cards 580201 - 580299 are optional and contain composition dependent parameters used for fuel rod clad shrinkage calculations.

A summary of the card input for thermal feedback is as follows:

```
          010036 : thermal feedback specification
500001 - 500009 : miscellaneous thermal parameters
500011 - 500014 : polynomial coefficients for correlations
510001 - 510099 : flow fraction, mixing, inlet temperature by track
520001 - 520099 : homogenization data by composition
530001 - 530099 : fuel element data by composition
540001 - 540099 : table assignment data by composition
550101 - 550199 : reference hydrogen density by composition
550201 - 550299 : reference moderator temperature by composition
550301 - 550399 : reference fuel temperature by composition
56RR11 - 56RR39 : gap conductance interpolating table RR
57TT11 - 57TT39 : fuel meat conductivity interpolating table TT
580001 - 580099 : composition dependent fuel rod clad shrinkage data
580101 - 580199 : composition dependent fuel rod clad shrinkage data
580201 - 580299 : composition dependent fuel rod clad shrinkage data
```

Details of each of these cards is given below.

Thermal Feedback Specification

010036, TRYS, IDCOVG, IDRHO, IDTM, IDTF, IDFISS, EDIT, EPSC, EPSS, IDT3, IDR1, IDSIG

TRYS is the maximum number of thermal feedback iterations. If this value is zero, feedback is not done and only a single spatial calculation is done. Thermal feedback will be discontinued after this many iterations, but the program will go back through another recalculation of cross sections and flux based on the last thermal calculation.

IDCOVG is the numeric identification of the pseudo-nuclide to converge. This ID must be one of IDRHO, IDTM, or IDTF and determines which of moderator density, moderator temperature, or fuel temperature is to be measured for feedback convergence.

IDRHO is the numeric identification of the concentration representing moderator density.

IDTM is the numeric identification of the concentration representing moderator temperature.

IDTF is the numeric identification of the concentration representing fuel temperature.

IDFISS is the numeric identification of the fission counter (fissions/cc) nuclide.

EDIT is an edit indicator. A value of zero will produce no editing; a value of 1 will produce an edit of thermal results by edit set, plane grouping, and axial edit.

EPSC is the desired maximum relative error in the concentration of the IDCOVG "nuclide". The feedback process is converged when the maximum relative change in that concentration over all space (gross blocks) from one feedback try to the next is less than EPSC. This value is floating point.

EPSS is the desired convergence of the flux iterations before a new thermal feedback calculation is performed. This value is floating point.

The following three values are optional and are present if and only if fuel rod clad shrinkage calculations are to be done.

IDT3 is the numeric identification of the concentration representing the maximum fuel centerline temperature over lifetime.

IDR1 is the numeric identification of the concentration representing the clad inner radius.

IDSIG is the numeric identification of the concentration representing the clad stress.

If editing is requested for this feedback calculation, it is done for every feedback try. The edit "limiting" associated with the average concentration edits as well as the axial edit limitations are applicable to this feedback editing (see card 011000 in Section 12.2).

Miscellaneous Thermal Parameters

50000S, P, fw, fm, Wt, k1, K, DELTA1, DELTA2, ALPHA, BETA, n, m, GAMMA, KVF, B, LAMBDA, ALPHFG, ALPHT, D1, DELTA, DELTAt, E, E1, E2, E3, E4, E5, KAP, RT, Trel

P is the system pressure in psia. This value must be between 14.504 and 3190.

fw is the fraction of fission energy deposited in the fuel region water.

fm is the fraction of fission energy deposited in the fuel meat and clad.

Wt is the total flow rate per unit area; this is per unit homogenized area as seen in the geometry input. This value must not be zero. The units of this quantity are lb/hr-ft**2.

NOTE

Plane zero is assumed to be the inlet and plane boundary the outlet; if Wt is negative, the reverse is assumed.

kl is the thermal conductivity of the clad in Btu/hr-ft degrees F.
K is a coefficient in the Dittus-Boelter equation.
DELTA1 is a coefficient in the vapor fraction correlation.
DELTA2 is a coefficient in the vapor fraction correlation.
ALPHA is the exponent of the Prandtl number in the vapor fraction correlation.
BETA is the exponent of thermal conductivity in the vapor fraction correlation.
n is the exponent appearing in the correlation for bubble layer thickness.
m is the exponent appearing in the correlation for slip ratio.
GAMMA is the second pass inlet enthalpy multiplier.
KVF is the coefficient for the Dittus-Boelter film coefficient in the vapor fraction calculation.
B is the coefficient in the Eddy diffusivity fit.
LAMBDA is the exponent in the Eddy diffusivity fit.

The following fourteen values are present if and only if fuel rod clad shrinkage calculations are to be done.

ALPHFG is the number of noble gas atoms per fission.
ALPHT is the number of ternary Helium atoms per fission.
D1 is the multiplier of the group-one flux.
DELTA is the constant used to distinguish large gap from small gap, in inches. This value must not be zero.
DELTAt is the time since the last thermal feedback calculation, in hours.
E is Young's modulus divided by [1-Poisson's ratio], in psi. This value must be strictly positive.
E1-E5 are parameters used in the calculation of gas conductivity in the gap. The value of E3 must be strictly greater than the value of E4.
KAP is the energy (in BTU) released per fission.
RT is the fractional release of ternary fission Helium from fuel.
Trel is the temperature above which gas escapes from the fuel, in degrees F.

All values are floating point.

The S = 1, 2, ... , 9 sequentially. Use as many cards in this sequence as desired.

Polynomial Coefficients

50001S, X(0), X(1), ... , X(5)

X(i) is a polynomial coefficient. The type of coefficient specified is determined by the value of S in the card number as follows:

a. For S = 1, specify the a(n) polynomial coefficients in the expression for the function of quality appearing in the vapor fraction calculation;
b. For S = 2, specify the b(n) polynomial coefficients in the correlation for slip ratio;
c. For S = 3, specify the c(n) polynomial coefficients in the vapor fraction calculation;
d. For S = 4, specify the d(n) polynomial coefficients in the correlation for slip ratio.

For each S = 1, 2, 3, and 4, all of the specified polynomial coefficient values are floating point.

From 1 to 6 polynomial coefficients are supplied on EACH card so that up to a fifth degree polynomial can be specified. Trailing coefficients which are omitted are assumed to be zero.

Flow Fraction, Mixing, Inlet Temperature by Track

5100SS, F, w/wref, Tin, T(1),
F, w/wref, Tin, T(2), ...

F is the fraction of total flow in each track. This value is floating point. Recall that the total flow per unit area Wt is known from the miscellaneous thermal input data (cards 50000S). This track data specifies a fraction of that flow for a set of tracks. The program then multiplies this fraction times the transverse area (the problem geometry area, not necessarily the flow area) of the track times Wt to obtain the actual flow rate in each track.
If F is zero for a track, the moderator temperature in that track is set equal to the transverse planar average moderator temperature at each axial level. This transverse planar average is performed only over the fueled portion of the problem unless there are no fueled portions at a given axial level in which case the average over the total transverse space is used in the first level and the average from the previous level is used in later levels.

w/wref is the multiplier appearing in the turbulent mixing calculation. This value is floating point. Turbulent mixing is not allowed in 1-D and 3-D geometries. Therefore, for those geometries this value must be zero for all tracks. In addition, mixing is not allowed between first and second pass tracks or on the outside track (column boundary) in a 2-D cylindrical problem; in these tracks w/wref = 0.0 is required.

Tin is the inlet temperature in degrees F. This value is floating point. The sign and value of Tin are used to classify tracks with respect to pass number. Tin positive implies the track is in the first pass; Tin negative implies the track is in the interpass (in the first pass, but does not contribute to second pass inlet enthalpy); and Tin = 0.0 implies the track is in the second pass.

T(i) is a track number. The data on these cards consists of triplets of floating point values in expansion format by track. A track has different meanings depending on the dimensionality of the problem. In one dimension, there is only one track. In two dimensions, columns defining vertical boundaries of gross blocks are track boundaries (rectangular blocking performed automatically by the program in R-Z geometry guarantees that all tracks run through the entire vertical mesh in a straight line). In three dimensions, gross blocks in a gross plane represent the tracks in that plane. The geometry treatment in the program is such that these planar blocks are the same size for every gross plane. In other words, the stacking of the gross planes results in thermal hydraulic tracks of uniform area throughout the axial extent of the problem. No communication between tracks is allowed in 3-D.

The T(i) in a 2-D problem can only be those column numbers which are vertical interfaces.

The T(i) in a 3-D problem can only be final figures or planar regions, whichever correspond to compositions.

The T(i) must be given in strictly increasing order and the last must be the largest track number (1 in 1-D, column boundary in 2-D, maximum figure or region in 3-D) in the problem.

The SS = 01, 02, ... , 99 sequentially.

Homogenization Data by Composition

5200SS, Ah, Af, Vc, Vf, Ay, lz, C(1),
Ah, Af, Vc, Vf, Ay, lz, C(2), ...

Ah is the heat transfer area per unit nuclear design volume in units of inverse feet. This value is floating point and must be positive.
Af is the flow area in the axial direction per unit nuclear design area. This value is floating point.
Vc is the volume of coolant per unit nuclear design volume. This value is floating point and must not be zero.
Vf is the volume of fuel meat per unit nuclear design volume. This value is floating point.
Ay is the flow area in the transverse direction per unit nuclear design area. This value is floating point.
lz is the wetted perimeter per unit nuclear design area for flow in the axial direction in units of inverse feet. This value is floating point and must be positive.
C(i) is a composition number. The data on these cards consists of sextuplets of floating point values in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

Fuel Element Data by Composition

5300SS, rs, r1, r2, r3, ff, C(1)
rs, r1, r2, r3, ff, C(2), ...

rs is the fuel cladding outside radius or half thickness in inches. This value is floating point.
r1 is the clad inside radius in inches. This value is floating point and must be less than rs.
r2 is the fuel element outside radius in inches. This value is floating point and must be less than or equal to r1.
r3 is the fuel element inside radius in inches. This value is floating point and must be less than r2 as well as non-negative.
ff is a fuel structure indicator as follows: ff negative implies no fuel; ff = 0 implies rod fuel; and ff positive implies plate fuel.
C(i) is a composition number. The data on these cards consists of quintuplets of data [four floating point values and one integer value] in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

Table Assignment Data by Composition

5400SS, RR, TT, C(1),
RR, TT, C(2), ...

RR is a table number indentifying an interpolating table for gap conductance.
TT is a table number indentifying an interpolating table for fuel meat conductivity.
C(i) is a composition number. The data on these cards consists of pairs

of integers in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

Reference Data by Composition

550XSS, REF(1), C(1), REF(2), C(2), ...

REF(i) is a reference value for composition C(i). This value is floating point. The data being specified is determined by the value of X in the card number as follows:

a. For X = 1, specify hydrogen density;
b. For X = 2, specify moderator temperature (degrees F);
c. For X = 3, specify fuel temperature (degrees F).

C(i) is a composition number. The data on these cards consists of floating point values in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

Gap Conductance Interpolating Tables

56RRXS, VAR(1), VAR(2), ...

VAR(i) is the i-th value for the X-th variable in the gap conductance interpolating table numbered RR. Two sets of independent variable values and the set of dependent variable values are each given separately and the value of X determines which set of variable values is being specified as follows:

a. For X = 1, specify the first set of independent variable values, heat flux in units of Btu/hr-ft**2. These values are floating point and must be sorted (either up or down).
b. For X = 2, specify the second set of independent variable values, fissions/cc times 10**-20. These fissions/cc values relate to the calculated fissions/cc values AS MODIFIED by the specified (on cards 5200SS) volume of fuel meat per unit nuclear design volume and thus are assumed to be fissions per cc of fuel meat. These values are floating point and must be sorted (either up or down).
c. For X = 3, specify the dependent variable values, gap conductance in units of Btu/hr-ft**2 degrees F. These values are floating point and are assumed to be in the following order: for the first heat flux value, give the gap conductance values corresponding to each of the specified fissions/cc values; then for the next heat flux value, give the gap conductance values corresponding to each of the specified fissions/cc values; and so forth.

For each RR = 01, 02, ... , 99 sequentially: for each X = 1, 2, and 3, the S = 1, 2, ... , 9 sequentially.

If the fuel rod clad shrinkage calculations are done, gap conductance is calculated directly as a function of clad shrinkage and the data in these gap conductance tables is not used. However, at least one such table must be present even though it is not used.

Fuel Meat Conductivity Interpolating Tables

57TTXS, VAR(1), VAR(2), ...

VAR(i) is the i-th value for the X-th variable in the fuel meat conductivity interpolating table numbered TT. Two sets of independent variable values and the set of dependent variable values are each given separately and the value of X determines which set of variable values is being specified as follows:

a. For X = 1, specify the first set of independent variable values, fuel temperature in degrees F. These values are floating point, there must be at least two such values given for each table TT specified, and the values must be sorted (either up or down).
b. For X = 2, specify the second set of independent variable values, fissions/cc times 10**-20. These fissions/cc values relate to the calculated fissions/cc values AS MODIFIED by the specified (on cards 5200SS) volume of fuel meat per unit nuclear design volume and thus are assumed to be fissions per cc of fuel meat. These values are floating point and must be sorted (either up or down).
c. For X = 3, specify the dependent variable values, fuel meat conductivity in units of Btu/hr-ft degrees F. These values are floating point and are assumed to be in the following order: for the first fuel temperature value, give the fuel meat conductivity values corresponding to each of the specified fissions/cc values; then for the next fuel temperature value, give the fuel meat conductivity values corresponding to each of the specified fissions/cc values; and so forth.

For each TT = 01, 02, ... , 99 sequentially: for each X = 1, 2, and 3, the S = 1, 2, ... , 9 sequentially.

Composition Dependent Fuel Rod Clad Shrinkage Data

5800SS, BETA0, BETA1, BETA2, A1, R, C(1),
BETA0, BETA1, BETA2, A1, R, C(2), ...

BETA0-BETA2 are parameters in the calculation of the thermal expansion of fuel.
A1 is a parameter in the expression for the calculation of clad strain. This value must be strictly positive.
R is a parameter describing the fuel-clad interaction.
C(i) is a composition number. The data on these cards consists of quintuplets of floating point values in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

This data is present if and only if fuel rod clad shrinkage calculations are to be done.

Composition Dependent Fuel Rod Clad Shrinkage Data

5801SS, B1, B2, B3, C1, C2, C3, C(1),
B1, B2, B3, C1, C2, C3, C(2), ...

B1-B3 are parameters in the expression for the calculation of fuel swell.
C1-C3 are parameters in the expression for the calculation of fission gas release.
C(i) is a composition number. The data on these cards consists of sextuplets of floating point values in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

This data is present if and only if fuel rod clad shrinkage calculations are to be done.

Composition Dependent Fuel Rod Clad Shrinkage Data

5802SS, Ar/Aw, A4, Cg, Cs, Pg, VR, C(1),
Ar/Aw, A4, Cg, Cs, Pg, VR, C(2), ...

Ar/Aw is the ratio of rod area to water area.
A4 is a parameter in the expression for the calculation of clad strain. This value must be strictly positive.
Cg is a parameter in the calculation of gap thermal conductivity. This value must not be zero.
Cs is a parameter in the calculation of gap thermal conductivity.
Pg is the pressure of gas in the gap (psia). This value must be strictly less than P, the system pressure.
VR is the ratio of the volume of gap plus plenum to the volume of the fuel.
C(i) is a composition number. The data on these cards consists of sextuplets of floating point values in expansion format by composition.

The C(i) must be given in strictly increasing order and the last must be the largest composition number in the problem.

The SS = 01, 02, ... , 99 sequentially.

This data is present if and only if fuel rod clad shrinkage calculations are to be done.

TABLE 15.5.1

Name	Quantity	Sample Values
P	p	-
fw	f_w	-
fm	f_m	-
Wt	W_{t_o}	-
k1	k_1	-
K	K	-
DELTA1	δ_1	1.0
DELTA2	δ_2	1.0
ALPHA	α	1.0
BETA	β	1.0
n	n	2.0
m	m	1.0
GAMMA	γ	-
KVF	K_{VF}	.03
B	B	.0
LAMBDA	λ	-
ALPHFG	α_{FG}	-
ALPHT	α_T	-
D1	D_1	-
DELTA	Δ	-
DELTAt	Δt	-
E	E	-
E1-E5	E_1-E_5	-
KAP	κ	-
RT	R_T	-
Trel	T_{rel}	-
a(n)	a_n	1.07,.0,.0,...
b(n)	b_n	.0,.0,...
c(n)	c_n	.0003333,.0,.0,...
d(n)	d_n	.0,.0,...

TABLE 15.5.2

Name	Quantity
F	F
w/wref	$\frac{w}{w_{ref}}$
Tin	T_{in}
Ah	A_h
Af	A_f
Vc	V_c
Vf	V_f
Ay	A_y
lz	ℓ_z
rs	r_s
r1	r_1
r2	r_2
r3	r_3
BETAØ-BETA3	β_0-β_3
A1	A_1
R	R
B1-B3	B_1-B_3
C1-C3	C_1-C_3
Ar/Aw	Ar/Aw
A4	A_4
Cg	C_g
Cs	C_s
Pg	P_g
VR	V_R

15.6. FEEDBACK INPUT PREPARATION: XENON FEEDBACK DATA

Xenon feedback may be performed for any geometry type and dimensionality but the problem must be depletable. The xenon and iodine concentrations in each gross block are updated every feedback try until the change in xenon concentration from one try to the next is less than some input specified value.

The xenon feedback option is selected by the use of a single card, numbered 010037, containing seven data items. These items include the maximum number of feedbacks tries, the identification of the xenon and iodine nuclides, an edit indicator, an extrapolation factor, and two "closeness" criteria. Details of the data on this card are given below.

Xenon Feedback Specification

010037, TRYS, ID(Xe), ID(I), EDIT, THETA, EPSC, EPSS

- TRYS is the maximum number of xenon feedback tries to do (zero for no feedback). The feedback will be terminated after this many tries, but the program will go back through another recalculation of cross sections and flux based on the last xenon feedback calculation. The search will then be terminated normally as though it had converged but with an appropriate comment.
- ID(Xe) is the numeric identification of the xenon nuclide.
- ID(I) is the numeric identification of the iodine nuclide.
- EDIT is an edit indicator. A value of zero will produce no editing; a value of 1 will produce average iodine and xenon results by edit set, plane grouping, and axial edit.
- THETA is an extrapolation factor. This floating point number must have a value between 0.0 and 1.0 inclusive. The concentration of xenon is extrapolated from one feedback try to the next by setting the effective xenon concentration to be a fraction THETA of the xenon computed directly from the flux plus a fraction 1.0-THETA of the xenon from the previous feedback try.
- EPSC is the desired maximum relative error in the xenon concentration. The feedback process is converged when the maximum relative change in the xenon concentration over all space (gross blocks) from one feedback try to the next is less than EPSC. This value is floating point.
- EPSS is the desired convergence of the flux iterations before a new xenon feedback calculation is performed. This value is floating point.

If editing is requested for this feedback calculation, it is done for every feedback try. The edit "limiting" associated with the average concentration edits as well as the axial edit limitations are applicable to this feedback editing (see card 011000 in Section 12.2).

16.1. MISCELLANEOUS INPUT PREPARATION: MISCELLANEOUS DATA

This section describes card input which does not fall into any other particular category. Most of these cards are optional.

The following is a summary of the miscellaneous data described in this section:

```
          000000 : card deletion data
000001 - 000018 : iteration strategy override data
          000100 : geometry bit-packing override
          000200 : disk allocation and restart override
          001000 : input check
          002000 : printed output page reduction
          010900 : default fuel-shuffling indicator or gross to fine
                   concentration file expansion indicator
010901 - 010999 : fuel-shuffling data
          017000 : block reduction edit request
017XX1 - 017XX9 : each XX a new block
018XX1 - 018XX9 : for each XX, each figure with all regions a new block
019XX1 - 019XX9 : for each XX, each region with all figures a new block
04g001 - 04g099 : source values for group g
062001 - 062999 : reduced gross plane definitions
```

Details of each of these cards follows.

Card Deletion

000000, C(1), +-C(2), +-C(3), ...

C(i) is the number of a card to be deleted from the input data. The form C(i), -C(i+1) implies all cards C(i), C(i)+1, C(i)+2, ... , C(i+1).

This card is used to delete other cards from consideration as input to the current case. The form of the data is a list of card numbers in any order except that a negative card number implies that the entire list of cards from the previous card number through that card number is to be deleted. For example, to delete cards numbered 1, 3, 5, 10, 11, 12, and 20 , the following form could be used:

20, 10 , -12 , 1 , 3 , 5

C(1) cannot be negative, there may not be two consecutive negative numbers, and if C(i) is negative then the magnitude of C(i) must not be less than C(i-1).

This card deletion is temporary; that is, the deleted cards will again appear in the next case (if any) as will this card **000000** unless other specific card replacement is done.

If this card is itself in the list of cards to be deleted, that deletion has no effect but the remainder of the list of cards WILL be deleted.

Not all cards to be deleted need be present in the input data. Card numbers in the list which are not in the card input data for the current case will not affect the deletion process.

The cards are deleted from the "effective card input" for the current case (see section 8.3).

Iteration Strategy Override Data

0000XX, PARAM

PARAM is a single parameter which can be optionally input to override the built-in iteration strategy parameters in the program. The meaning of the data depends on XX in the card number as follows:

a. For XX = 01, a guess for the initial estimate of SIGMA, the second mode to first mode eigenvalue ratio, may be input. This value is floating point and is defaulted to zero so that a calculated value will be used for the initial estimate.
b. For XX = 02, a value for the inner iteration error reduction criterion may be input. This value is floating point and is defaulted to 0.15 in two - dimensional problems, 0.1 in three - dimensional problems, 0.001 in fixed source and one-iteration problems, and one-half of these values if all of the boundary conditions are symmetry (cell problem).
c. For XX = 03, a value for the multiplicative factor for use in the "maximum flux to test" may be input. This value is floating point and is defaulted to 0.0001.
d. For XX = 04, a value of zero may be input to indicate that the inner iteration (outer iteration in 1-D) results are to be edited, or a value of 1 to indicate that such an edit is not to be done. This value is integer and is defaulted to zero.
e. For XX = 05, a value may be input to indicate the maximum number of outer iterations to be done. If the problem has not converged in this many outer iterations, the program terminates the iteration process normally as though it had converged. This value is integer and is defaulted to an infinitely large value.
f. For XX = 06, a value of zero may be input to indicate that a one-point sigma-total coupling is to be used in the two - dimensional quadrilateral geometry iteration, or a value of 1 to indicate that a nine-point coupling is to be used. This value is integer and is defaulted to zero.
g. For XX = 07, a value may be input to indicate which outer iteration to begin Chebyshev extrapolation if all of the internal measures indicate that such extrapolation is desirable. This value is integer and is defaulted to 4 unless a non-zero SIGMA is input in which case it is defaulted to 2.
h. For XX = 08, a value may be input to set the initial Chebyshev cycle number. If this number is non-zero, the program will remove certain limit restrictions on SIGMA that exist in early Chebyshev cycles. This value is integer and is defaulted to zero unless a non-zero SIGMA is input in which case it is defaulted to 3.
i. For XX = 09, a value may be input which specifies the criterion on the "GAMMA" quantity before Chebyshev acceleration is allowed to begin. This value is floating point and is defaulted to 0.025.
j. For XX = 10, a value may be input which specifies the criterion on the "EPS." quantity before Chebyshev acceleration is allowed to begin. This value is floating point and is defaulted to 0.2.
k. For XX = 11, a value may be input which specifies the minimum degree of a Chebyshev polynomial to be applied before the rate of convergence of the acceleration is examined to determine whether to re-estimate SIGMA and begin a new cycle. This value is integer and is defaulted to 1.
l. For XX = 12, a value may be input to specify the convergence criterion for the OMEGA iterations. This value is floating point and is defaulted to 0.01
m. For XX = 13, a value may be input to specify the number of inner iterations per pass to do in the OMEGA iterations. This value is integer and is defaulted to 8.
n. For XX = 14, a value may be input to specify the number of passes to make in the OMEGA iterations in each group. This value is integer and is defaulted to 4 in two - dimensional problems and to 3 in three - dimensional problems.
o. For XX = 15, a value of zero may be input to indicate that the

OMEGA iteration results are to be edited, or a value of 1 to indicate that such an edit is not to be done. This value is integer and is defaulted to zero.

p. For XX = 16, a value of the final eigenvalue (final in the sense of being after any feedbacks, searches, and sub-cases) expected may be input. If this value is non-zero and the epsilon criterion on card 17 is also non-zero, the program will abort if the final eigenvalue is not the expected value within the criterion. This value is floating point and is defaulted to zero.

q. For XX = 17, a value of the epsilon criterion on the final eigenvalue expected may be input. If this value is non-zero and the epsilon criterion on card 17 is also non-zero, the program will abort if the final eigenvalue is not the expected value within the criterion. This value is floating point and is defaulted to zero.

r. For XX = 18, a value of zero may be input to indicate that a final spatial is to be performed after the termination of xenon and/or thermal feedback, or a value of 1 to indicate that no final spatial is to be performed after the termination of these feedbacks. This value is an integer and is defaulted to 0.

Except for items p, q and r, these parameters apply only to explicit solutions and are ignored (no error) in synthesis problems.

The mode (integer or floating point) of these quantities is not checked by the program. Any parameter value which is input as negative or zero is ignored.

WARNING

These iteration strategy override parameters should be used with extreme caution and only after consultation with a cognizant programmer or analyst. The default values provide an "optimum" iteration strategy for a wide range of problems and are based on many years of program use. A discussion of the iteration strategy and the use of these parameters are given in Reference 4.

During searches and feedbacks, these override parameters are valid only during the first spatial calculation. Later spatial calculations in the same case or sub-case modify some of the parameters to reflect measurements already acquired from earlier calculations.

Geometry Bit-Packing Override

000100, F, R, C, T, H

F is the number of bits to use for packing the final figure number (default is 10).
R is the number of bits to use for packing the planar region number (default is 10).
C is the number of bits to use for packing the channel number (default is 30).
T is the number of bits to use for packing the track number (default is 7).
H is the number of bits to use for packing the hexagonal transformation number (default is 3).

These values are integers and must be positive. The data is optional and from one to five values may be supplied. The values must sum to a value no greater than the number of bits in a word (60).

This card should not be used without consultation with the cognizant programmer.

Disk Allocation and Restart Override

000200, MANY, NORESTART

MANY is the initial number of tracks per disk to allocate. This number is defaulted by the program to an adequate value and the program will acquire additional tracks if necessary so that the user is not normally concerned with this value.

NORESTART can be used to override automatic restarts that normally occur after a machine error has been detected. If this value is zero, no automatic restart will be done; any other value (default value is 1) will cause the normal behaviour which implies a restart attempt.

This card is optional and one or two values may be present. The first input quantity (MANY) can be used to force the program to run entirely without disks, force the use of disks, or let the program decide (which is the normal condition). If this value is zero (default), the program attempts to make a conservative estimate of the total storage required and will run the problem with or without disks depending on the result of this estimate. If this value is positive, the program will force the use of disks and, in addition, if this value is positive and equal to 1 modulo 100, then disk checksumming is performed. If this value is negative, the program will run the problem without using disks.

This card should not be used without consultation with the cognizant programmer.

Input Check

001000, DATA

DATA is any kind of input, just to indicate the presence of this card. There may be any number of items on this card, and the type of data may be integer, floating point, or alphanumeric.

If this card is present, whether in error or not and no matter what it contains, the path indicated on card **010000** is ignored and set to 7 (input check all cases, no filing). This allows an input check of other data on card **010000** without changing that card to obtain the input check.

Printed Output Page Reduction

002000, EMPTY, FULL

EMPTY is the number of lines that can already be printed on a page before a page eject will be done for a new type or collection of output. This item defaults to zero.

FULL is the number of lines remaining on a page for which no new set (of the same type) of output will begin if the entire set will not fit. This item defaults to one-half of a page.

This card can be used to compact the printed output without reducing the amount of data printed.

The program always does a page eject at the beginning of a case and for picture edits and mesh edits. For all other editing, page ejects are done only at the beginning of a new type of edit (for example, from flux weighted macroscopic data to depletion data) and then only if a page is not already "empty". An "empty" page is determined by the number of lines actually existing on the current page versus the input item EMPTY. If the number of lines already

printed on a page is less than or equal to EMPTY, a page eject is not performed but, instead, an entire line of slashes (/) is output to separate the two types of edit.

Within an edit type, there may be many sets of data. For example, in the flux weighted macroscopic data, the power fractions are grouped, then the absorption rates are grouped, etc. The program determines how many lines of non-zero data will be printed in the next set and if it is less than the number of lines remaining on the current page, two blank lines are output followed by the data. If the data will not fit on the current page, however, the program examines the input value FULL. If there are more than FULL lines remaining on the current page, a page eject is not performed but rather two blank lines are output followed by the data.

The most compact form of output occurs when EMPTY is set to a value larger than the number of lines on a page (say 100) and FULL is set to zero.

Fuel-Shuffling Default or Gross to Fine Expansion

010900, DEF

DEF is either the default fuel-shuffling indicator or a request for the gross to fine block concentration expansion option.
If DEF is -1, gross to fine block concentration expansion is indicated. In this case the problem must be fine blocked and an input File Manager concentration file must be gross blocked only.
Otherwise, DEF is the default indicator of the type of transformation to perform for final figures in the current problem geometry which are not explicitly transformed via the data on cards 0109SS. A DEF value of zero implies that such final figures are to receive zero values for concentrations; a DEF value of one implies that such final figures are to receive concentrations from like-numbered final figures in the geometry associated with the input concentration file (i.e. they are to be transformed one-to-one).

This card is optional and, if missing, a DEF value of one (one-to-one transformation for missing figures) is assumed.

Fuel-Shuffling Data

0109SS, OLDFIG(1), OLDBIAS(1), NEWFIG(1), NEWBIAS(1),
OLDFIG(2), OLDBIAS(2), NEWFIG(2), NEWBIAS(2), ...

OLDFIG(i) is a final figure number in the input File Manager geometry file associated with the input File Manager concentration file.
OLDBIAS(i) is the channel bias number used in OLDFIG(i) in the input File Manager geometry file associated with the input File Manager concentration file.
NEWFIG(i) is the final figure number in the current problem geometry that is to be assigned the gross block concentrations associated with OLDFIG(i) in the input files.
NEWBIAS(i) is the channel bias number used in NEWFIG(i) in the current problem geometry that is used to determine the order of the fine block concentrations that are to be mapped from OLDFIG(i) to NEWFIG(i).

This data consists of quadruplets of data mapping both the gross blocks and the fine blocks from a previous geometry into the current geometry.

Not all of the final figures which exist in the current geometry need be listed (as NEWFIG(i)) and in this case the default condition described on card 010900 determines whether zero values are stored or a one-to-one transformation is done. In addition, not all of the final figures in the old geometry need be

used. However, duplicate values of NEWFIG(i) are not allowed since an ill-defined transformation would result. The order of the mapping is arbitrary.

The concentrations in each gross or fine block are obtained from the appropriate block in the old concentration file or the concentrations may be set to zero. If the value of OLDFIG(i) is zero, then all of the concentrations in each gross block and in each fine block contained in final figure NEWFIG(i) are set to zero. In this case, the OLDBIAS(i) and NEWBIAS(i) values are meaningless and can be any value.

Both an input concentration File Manager file and an associated geometry input File Manager file must be provided when this expansion data is present.

This capability cannot be used for one - dimensional problems or cylindrical geometry problems.

The SS = 1, 2, ... , 99 sequentially.

Block Reduction Editing

017000, EDIT

EDIT is an edit indicator. If EDIT is zero, no editing is done; if EDIT is 1, an edit of the transverse and/or axial block reduction data is performed during input processing.

This card is deleted from case to case.

Transverse Block Reduction

01XXXS, F(1), +-F(2), ... , 0 , R(1), +-R(2), ...

F(i) is a final figure number. The form F(i), -F(i+1) implies final figure numbers F(i), F(i)+1, F(i)+2, ... , F(i+1). The F(i) must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive.

R(i) is a planar region number. The form R(i), -R(i+1) implies planar region numbers R(i), R(i)+1, R(i)+2, ... , R(i+1). The R(i) must be strictly increasing in absolute value, there may not be two consecutive negative numbers, and the first number must be positive.

The list of final figure numbers must be separated from the list of planar region numbers by a zero.

The meaning of this data varies with the subseries number XXX which is divided into four ranges as follows:

XXX = 700 - 799 : Each XXX is a new gross block.

XXX = 800 - 899 : For each XXX, each figure with all regions is a new gross block.

XXX = 900 - 999 : For each XXX, each region with all figures is a new gross block.

Each new gross block defined must exist; i.e. the area of the new block cannot be zero.

An old gross block can become part of AT MOST one new block.

Not all old blocks need be defined if they are to be translated one-to-one.

The first final figure listed and the first planar region listed in the

definition of the new block are the final figure and planar region assigned to the new block.

The transverse block reduction can be requested independent of axial block reduction.

Any of the subseries may be omitted. In any given range X00 - X99, the subseries number must be X00, X01, ... , X99 sequentially.

The S = 1, 2, ... , 9 sequentially for each XXX.

Fixed - Source Values

04g0SS, S(1), C(1), S(2), C(2), ...

S(i) is a source value for group g in compositions C(i-1)+1 through C(i). This is a floating point value.

C(i) is a composition number. This data consists of a floating point value of the source in expansion format by composition. The C(i) must be strictly increasing in order and the last such value must be equal to the maximum composition number.

This data must be present if the "problem type" is fixed source and must not be present otherwise.

For each group g, the SS = 01, 02, ... , 99 sequentially.

Axial Block-Plane Reduction

062SSS, Z(1), Z(2), ...

Z(i) is an axial point number. These values must be in strictly increasing order and the last value must equal the plane boundary.

The only Z(i) values allowed in this data are the original non-reduced gross plane boundaries. That is, the new gross planes are made up of collections of contiguous old gross planes.

Other problem input data such as synthesis trial function zone boundaries, plane grouping definitions, and three - dimensional search parameters must satisfy their normal requirements based on the new axial gross plane boundaries.

The composition correspondences from the lowest numbered old gross plane in a new gross plane become the composition correspondences in the new gross plane.

The axial block reduction can be requested independent of transverse block reduction.

If planar region / plane dependent area distortion factors (area ratios) are present, this reduction will axially average such factors.

The SSS = 001, 002, ... , 999 sequentially.

17.1. OUTPUT EDITING: INPUT PROCESSING OUTPUT

The program output always begins with a one page edit of USER NOTICES. These notices describe the latest changes or additions to the program. If the program is executed with no card input data, a special edit is printed. This special edit consists of ALL past user notices and an input CHECKLIST which includes a brief description of every possible input card.

For every case of input, the following are always edited during input processing:

(a) CARDFILE cards in the order they are encountered;

(b) Card data from card files in the order they are processed;

(c) Card input data for the current case;

(d) A one page summary of important problem parameters; and,

(e) In synthesis cases, the trial function descriptions.

If sub-cases are being executed, (a) through (e) are edited only in the parent case but a short summary edit of important problem parameters at the beginning of each sub-case is always included.

All other editing of input data which can occur during input processing (except, of course, error commenting) is optional. There are five major sections of optional input editing which can be requested:

1. Geometry data,

2. Concentration data,

3. Harmony input data,

4. Integration edit definitions, and

5. Geometry pictures.

These edits, as well as all other optional edits in the program, are defaulted "off"; that is, they are not done unless specifically requested. In addition, such edit requests are deleted from case to case and thus must be requested explicitly in each case if desired.

1. Geometry Data

During input processing but before the actual grid generation, the geometry data is optionally edited. If fine blocking is being done, the list of planar regions to be fine blocked is edited. Basic figure data is edited giving the identification of the figure and the mesh spacings assigned to that figure. If fine blocking is being done, the channel and track data (if any) for that basic figure and for each auxiliary figure is also edited. For rectangular, cylindrical, and spherical geometries only, the accumulated column and row intervals are edited. For three dimensional problems, the axial mesh intervals and accumulated mesh intervals are edited. Final figure or compound figure data is also edited under this option.

The area of each of the planar regions for the entire problem is edited after the grid has been generated. Composition correspondences are edited for plane zero and for each plane in which the correspondences change.

For quadrilateral geometry, a separate input edit option can be utilized to obtain the calculation and editing of grid distortion indicators. This data includes maximum, minimum, and average values of various distances, angles, ratios of lengths, and ratios of angles. This data is for the solution figure only and may be printer - plotted as well as printed. If the data is printer - plotted, a histogram of percentages of values between the minimum and maximum are shown.

2. Concentration Data

The card input concentrations by composition are edited under input option. The data is printed in columns, eight nuclides (columns) at a time. Lines of data which are identically zero are omitted.

3. Harmony Input Data

Nuclide identifications are edited during input processing and give for each nuclide a numeric ID, the associated alphanumeric ID, and an indication of whether the nuclide is fine block depletable.

The edit of table set data during input processing is a compromise between printing every number in each table to be used by the program in each composition and printing a list of the table set ID's by composition. For simple table set usage, the latter is probably sufficient. When the table set overlay input is used or when table sets are taken from an input table set File Manager file the former may be required. It has been assumed that situations in which every number must be displayed are rare and can be handled by special programs.

Each table set referenced by the assignment or overlay input data is identified by listing the numeric and alphanumeric ID's assigned to them. Note that this is the only usage of the alphanumeric ID. Then for each composition, each table to be used is described by giving the table set ID in which it was originally specified or defined, the identification of the quantity represented by the table, and the table number assigned by the program. This table number is probably not of interest but has been included for use in the analysis of certain extraordinary errors. In the identification of the quantity, five columns of numbers are listed for group, nuclide, type, order of interpolation, and area distortion factor. Depending on the type of table, some of the columns are left blank because the data is not appropriate. If the area distortion factors are input by planar region and gross plane, that data is edited separately.

A special short form of edit is available which provides only the numeric table set ID and area distortion factor by composition (or by planar region for the first plane only), as well as numeric and alphanumeric nuclide ID's and numeric and alphanumeric table set ID's.

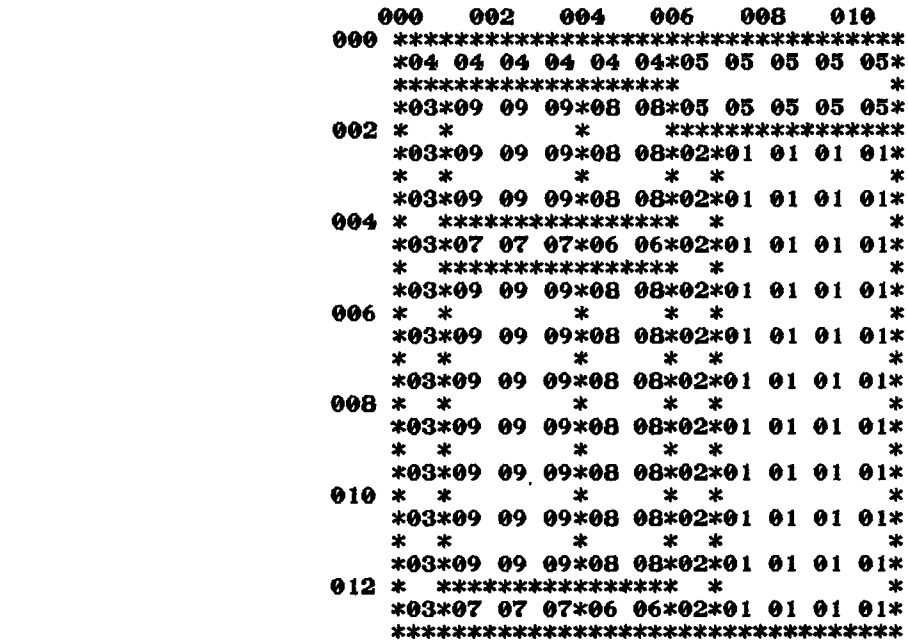
4. Integration Edit Definitions

The expanded edit set definitions may be edited under input option. This edit includes the list of final figures with associated planar regions that constitute an edit set. For edit sets consisting of a single final figure and a single planar region, successive edit sets are edited on the same line, four per line. For both final figure numbers and planar region numbers, the form N, -M implies the numbers N, N+1, N+2, ... , M.

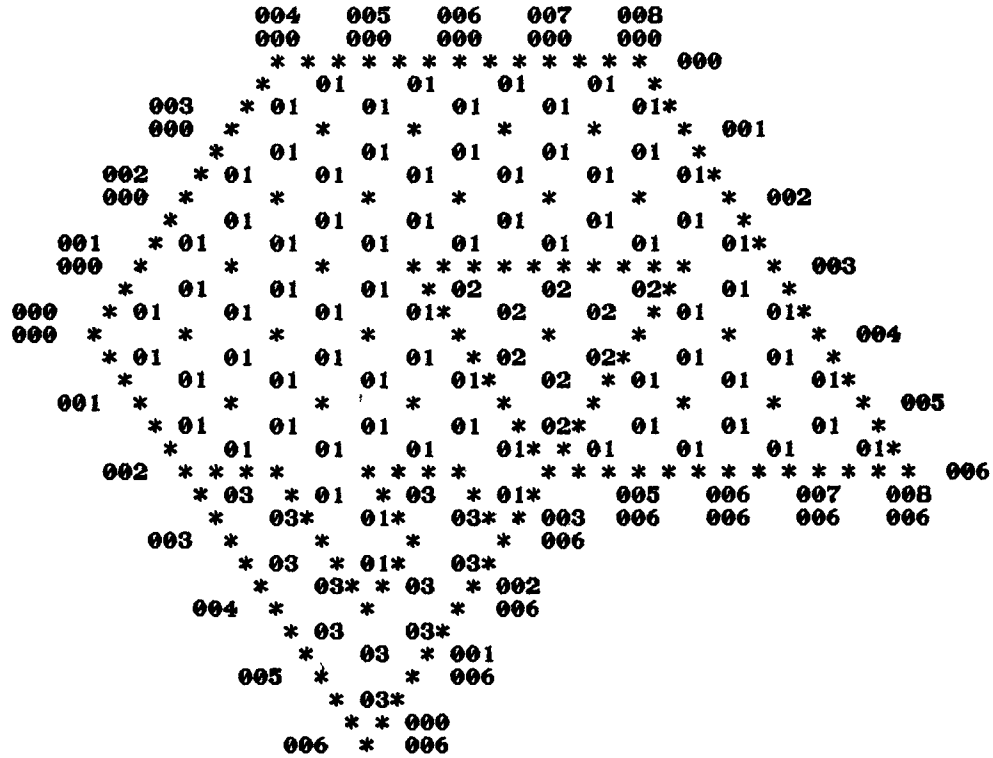
5. Geometry Pictures

Geometry picture edits and plots are described in Section 10.6 and this section will not repeat that description. Rather, this section includes three sample picture edits for rectangular, hexagonal, and quadrilateral geometries.

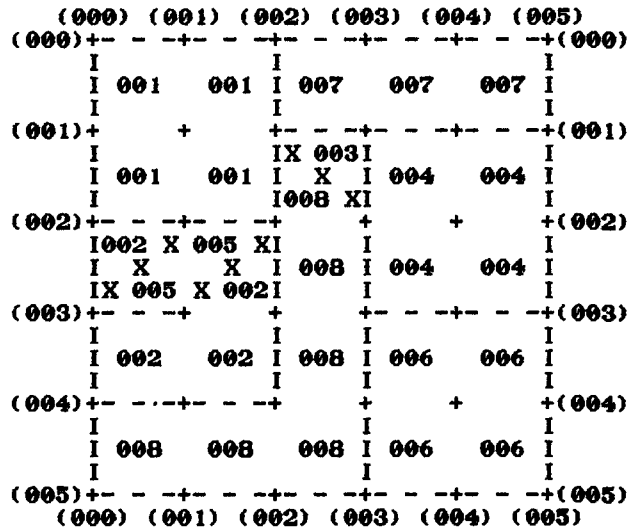
RECTANGULAR PICTURE



HEXAGONAL PICTURE



QUADRILATERAL PICTURE



17.2. OUTPUT EDITING: MACROSCOPIC DATA OUTPUT

Under input option, volume - weghted average macroscopic data may be obtained for each group. For any macroscopic parameter, the average value is calculated by integrating the parameter over the volume of the edit region and then dividing by the edit region volume. All macroscopic parameters listed in table 11.5.1 are edited. Note that the buckling is calculated from a total cross section and hence may not match exactly the input value. Note also that the fission cross section is replaced by the input source in a fixed source problem.

This data is edited by edit set and plane grouping. The edit "limiting" associated with the volume - weighted edits is applicable to this editing (see card 011000 in Section 12.2).

Any edit set for which all of the average values are identically zero is not printed and of course the division by a zero volume is not performed.

17.3. OUTPUT EDITING: ITERATION OUTPUT

This section describes the parameters edited during the spatial calculation for explicit flux solutions. Most of these quantities are discussed in detail in Reference 4.

The omega calculation edits the quantities RHO, OMEGA, SIGMA, and DELTA for each pass in each group. This omega iteration edit is optional but is defaulted to do an edit unless specifically requested otherwise. The number of passes performed depends upon the problem size, the storage available, and the rate of convergence of the calculation. RHO is an estimate of the largest eigenvalue of the inner iteration matrix, OMEGA is an overrelaxation parameter calculated from RHO, and the quantity in parentheses following OMEGA is the current iteration count. SIGMA is an estimate of the second largest eigenvalue of the inner iteration matrix divided by RHO, DELTA is the factor by which the initial residual in each group should be reduced each outer iteration, and the quantity in parentheses following DELTA is an estimate of the number of inner iterations required to achieve this residual reduction.

A summary of the inner iteration results in each group is given for each outer iteration. This includes the total number of inner iterations performed, values of R(1) and DELTA, and the number of passes through the mesh required to perform the inner iterations (if greater than one), where R(1) is the initial residual and DELTA is some factor times the error reduction actually achieved. This inner iteration edit is optional but is defaulted to do an edit unless specifically requested otherwise.

The omega and inner iteration (outer iteration in 1-D) results are edited during searches and feedbacks for the first spatial calculation only. Thereafter, these edits are automatically "turned off" by the program.

The outer iteration results edited are SIG/I, SIG/O, MAX, MIN, GAMMA, PT/AV, RATIO, EPS, and LAMBDA. SIG/I and SIG/O are estimates of the convergence rate as measured by the inner and the outer iterations respectively. MAX and MIN are the largest and smallest pointwise flux ratios between the current and previous iteration, each multiplied by LAMBDA. GAMMA is a normalizing factor (which approaches unity), and PT/AV is an estimate of the largest point flux error divided by the average flux error. RATIO is an estimate of the convergence rate obtained during a Chebyshev extrapolation cycle divided by the predicted rate, and the quantity in parentheses following RATIO is the degree of the Chebyshev polynomial being applied (zero for power iterations). EPS is the absolute value of the largest deviation of the pointwise flux ratio from unity, and the quantity in parentheses following EPS is the outer iteration number. Incidentially, the outer iteration number is set negative if a negative flux value is detected at any point for which the fission source is non-zero. LAMBDA is the length of the current fission source vector divided by the length of the initial vector (where length is calculated as the sum of the absolute values of the components) on the first outer iteration, and is GAMMA times the LAMBDA value for the previous outer iteration thereafter.

Multiple outer iterations are performed in fixed source and one iteration problems, but the input or fission source is not altered between iterations. LAMBDA is set to unity in fixed source problems and approaches unity in boundary value problems. The REACTIVITY(PERCENTAGE), defined as:

$$100(L-1)/L$$

where L stands for the eigenvalue LAMBDA, and DOMINANCE, which is an estimate of the ratio of the second largest to the largest eigenvalue, are edited following the last outer iteration. In slowly convergent problems, the message:

INPUT EPS. CRITERION CHANGED

is included in the output to signal that Inequality 2.2.1 has been altered to assure adequate convergence. Under operator control the current outer iteration number, the estimated final iteration number, and the value of LAMBDA may be monitored at the display console. This console message is of the form:

LAMBDA(12 OF 34) = 123456+01

17.4. OUTPUT EDITING: INTEGRATION EDIT OUTPUT

All of the edit quantities described in this section are integrated over edit set space and then printed by edit set and plane grouping. Any line of output which contains identically zero data is not printed. In addition, the average power and the average flux by group may be printed by edit set and axial edit. In this edit form, any edit set which contains identically zero data is not printed. If the calculation of any quantity described in this section would involve a division by zero, that division is not done and the result is set to zero.

After the spatial calculation, a single line containing FNORM, PNORM, and the POWER VOLUME is printed. These values are defined by Equations 17.4.1 - 17.4.3 with the integrals taken only over the fueled portion of the problem. The fueled portion of the problem is defined to be that volume made up of gross blocks for which kappa sigma fission is non-zero in some group. If the denominator is zero in Equation 17.4.2, PNORM is set equal to 1.0 for this edit. If a power level is not supplied in the input (i.e. if the problem is not depletable), FNORM is set equal to PNORM. If the denominator is zero in Equation 17.4.1 or if FNORM is zero, FNORM is set equal to PNORM for this edit.

The first set of integration edits includes the volume and the integrated and averaged flux for each group. The integrated and averaged total thermal flux is also edited in a two-thermal-group problem. All flux integrals and averages are multiplied by FNORM before being edited.

The second set of integration edits consists of the total power contributed by the region being integrated together with the relative power density, which is the fraction of the total power contributed by the region divided by the fraction of the fuel volume present in the edit set (i.e. the denominator is the edit set volume divided by the total fuel volume). The fraction of the edit set power contributed by each group is also edited, as is the total thermal fraction in a two-thermal-group problem.

The third set of integration edits consists of the fraction of the total absorption contributed by the region being integrated together with the fraction of the total absorption and the fraction of the region absorption contributed by each group. In a two-thermal-group problem these fractions are also edited for the total thermal absorption.

The fourth set of integration edits consists of the group - independent buckling, K-infinity by group and the sum over groups, and K-effective by group and the sum over groups. The group - independent buckling is obtained by eliminating the flux and solving for B**2 in the set of Equations 17.4.4 using the definitions in Equations 17.4.5 - 17.4.6. In particular, Equation 17.4.6 gives the definition of the flux - weighted average value for any macroscopic parameter. Such parameters are the basic integrated data used for all calculated quantities edited in this section. If there are two thermal groups, the last two of Equations 17.4.4 are replaced by Equations 17.4.7 - 17.4.8 with the definitions given in Equations 17.4.9. K-effective for group g is the contribution of group g to the total criticality, calculated by Equations 17.4.10 - 17.4.11. K-infinity for group g is calculated in the same manner but with leakage ignored in the total cross section term. In a two-thermal-group problem a single thermal K-effective is calculated via Equation 17.4.12 and similarly for K-infinity. The calculations of K-infinity, K-effective, and of the group - dependent and group - independent buckling all require knowledge of the source integral. Since the integral of the input source is not available in fixed-source problems, these calculations are bypassed in such problems. Except for the group - dependent buckling, these calculations are also bypassed in any region in which the source integral is zero.

The fifth and final set of integration edits consists of the flux - weighted macroscopic parameters. In all but a pair of thermal groups the quantities edited are thoses listed in 17.4.13 - 17.4.14 using the definition in Equation 17.4.15. In a fixed source problem, the edit of nu sigma fission is replaced by Equation 17.4.16. The quantities edited in the first group of a thermal pair are listed in 17.4.17 and in the second group of a thermal pair the quantities edited are listed in 17.4.18 where each quantity is weighted by the group flux with which it is associated in Equations 2.1.3 - 2.1.4. The group dependent bucklings in a two-thermal-group problem are obtained by solving simultaneously the pair of Equations 17.4.19 - 17.4.20.

EQUATIONS 17.4.1 - 17.4.6

$$\text{FNORM} = \frac{\text{Input Power}}{\sum_{g=1}^{G} \int \kappa \Sigma_g^f \phi_g \, dV} \qquad 17.4.1$$

$$\text{PNORM} = \frac{\int_{\text{fuel}} dV}{\sum_{g=1}^{G} \int \kappa \Sigma_g^f \phi_g \, dV} \qquad 17.4.2$$

$$\text{POWER VOLUME} = \int_{\text{fuel}} dV \qquad 17.4.3$$

$$\left\{ (B^2 \overline{D_g} + \overline{\Sigma_g^t}) \phi_g = \frac{\chi_g}{\lambda} \sum_{j=1}^{G} \overline{\nu \Sigma_j^f} \, \phi_j + \overline{\Sigma_{g-1}^r} \, \phi_{g-1} \right\}_{g=1}^{G} \qquad 17.4.4$$

$$\Sigma_g^t = \Sigma_g^a + \Sigma_g^r + D_g B_g^2 \qquad 17.4.5$$

B_g^2 = Input Buckling

$$\bar{\Sigma} = \frac{\int \Sigma \phi dV}{\int \phi dV} \qquad 17.4.6$$

EQUATIONS 17.4.7 - 17.4.11

$$\left(B^2\overline{D^1_{G-1}} + \overline{\Sigma^{t1}_{G-1}}\right)\phi_{G-1} = \frac{\chi_{G-1}}{\lambda}\sum_{j=1}^{G}\overline{\nu\Sigma^f_j}\,\phi_j + \overline{R_{G-1}\Sigma^r_{G-2}}\phi_{G-2} - \left(B^2\overline{D^2_{G-1}} + \overline{\Sigma^{t2}_{G-1}}\right)\phi_G \qquad 17.4.7$$

$$\left(B^2\overline{D^1_G} + \overline{\Sigma^{t1}_G}\right)\phi_G = \frac{\chi_G}{\lambda}\sum_{j=1}^{G}\overline{\nu\Sigma^f_j}\,\phi_j + \overline{R_G\Sigma^r_{G-2}}\,\phi_{G-2} - \left(B^2\overline{D^2_G} + \overline{\Sigma^{t2}_G}\right)\phi_{G-1} \qquad 17.4.8$$

$$\Sigma^{t1}_{G-1} = \Sigma^1_{G-1} + D^1_{G-1}B^2_{G-1}\,,\quad \Sigma^{t2}_{G-1} = \Sigma^2_{G-1} + D^2_{G-1}B^2_G\,,$$
$$\Sigma^{t1}_G = \Sigma^1_G + D^1_G B^2_G\,,\quad \Sigma^{t2}_G = \Sigma^2_G + D^2_G B^2_{G-1}\,. \qquad 17.4.9$$

$$K^{eff}_g = \left(\frac{\overline{\Sigma^r_{g-1}}\,K^{eff}_{g-1}}{\overline{\nu\Sigma^f_{g-1}}} + \chi_g\right)\frac{\overline{\nu\Sigma^f_g}}{\overline{\Sigma^t_g} + \overline{D_g}\,\overline{B^2_g}} \qquad 17.4.10$$

$$K^{eff}_1 = \frac{\chi_1\,\overline{\nu\Sigma^f_1}}{\overline{\Sigma^t_1} + \overline{D_1}\,\overline{B^2_1}} \qquad 17.4.11$$

EQUATIONS 17.4.12 - 17.4.16

$$K_{th}^{eff} = \frac{K_{G-2}^{eff}}{\overline{\nu\Sigma_{G-2}^{f}}} \left\{ \left[\overline{R_G \Sigma_{G-2}^{r}} \left(\overline{\Sigma_{G-1}^{t1}} + \overline{D_{G-1}^{1}}\ \overline{B_{G-1}^{2}} \right) - \overline{R_{G-1} \Sigma_{G-2}^{r}} \left(\overline{\Sigma_{G}^{t2}} + \overline{D_{G}^{2}}\ \overline{B_{G-1}^{2}} \right) \right] \overline{\nu\Sigma_{G}^{f}} \right.$$

$$\left. + \left[\overline{R_{G-1} \Sigma_{G-2}^{r}} \left(\overline{\Sigma_{G}^{t1}} + \overline{D_{G}^{1}}\ \overline{B_{G}^{2}} \right) - \overline{R_G \Sigma_{G-2}^{r}} \left(\overline{\Sigma_{G-1}^{t2}} + \overline{D_{G-1}^{2}}\ \overline{B_{G}^{2}} \right) \right] \overline{\nu\Sigma_{G-1}^{f}} \right\} \qquad 17.4.12$$

$$\Big/ \left[\left(\overline{\Sigma_{G-1}^{t1}} + \overline{D_{G-1}^{1}}\ \overline{B_{G-1}^{2}} \right) \left(\overline{\Sigma_{G}^{t1}} + \overline{D_{G}^{1}}\ \overline{B_{G}^{2}} \right) - \left(\overline{\Sigma_{G-1}^{t2}} + \overline{D_{G-1}^{2}}\ \overline{B_{G}^{2}} \right) \left(\overline{\Sigma_{G}^{t2}} + \overline{D_{G}^{2}}\ \overline{B_{G-1}^{2}} \right) \right]$$

$$\overline{D_g},\ \overline{\Sigma_g^a},\ \overline{\Sigma_g^r},\ \overline{\nu\Sigma_g^f},\ \overline{\kappa\Sigma_g^f}\ . \qquad 17.4.13$$

$$\overline{B_g^2} = \frac{1}{\overline{D}_g\ \bar{\phi}_g} \left(\frac{\chi_g}{\lambda} \sum_{j=1}^{G} \overline{\nu\Sigma_j^f}\ \bar{\phi}_j + \overline{\Sigma_{g-1}^r}\ \bar{\phi}_{g-1} - \overline{\Sigma_g^t}\ \bar{\phi}_g \right) \qquad 17.4.14$$

$$\bar{\phi}_g = \int \phi_g dV \qquad 17.4.15$$

$$\overline{S_g} = \frac{\int S_g \phi_g dV}{\int \phi_g dV} \qquad 17.4.16$$

EQUATIONS 17.4.17 - 17.4.20

$$\overline{D^1_{G-1}},\ \overline{D^2_{G-1}},\ \overline{\Sigma^1_{G-1}},\ \overline{\Sigma^2_{G-1}},\ \overline{\nu\Sigma^f_{G-1}},\ \overline{R_{G-1}\Sigma^r_{G-2}},\ \overline{B^2_{G-1}}\ . \qquad 17.4.17$$

$$\overline{D^1_{G}},\ \overline{D^2_{G}},\ \overline{\Sigma^1_{G}},\ \overline{\Sigma^2_{G}},\ \overline{\nu\Sigma^f_{G}},\ \overline{R_{G}\Sigma^r_{G-2}},\ \overline{B^2_{G}}\ . \qquad 17.4.18$$

$$(\overline{B^2_{G-1}}\ \overline{D^1_{G-1}} + \overline{\Sigma^{t1}_{G-1}})\ \tilde{\phi}_{G-1} = \frac{\chi_{G-1}}{\lambda}\sum_{j=1}^{G}\overline{\nu\Sigma^f_j}\ \tilde{\phi}_j + \overline{R_{G-1}\Sigma^r_{G-2}}\ \tilde{\phi}_{G-2} - (\overline{B^2_G}\ \overline{D^2_{G-1}} + \overline{\Sigma^{t2}_{G-1}})\ \tilde{\phi}_G \qquad 17.4.19$$

$$(\overline{B^2_G}\ \overline{D^1_G} + \overline{\Sigma^{t1}_G})\ \tilde{\phi}_G = \frac{\chi_G}{\lambda}\sum_{j=1}^{G}\overline{\nu\Sigma^f_j}\ \tilde{\phi}_j + \overline{R_G\ \Sigma^r_{G-2}}\ \tilde{\phi}_{G-2} - (\overline{B^2_{G-1}}\ \overline{D^2_G} + \overline{\Sigma^{t2}_G})\ \tilde{\phi}_{G-1} \qquad 17.4.20$$

17.5. OUTPUT EDITING: ISOTOPIC EDIT OUTPUT

This section contains a description of the nuclide data edited over integration volumes consisting of edit sets with plane groupings and axial edits. Meshwise and blockwise nuclide editing is described in Sections 17.7 and 17.8. All of the editing described in this section is performed in the depletion segment of the program and is performed only if that segment is executed; it is not performed if the depletion path specified is the no - deplete path.

Depletion editing is preceded by a description of the depletion performed. This includes the time at the beginning and end of the depletion interval, the power level, the thermal flux renormalization interval, and the number of such intervals. The subinterval length for cross section and chain re-evaluation and the number of subintervals is given for each composition. In addition, if fine blocking is being done, the nuclides to be fine block depleted are edited.

Defined collections of nuclide reaction rates and concentrations as well as combinations of constants and collections are edited by value - name pairs. This data is always integrated over all problem space and is computed at the beginning of the depletion interval.

Power fractions, absorption rates, and fission rates are edited at the beginning of the depletion interval. Values are edited by group and summed over groups for each nuclide requested. The power fraction in group g for nuclide i is given by Equation 17.5.1 where the sum over j represents a sum over ONLY those nuclides j for which a power fraction edit was requested.

Similarly, the absorption rates are given by Equation 17.5.2 and the fission rates are given by Equation 17.5.3 where the flux used in these integrals is normalized by FNORM (Equation 17.4.1). If the depletion time interval is zero and FNORM is zero, then FNORM = 1.0 is used so that nonzero reaction rate edits may be obtained.

In a two - thermal - group problem, the epithermal and thermal group absorption cross sections used are those shown in Equations 17.5.4.

Average nuclide concentrations and loadings are edited at the end of the depletion interval for each nuclide requested. The average concentration for nuclide i is given by Equation 17.5.5. Loadings in kilograms may also be edited. The loading for nuclide i is given by Equation 17.5.6 where A is the Avogadro constant and W is the atomic weight of the nuclide.

Lines of data which are identically zero are not printed. Since nuclide concentrations and loading data are printed in columnar form, an entire column of zero values is also not printed for that type of data.

EQUATIONS 17.5.1 - 17.5.6

$$P_i^g = \frac{\int_G \kappa^g \sigma_i^{f,g} G_i^{f,g} N_i \phi_g dV}{\sum_{g=1}^{G} \sum_j \kappa^g \sigma_j^{f,g} G_j^{f,g} N_j \phi_g dV} \qquad 17.5.1$$

$$A_i^g = \int \sigma_i^{a,g} G_i^{a,g} N_i \phi_g dV \qquad 17.5.2$$

$$F_i^g = \int \sigma_i^{f,g} G_i^{f,g} N_i \phi_g dV \qquad 17.5.3$$

$$\sigma^{a,G-1} = \sigma_{21}^a \text{ and } \sigma^{a,G} = \sigma_{11}^a \qquad 17.5.4$$

$$\overline{N_i} = \frac{\int N_i dV}{\int dV} \qquad 17.5.5$$

$$L_i = 10^{21} \frac{W_i}{A} \int N_i dV \qquad 17.5.6$$

17.6. OUTPUT EDITING: POINTWISE OUTPUT

Before editing, pointwise flux values are normalized by FNORM (Equation 17.4.1) and pointwise and partition power values are normalized by PNORM (Equation 17.4.2). Flux values are printed in floating - point format with a six - digit fraction. Power values are also printed in this format unless a relative maximum edit is requested. In this case all pointwise power editing is done using the fixed - point format x.xx which provides a higher density of information on each output page. In addition the zero values at non - fuel points are suppressed to outline the fueled regions of the mesh.

A partition power value is calculated for each mesh figure at a point using the CROSS BLOCK fission cross section (kappa sigma fission) values for the mesh figure and the group flux values at the point. Partition power is edited only for those points at which any two nonzero values differ by more than 5%. Pointwise average power is calculated as the numerical average of the nonzero partition power values at a point and pointwise peak power is the largest of these values.

A relative maximum edit may be obtained in conjunction with either pointwise average or pointwise peak power. A point is considered a relative maximum if its power value exceeds the values at all of its possible neighbors, where neighbors are determined in the difference equation sense (see Section 2.4). The edit is performed by printing the pointwise values a second time, with the power set to zero at each point for which the power is nonzero but is not a relative maximum and blank elsewhere.

17.7. OUTPUT EDITING: MESHWISE OUTPUT

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. Any of this data may be edited for each mesh element in non - quadrilateral geometry problems. Since, in general, a block is larger than a single mesh element, this edit smears the data into the appropriate mesh elements so that the data can be printed in a regular grid pattern. There are two different types of mesh edits and, in the case of one - dimensional problems, a third type of mesh edit.

The first type of mesh edit simply prints a value for each mesh element. In hexagonal geometry, there are two triangular mesh elements for each set of point columns and these triangles are oriented in a fixed pattern for the portion of the chevron to the left of the main diagonal and a different but again fixed pattern to the right of the main diagonal. The printing of the values is offset to show the appropriate trianglular mesh element orientation. The region to be edited is specified separately for nuclide concentrations; for the average power, the edit region specified for pointwise power edits is used. The data is printed in floating point format.

Another type of mesh edit, called a display edit, is very compact since it does not print a value for each mesh element but instead prints a single character for each mesh element. This character represents a "range" of values between a maximum and minimum. A table is included with each item edited giving the characters and the associated ranges. Each item edited may be edited over a separate edit region.

A third type of edit is available for one - dimensional problems. The quantities may be printer - plotted as well as printed. This data is printed in columnar form.

17.8. OUTPUT EDITING: BLOCKWISE OUTPUT

The average power and all nuclide concentrations exist for each gross block in the problem; if the problem includes fine blocking, the power and a subset of the concentrations exist for each fine block. This block data may be edited directly. Such an edit is much more compact than a mesh edit since there is no expansion of the data over all mesh elements associated with a block and there is no imposed mesh grid structure. However, since block identification by block number is difficult to decipher, this type of edit utilizes a user defined structure in the various geometry labels associated with each block to identify the printed data. For gross block data, final figures and planar regions as well as axial plane limits are used to identify the data of interest. For fine block data, channels and tracks as well as axial plane limits are used to identify the data of interest.

These types of edit are called HIERARCHICAL edits because the user defines an ordered set of structures and this set represents a hierarchy of levels of structures. The user creates this structure by defining disjoint fields in the existing geometry labels (final figure and planar region or channel and track). Each field is defined as a set of contiguous decimal digits in the geometry labels. A name is assigned to each set of digits; that is, to each field. These names are then used to identify the output data. These definitions are hierarchical; that is, they have an order and this order determines the order of the data printed. To select an edit, a particular value of each field is selected, from the first (highest) level down to the last specific level desired. The program will then obtain the data associated with the specified field values and print ALL sub-structures included.

For example, the user might define three fields in a channel label and name these fields "CLUSTER", "SUB-ASSEMB", and "ELEMENT"; the entire track label might be named "TRACK". These four labels might represent structures called cluster, sub-assembly, element, and track respectively. Then an edit request might be to print data for a particular quantity such as fine block power, say, for cluster 17. The program would then find cluster 17 and print all fine block power data in that cluster, identifying the various pieces with appropriate labels "SUB-ASSEMB" number, "ELEMENT" number, and "TRACK" number. All sub-assemblies in cluster 17 would be printed in numerical order, all elements in each sub-assembly would be printed in numerical order, and all tracks in each element would be printed in numerical order. Further, in this same example, perhaps only data for sub-assembly 23 in cluster 8 is desired. The program would then scan the data for sub-assembly 23 in cluster 8 and print all data in that structure, identifying the various pieces with the appropriately lalbelled "ELEMENT" number in numerical order, and for each element print data for all "TRACKS" in numerical order.

Multiple hierarchies may be defined in the same problem. In the example given, the order of the definitions of "SUB-ASSEMB" and "CLUSTER" might be interchanged, with the result that these two fields would be interchanged in the hierarchy. This would then allow, for example, the specification of sub-assembly 14 and the program would print the results for every cluster which contained sub-assembly 14 in numerical order of cluster, then for each such cluster, would print the results for each element in numerical order of element, and finally for each such element would print the results for each track in numerical order of track.

For each quantity edited, the maximum and minimum values and their "location" (given by defined labels as noted previously) are printed. In the scan for maximum and minimum values, zero values are ignored. An option exists to scan a defined structure and print only such maximum and minimum values and their location.

Of course, this edit system depends on the user to include some structure in the various geometry labels. In the example, digits 3 and 4 in a channel label might always represent the cluster number; digits 6 and 7 might always represent the sub-assembly number; digit 1 might always represent the element number. For such a structure, element 3 in sub-assembly 19 in cluster 12 would have a channel label of 1901203. The track label in this example contained only a single field so it could contain track numbers in any order convenient for proper identification of results.

In these edits, sub-structures which contain nothing but zero data values are not printed. At the lowest level, data values are printed across a line and leading zero values are skipped.

The labels used in identifying the output are abbreviated to the first n characters of the input lables where n is the number of digits in the field. The data values may be optionally printed in a very compact fixed point form $x.xx$ or in a more general floating point form. The following example shows the general form of this type of output for a quantity whose structure is given by the sample names and field widths as described previously. The data values in this example are in the fixed point format. The example represents all of the fine block power data in sub-assembly 23 within cluster 8 ordered by element and then by track.

```
          FINE  BLOCK        POWER
          CLUSTER     8/ SUB-ASSEMB 23/
          ELEMENT    E/ TRACK      TRA/
E TRA
1   1...  1.05   .91   .81   .81   .89   .94   .98   .94   .85
2   6...  1.07   .89   .78   .79   .91
3   7...  1.03   .98   .87   .76
4   3...  1.05  1.01   .95  1.08  1.24  1.32  1.41  1.37

 MINIMUM  FINE  BLOCK        POWER
          CLUSTER     8/ SUB-ASSEMB 23/
          ELEMENT    E/ TRACK      TRA/
E TRA
3  10...   .76

 MAXIMUM  FINE  BLOCK        POWER
          CLUSTER     8/ SUB-ASSEMB 23/
          ELEMENT    E/ TRACK      TRA/
E TRA
4   9...  1.41
```

17.9. OUTPUT EDITING: CONTROL SEARCH OUTPUT

The program output during a control search consists of one set of results for each search "try"; that is, one set of results for each spatial calculation. The type of results obtained depend on which one of four different control searches is being performed: (1) one - dimensional multi - configuration search; (2) poison search; (3) two - dimensional or three - dimensional movable fuel or control rod search; and (4) three - dimensional synthesis fast rod search.

In the first type of control search (one - dimensional multi - configuration search), the following items are printed for each search try.

(a) Number of outer iterations, eigenvalue, reactivity (percentage), and dominance.
(b) Current configuration number.
(c) Point number.
(d) Height (inches).
(e) Worth per inch.
(f) Mean height of calculated worth.

In addition, some warning comments may appear. If the desired eigenvalue is not obtainable, or if a change in position or configuration produces an inconsistent reactivity change, these facts are printed. Items (c) through (f) do not appear if the current configuration has no specified movable boundary. Otherwise, item (c) is the movable boundary nearest the bottom of the core where bottom is optionally point zero or the last point in the problem; item (d) is the distance (in inches) of the point (described above, item (c)) from a specified reference point. Items (e) and (f) are not printed for the first try in a given configuration, but (e) represents the change in eigenvalue (per inch) due to a move within one configuration, and (f) is measured in a manner similar to the method described for item (d), but represents the height midway between two consecutive positions within one configuration. Finally, when the search has converged, the position of each composition (in composition - point pairs) in the current configuration is printed with movable boundaries (if any) indicated by a negative composition number.

In the second type of control search (poison search), the following items are printed for each search try.

(g) Number of outer iterations, eigenvalue, reactivity (percentage), and dominance.
(h) Current fraction value.
(i) Worth (per fractional change).
(j) Next (predicted) fraction value.

Item (i), the worth of the control element, represents the change in eigenvalue due to a change in the fraction value. If the worth becomes "too small" in absolute value, that fact is noted and the problem is immediately aborted.

In the third type of control search (two or three - dimensional movable fuel or control rod search), the following items are printed for each search try.

(k) Number of outer iterations, eigenvalue, reactivity (percentage), and dominance.
(l) Current control position.
(m) Incremental move.
(n) Non - incremental move.
(o) Current worth (per centimeter) and the implied move required.
(p) Actual move with predicted eigenvalue.

In addition, some warning comments may appear. These comments will appear if fine mesh moving is held up for convergence of other feedbacks; the desired reactivity cannot be obtained; the maximum number of search tries has been executed; when mesh spacings have become "too small" during fine mesh moving; and when a fine mesh move is impossible due to interface line-up difficulties. Moves and positions are given in terms of distances (in centimeters) from a specified reference point. If the worth becomes "too small" in absolute value, that fact is noted and the problem is immediately aborted.

In the fourth type of control (three - dimensional synthesis fast rod search), the items edited are exactly those described for the third type above with fine mesh moving (two - dimensional movable fuel or control rod search) with a few additional comments. These additional comments are warnings of unusual conditions and include the fact that exact (fine mesh) moving cannot take place because there are no "free" mesh points interior to a block plane, and the fact that a zone boundary has been moved in order to allow a particular fine mesh move.

17.10. OUTPUT EDITING: THERMAL FEEDBACK OUTPUT

At the end of the calculation of fuel and moderator temperatures and moderator density during each feedback try, the maximum relative error of the convergence parameter is edited. Also the total flow is edited at the end of the first feedback try. The maximum of the error is taken over every gross block. The definition of the error of the convergence parameter is the relative change in the parameter from the previous feedback try. This parameter is not the concentration representation of the temperatures or density, but is defined as follows:

(1) For fuel temperature, the square root of the calculated fuel temperature (in degrees Rankine) is tested;
(2) For moderator temperature, the calculated moderator temperature (in degrees Fahrenheit) is tested; and
(3) For moderator density, the calculated hydrogen number density is tested.

Under input option, integrations are performed for various thermal quantities defined by Equations 17.10.1 and are printed for each edit set by plane grouping and axial edit. The notation is that used in Reference 14, and the units of each quantity are shown in parentheses directly below the item name.

If editing is requested for this feedback calculation, it is done for every feedback try. The edit "limiting" associated with the average concentration edits as well as the axial edit limitations are applicable to this feedback editing (see card 011000 in Section 12.2).

The pseudo nuclide concentrations representing thermal feedback calculational results are like any other concentration and as such may be edited in an integral fashion or by local value to obtain the spatial distribution.

EQUATIONS 17.10.1

$$\text{Fuel temperature (deg. F)} = \frac{\int T_F \, V_F \, dv}{\int V_F \, dv}$$

$$\text{Moderator temperature (deg. F)} = \frac{\int T_M \, \bar{\rho} \, V_C \, dv}{\int \bar{\rho} \, V_C \, dv}$$

$$\text{Moderator density (fractional change)} = \frac{\int \frac{N_H - N_H^{ref}}{N_H^{ref}} \, dv}{\int dv} \qquad 17.10.1$$

$$\text{Vapor (volume fraction)} = \frac{\int R \, V_C \, dv}{\int V_C \, dv}$$

$$\text{Heat flux (BTU/hour - ft}^2\text{)} = \frac{\int \phi \, A_H \, dv}{\int A_H \, dv}$$

17.11. OUTPUT EDITING: XENON FEEDBACK OUTPUT

At the end of the calculation of equilibrium concentrations of iodine and xenon during each feedback try, the maximum relative error of the xenon is printed. This error is defined to be the relative change in concentration from the previous feedback try with the maximum taken over every gross block containing these isotopes.

Under input option, integrations are performed to obtain volume weighted averages for the equilibrium concentrations of iodine and xenon. These two concentrations as well as the volume are then printed for each edit set by plane grouping and axial edit.

If editing is requested for this feedback calculation, it is done for every feedback try. The edit "limiting" associated with the average concentration edits as well as the axial edit limitations are applicable to this feedback editing (see card 011000 in Section 12.2).

COMPUTER PROGRAM ABSTRACT

1. Program Name and Title:

   PDQ-8 ... A One, Two, and Three Dimensional Neutron Diffusion - Depletion Program.

2. Computer and Language(s):

   CDC-6600 / CDC-7600, FORTRAN. COMPASS equivalents of a few key subroutines are included.

3. Problem Solved:

   The PDQ-8 program (Reference a) is designed to solve the neutron diffusion - depletion problem in one, two, or three dimensions on the CDC-6600 and CDC-7600 computers. Very large problems can be accommodated. The three dimensional spatial calculation may be either explicit or discontinuous trial function synthesis. Up to five lethargy groups are permitted. The fast group treatment may be simplified P(3), and the thermal neutrons may be represented by a single group or a pair of overlapping groups. Adjoint, fixed source, one iteration, additive fixed source, eigenvalue, and boundary value calculations may be performed. The program allows for time dependent representation of cross section variation and generalized depletion chain solutions. The depletion is a combination gross block depletion for all nuclides as well as a fine block depletion for a specified subset of the nuclides. The geometries available include rectangular, cylindrical, spherical, hexagonal, and a very general quadrilateral geometry with diagonal interfaces. All geometries allow variable mesh in all dimensions. Various control searches as well as temperature and xenon feedbacks are provided.

4. Method of Solution:

   For the explicit spatial solution, difference equations are obtained at each point by integrating the differential equations over an appropriate mesh element. The resulting equations are three-point, five-point, seven-point, and nine-point for one dimension, two dimensional rectangular, two dimensional hexagonal and three dimensional rectangular, two dimensional quadrilateral and three dimensional hexagonal. The group equations are solved directly using Gauss elimination in one dimension, by use of the single-line cyclic Chebyshev semi-iterative method in two dimensions, and by use of the single line successive overrelaxation method in three dimensions. The source iterations are accelerated by use of Chebyshev extrapolation applied to the group fluxes. The synthesis solution utilizes the axially discontinuous trial function formulation and solves the iterative problem by use of the Weilandt method. The feedback capabilities are implemented by utilizing a system of time-dependent cross sections and generalized depletion chains.

5. Restrictions on the Complexity of the Problem:

   The total number of groups is limited to five, although six equations may be solved if the P(3) option is used. All storage is dynamic so no fixed problem size limits are imposed. However, as a general rule, the product of groups and points in an explicit solution is limited to roughly ten million due to disk capacity limitations. For synthesis calculations, the disk capacity limitation of about thirty million will limit the product of the number of gross blocks per plane and the number of trial functions or the product of the total number of gross blocks and the number of isotopes. These disk capacity limitations are for the CDC-7600; the capacity of the CDC-6600 is about one-tenth of the stated limitations.

6. Relationship to Other Programs:

   Cross sections ("tablesets") may be input on cards and/or may be obtained from a File Manager (Reference b) input file. Input card data may be merged with card data from one or more File Manager input files. The program will also accept input File Manager files containing pointwise flux, block concentrations, geometry, block flux, synthesis integrals, and quadrilateral geometry figures. On request, the program will prepare File Manager output

files containing pointwise flux, block concentrations, partition power, various edit integrals, geometry, gross block power, block flux, synthesis mixing coefficients, synthesis integrals, fine block power, and quadrilateral geometry figures.

7. Typical Running Time:

The program can solve two dimensional problems at the rate of about one million group-points per hour and three dimensional problems at the rate of about one-half to three-quarters of a million group-points per hour. These rates are for the CDC-7600; the CDC-6600 is about one-fifth the speed of the CDC-7600. The synthesis spatial solution time is dependent on the number of trial functions used and the number of gross blocks. The actual running times may vary widely due to the convergence rate of the iterations, due to the use of control searches or feedbacks, or due to the complexity of the depletion formulation.

8. References:

(a) C. J. Pfeifer, C. J. Spitz, "PDQ-8 Reference Manual", WAPD-TM-1266 (1978).

(b) W. R. Cadwell, Editor, "Reference Manual - Bettis Programming Environment", WAPD-TM-1181 (1974).

(c) L. L. Lynn, "A Digital Computer Program for Nuclear Reactor Design Water Properties", WAPD-TM-680 (1967).

9. Unusual Features of the Program:

Except for the group flux spatial calculation, both explicit and synthesis solutions utilize the same input, calculational, and edit portions of the program so that consistent comparisons of the two methods can be easily obtained.

10. Status:

In production use.

11. Machine Requirements:

The central memory size should be at least 65K, the program will utilize up to 1000K of extended core memory, and will utilize up to four disks transferring in parallel.

12. Operating System:

SCOPE 3.3 (CDC-6600) / SCOPE 1.1 (CDC-7600)

13. Other Programming, Restrictions, or Operating Information:

The required software environment is described in Reference b. It includes routines for program loading, free-field input conversion and processing, storage and retrieval of "permanent" File Manager files, scratch input/output, storage allocation, and plotting. All files used to communicate with other jobs, including other PDQ-8 jobs, are in File Manager form. The water properties required for thermal feedback calculations are obtained from a package of subroutines described in Reference c.

14. Name and Establishment of Authors:

C. J. Pfeifer
C. J. Spitz

Westinghouse Electric Corporation
Bettis Atomic Power Laboratory
Post Office Box 79
West Mifflin, Pennsylvania 15122

APPENDIX B: PROGRAMMING DETAILS

This section is primarily intended as a guide for maintenance or implementation of the program by the cognizant programmer. The hardware and software environment is described in Reference 1. Descriptions of all environmental subroutines mentioned below are found in that reference.

The particular implementation of the program described in this section is on a CDC-7600 using the SCOPE 1.1 operating system and on a CDC-6600 using the SCOPE 3.3 operating system.

Programming Language

The program is written almost entirely in FORTRAN and an attempt has been made to adhere to the ANSI definition of standard FORTRAN. The exceptions to this include a few occurences of ENCODE/DECODE binary-BCD conversion statements, a few masking AND/OR statements, and a few octal constants. Also non-standard are calls to the environmental subroutine NEXT (descibed below in connection with overlay loading); calls to NEXT have varying numbers of parameters.

Single precision real variables are used throughout the program. On both the CDC-7600 and CDC-6600 each real variable occupies one floating-point format word (60 bits) which may range in absolute value from 1.E-294 to 1.E+322, with approximately 15 significant digits. Each integer variable occupies one fixed-point format 60-bit word. The blank common array (used as the free storage array in central memory) is assigned equivalent real and integer names.

Bit manipulation is performed via the environmental routines PACK and UNPACK. PACK stores several positive integer data items into a single 60-bit word according to a prescribed bit pattern. UNPACK performs the reverse operation. Groups of floating-point format words are compressed into packed words (two values per word) via the utility routine SQOZ. The reverse of this operation is performed by UNSQOZ. SQOZ is used only to reduce the size of output File Manager files.

Although FORTRAN is predominantly used, the program also includes several COMPASS language (CDC-6600/7600 Assembly Language) subroutines. In general these routines are designed to issue instructions to the arithmetic processor in an optimal fashion (based on the timing rules of the CDC-7600) resulting in efficient operation for heavily used computational loops. Less efficient FORTRAN versions are provided for all but one of these COMPASS subroutines. The one exception is GETPUT, which may be omitted entirely without affecting program results. It is included to reduce the overhead associated with calls to the random access storage allocation subroutines GET and PUT by instead calling routines TEG and TUP. GETPUT is found in the (0,0) overlay.

The remaining COMPASS routines are as follows:

MMOVER in overlay (0,0) is a special purpose storage transfer routine.
FINDER in overlay (0,0) is a search used in editing.
SCAN in overlay (1,21) is a search used in defining fine blocks.
EXPGEO in overlay (7,0) expands the hexagonal geometry file used in synthesis flux integrations; used to reduce the size of the geometry file being read and thus reduce I/O time.
MULT1 in overlay (7,0) is a computational loop used for the accumulation of macro weighted flux integrals in the synthesis calculation.
CONVEC, SUMVEC, SUMPRD, PRDIFH, SCPLNG, HEXSUM, HXINT2, PRDIFT, PRDVEC, QUINT1, QUINT2, QUDSM1, QUDSM2, UNPKR4, MULTQ, MULTN, COMBNQ, SUMSQ, PRDVCT, DIFVEC in overlay (7,1) are computational loops used in calculating synthesis flux integrals.
WCPLNG, WSUBST, WRESID, WRELAX, SCPROD in overlay (15,0) are computational loops used in the omega calculation.
CPLING, SUBST, RESID, RELAX in overlay (17,0) are computational loops used in the explicit spatial calculation.
CONVCT, VCTMPY, ACCRES in overlay (26,0) are computational loops used in the calculation of synthesis residuals.

Storage Allocation

The program uses the FTB-4 (Reference 1) set of subroutines and functions for storage allocation and scratch disk I/O.

FTB dynamically allocates all levels of storage to which the program has access. In general, the program assumes access to three levels of storage:

1. CENTRAL is the storage directly accessible by the arithmetic processor. On the CDC-7600 this is Small Core Memory (SCM) containing 65K words. On the CDC-6600 this is Central Memory which also contains 65K words.

2. RANDOM is a high speed random-access store essentially serving to supplement central memory; this storage is assumed to be not directly accessible by the arithmetic processor. In general, random refers to Large Core Memory (LCM) on the 7600 and Extended Core Storage (ECS) on the 6600, each containing 500K words. Specifically, the random unit is determined by the contents of the labelled common block RANDOM which is set by the program in the subroutine START in the (0,0) overlay. This unit is set to SCM or LCM on the 7600 (Central or ECS on the 6600), whichever contains the larger amount of available storage. This allows the program to operate using central memory in place of a separate random access store (although this may result in a decrease in efficiency).

   NOTE

   The program never reads or writes LCM (or ECS) directly; such access is always performed through the FTB-4 routines.

3. DISK is a very large auxiliary store. There are assumed to be four logical (scratch) disks available to the program. These disks are read and written using a special driver. The units used on the 7600 contain a maximum of 40 million words; on the 6600 the maximum is 4 million words. The need for these scratch disks is eliminated in two instances. First, the program, based on the control parameters of the problem, estimates its storage needs. If this estimate is less than the available amount of random store, then the random unit will be used in place of all FTB disk units. Second, the user may force this decision to be made by turning on sense switch 5 or by use of a special input card. Caution is advised in this case as the program will attempt to use random in place of the scratch disks regardless of the actual needs of the program.

A "file" in the FTB sense refers to an allocation of storage on any of these levels. The unit on which the file is to reside is specified by the calling program; additionally, the calling program must descibe the precise logical structure of the file and supply a numerical identifier (ID) in advance of writing the file. When no longer needed, files may be deleted by the calling program (freeing the storage).

The free storage in central memory made available to FTB is a contiguous array (referred to as the FTB array) extending from the beginning of blank common to the last available central memory location. FTB allocates contiguous subsets of this array. Files are allocated both forward (from blank common origin) and backward (from the end of blank common) in the FTB array. Permanent files (mainly files which will remain in central memory for the duration of the problem) are allocated in the higher numbered memory locations (backward in the common array); temporary files are allocated nearer blank common origin. Permanent and temporary files are discriminated in this manner as it is the responsibility of the program (rather than the allocator) to keep the available free storage contiguous. The first temporary file (ID=1) is reserved for holding the text of primary and secondary program overlays as is explained below.

The available storage in the random unit is also allocated in contiguous subsets. All of the LCM (or ECS) to which the program has access is made available to FTB. Should this be smaller than the available amount of central (at the beginning of the problem), the central FTB array will be used as the random unit as well as its normal use and LCM (or ECS) will not be used.

The four FTB disks may be active at the same time. To minimize head motion, only one file may be active on each disk at any time. Disk unit numbers for key data files are set in the INPCTL subroutine in overlay (1,0). Units for other files are frequently determined using the NDIFU1, NDIFU2, and NDIFU3 subroutines in the root to produce unique unit numbers. The disks are buffered through LCM with 20K decimal word buffers per disk on the 7600 (a total of 80K words in LCM). On the 6600, 4K word Central Memory buffers are used for each disk (total of 16K Central). Note that processing disk files also requires central memory space for an access area (one logical set) and a small extended description.

Overlay Structure

The absolute text of the program is segmented into an overlay structure consisting of up to three levels: root, primary, and secondary. Overlay levels are identified by a pair of octal integers (L1,L2).

The overall program control is centered in the main overlay (0,0) which is also referred to as the root. The root overlay occupies the lower numbered memory locations, and always remains in central memory during program execution. Primary overlays are labelled (L1,0) where L1 is nonzero. Some primary overlays have associated secondary overlays labelled (L1,L2), where L1 is the primary overlay number and L2 is nonzero. Routines in the root must use the environmental subroutine NEXT to call routines in primary overlays. Similarly, routines in primary overlays must use NEXT to call routines in their associated secondaries. Calls to subroutines within the same overlay, and to lower levels (from secondary to associated primary, from secondary to root, from primary to root) are made using normal calling sequences.

Calls to NEXT designate an overlay level (L1,L2) and a subroutine contained in this overlay. If the specified overlay level is not currently resident in central memory, NEXT loads the overlay into central from an indexed program file, and then transfers control to the designated subroutine within the overlay.

Blank common origin is the last central memory location in the root, and blank common extends to field length (the last central memory location available to the program). The text of all primary overlays is loaded into core beginning at the second location of blank common. Secondary overlays are loaded immediately following their associated primary overlay.

Because blank common is used by the dynamic allocator FTB, it is necessary for the allocator allow space for the overlay loaded. This is accomplished by the root subroutine ORIGIN which is called by NEXT after the overlay has been loaded but before transfer of control to the designated subroutine in the overlay. ORIGIN changes the size of the FTB file ID=1 in central memory to accomodate the storage needed for the text of primary and secondary overlays. ORIGIN uses the contents of the labelled common block SIZE (which is set by NEXT) to allocate exactly the necessary storage to accomodate the text for the current overlay.

A summary of the overlay structure of the program, including the function of each segment and the routines which it contains, is given in Section 1.3.

Subroutine Communication

Communication between subroutines is done mainly through parameters passed in the standard calling sequences. Note that these parameter lists are also passed when a suboutine is called through the NEXT routine. Additionally the program contains a few labelled common blocks which are used by several segments. With the exception of the CONTRL common block, these labelled commons

contain information which is largely hardware dependent. These labelled common blocks are as follows:

CONTRL contains the master control variables of the program. This labelled common block is declared in a few routines which need access to many of these control parameters, namely the main program named PDQ08, input subroutines INPCTL, CNTINP, IFILES, the synthesis calculation control routine SYNTH, and the output filing control routine OFILES.

BLOK contains an array holding the bit pattern for the packed words in the first geometry file.

COMP contains an array holding the bit pattern for packed composition correspondences and moving boundary indicators used for one-dimensional multi - configuration search problems.

DISK contains a single item, the number of scratch (FTB) disks being used.

GEOM contains an array holding the bit pattern for packed words in the second, third, and fourth geometry files.

RANDOM contains the FTB unit number of the random unit.

VERS contains the program identification.

WORD contains a single item, the number of bits per word (60 on the CDC-6600 and 7600).

The bit patterns in the BLOK, COMP, GEOM, and WORD labelled common blocks are set in subroutine INPCTL in overlay (1,0). The contents of labelled commons DISK, RANDOM, and VERS are set in subroutine START in overlay (0,0).

File Manager

Permanent files are stored and retrieved through the File Manager system described in Reference 1. Briefly, this system permits a program to process files in terms of their logical structure, with no knowledge of the physical format of the files required. File processing is also independent of the physical device used for the permanent retention of the file.

A single routine, called FMG (Reference 1), is used by the program for all communications with the File Manager, both for reading and writing these files. File Manager files are subdivided into sets of data, and the set structure of a file is fundamental to its processing. Two different set structures are provided by the File Manager and each is used for one or more of the output files. In the first structure, the set size is constant and the total number of sets is known in advance. The set size and number of sets are then given to the File Manager before the file is written and are returned by the File Manager before the file is read. In the second structure, the set size is variable in which case it is assumed the number of sets is not known. Here, the size of each set must be given to the File Manager as the set is written and is returned by the File Manager as the set is read. In this case the number of sets given to the File Manager and returned by the File Manager is zero. The writing program must indicate when it has written the last set and the File Manager will indicate to the reading program when the last set has been read.

Three levels of identification are associated with each file: the integer version number and an alphanumeric synonym of up to ten characters both supplied as input by the user, and an integer data type number supplied by the program. Any file type may be written separately as a stand - alone file or it may be combined with any other file type(s) as a sectioned file, but any one file type may be written only once within a single case or sub-case. The content of each section in a sectioned file is written exactly as a stand - alone file, including header set(s), for the appropriate file type. Each section is a "named" section whose section name is the three character alphanumeric equivalent of the particular data type. The File Manager store - directives are scanned first for a stand - alone file directive (the appropriate version number, synonym, and data type); if not found, the same version number and synonym pair together with data type 250 are used to scan the File Manager store - directives to assure that such a directive is present. Then all file - store requests with this same condition (stand - alone File Manager store - directive missing for the particular data type) are scanned for the same version number - synonym pair; if a match is found, those files are grouped together into a single sectioned file. Of course, the program is prepared to read as an input File Manager file either a stand - alone or a sectioned file for any file data

type (including those not written by the program) and scans the File Manager files present in exactly the same way as described for writing output files: *stand - alone first, then sectioned files.*

Input File Manager card files are processed in routine RCARDS in overlay (1,1); input synthesis trial function files are processed in routine SIN7 in overlay (1,27); all other input File Manager files are processed in routine IFILES in overlay (1,3). Output File Manager files are written by the routines in overlay (27,0). The presence of proper File Manager directives for each of the specified files to be output is checked during input processing by routine PREPOS in overlay (1,32). PREPOS initiates a request to write each of the files which is to be output. This will result in an error being flagged if the appropriate File Manager directive is missing; this write request is subsequently dropped before exiting the PREPOS routine.

Input Conversion

The program uses the environmental subroutine CARDS (Reference 1) to convert input cards into a form which is used by the input processing routines. The CARDS routine reads input in a generalized manner that allows the internal representation of each item on each card to be determined by the contents of the field. Each input card contains an identifying number which enables the contents to be referenced independent of the physical location of the card in the deck. The call on CARDS converts all input cards for a case, storing these in the form of a LIST which contains the converted data items, and a TABLE which contains the card numbers and pointers to the data in the list. The INPF package which is used to actually process the input is designed to use this table-list structure.

In addition to normal card input, card images may also be input from File Manager card files. The user specifies input card files on CARDFILE cards in the input deck (see Section 9.2). The input subroutine RCARDS in overlay (1,1) merges any requested card files with the actual card input deck to form the complete input string which is to be manipulated by CARDS. RCARDS reads the card input from the current case (using environmental routine RD80A1) and copies these to TAPE1 diverting all CARDFILE cards to TAPE2. The File Manager card files designated by the cards on TAPE2 are then accessed, and the appropriate case of card images from each file is copied to TAPE2. The actual input cards (less the CARDFILE cards) from TAPE1 are then appended to the input string on TAPE2. TAPE2 then contains the complete input string which is to be converted by CARDS. TAPE1 and TAPE2 are symbolic names used by the program to refer to system files named PASS001 and PASS002 respectively. The call on CARDS is made in CNTINP in overlay (1,2).

Input Processing

The input processing subroutines are contained in the (1,0) overlay and its associated secondary overlays. Overall control for input processing is vested in the INPCTL subroutine in this overlay.

Subroutines in the INPF package (see Reference 1) are used to access and manipulate the table-list which contains the converted input string data as described above. The subroutine LINK in the INPF package is the basic linkage between the program and the table-list. The subroutine MODER in the package is used to check the mode of each data item against a list supplied by the calling routine. The remaining INPF routines supply specialized data moving and checking capability (although basically utilizing LINK and MODER), or serve to manipulate the table-list itself.

The program makes extensive checks on the input data and any input error results in an appropriate error comment. Following the discovery of any input errors, the program will abort the problem after continuing to check as much of the remaining input as possible. Any unused input cards after the input processing is complete are listed via the INPF subroutine INP8 called from INPCTL. The presence of unused cards at this time is considered an error.

The table-list must be in central memory to be manipulated via the INPF routines. Some of the input processing overlays of the program, however, do no require access to the table-list. In order to free this central memory storage, the table list is written to disk before these particular overlays are entered, and retrieved from disk prior to entering succeeding overlays which need access to the table-list. These transfers are perfomed by the SAVER routine in (1,0) called by INPCTL.

When the table-list is in central memory, the storage allocated to it (via FTB) is at the temporary end of the free storage array (nearer the beginning of blank common). The subroutine MEXT is used to shift the table-list to the permanent end of the free storage array, load the required secondary overlay, and shift the table-list back to the temporary end of the FTB array. MEXT effects the loading of the appropriate overlay by calling (through NEXT) a dummy subroutine in the overlay.

Program Initialization

Program initialization is centered in the root subroutine START. START is the only subroutine in the program containing statements whose execution is machine dependent (in this implementation a function of whether running on the CDC-7600 or CDC-6600). The environmental function subprogram JPARAM is utilized to determine the SCM and LCM (Central and ECS on the 6600) available, and which machine is being used. START initializes the storage allocator FTB, specifying the number of scratch disks to be used, the initial number of tracks per disk (on the 7600 only), the size of the disk buffers, the available SCM and LCM on the 7600 (Central and ECS on the 6600), and the unit to be used as the random unit. START also allocates storage for FTB file ID=1 which is used to hold the text for the primary and secondary overlays. START sets up the program identification in the labelled common block VERS. START also initializes the loader via a call on the environmental routine NEXTIN to provide space for the index of overlays for the absolute program file (which is in indexed format).

Sense Switches

The following sense switches produce the indicated effects on a running program:

SWITCH 2 - forces termination of the current iteration and feedback.
SWITCH 3 - forces termination of the problem at the end of the current case or sub-case.
SWITCH 4 - provides a dayfile monitor of overlay names and some intermediate results (including eigenvalues at each outer iteration and the expected total number of outer iterations, depletion pass numbers, and search control positions and configuration numbers).

Switches 2 and 3 are primarily intended for use by the operator. In addition SWITCH 5 (discussed above) may be used to force the program to run without disks.

APPENDIX C: PROGRAM STRUCTURE

This section is primarily intended for use in program implementation or maintenance by the cognizant programmer. The names of all of the subroutines contained in each overlay are listed below. Each overlay is identified by a title of the form SEGNAM (L1,L2), where SEGNAM is the identifier displayed at the console (and in the dayfile if sense switch 4 is enabled) when the overlay is loaded, and L1 and L2 are octal integers identifying the primary and secondary overlay levels respectively. Overlays having more than one title are called from several places and perform different functions on each of the calls. It should be noted that the term "file" as used below refers to an internal FTB file unless otherwise specified.

PDQ08 (0,0)

PDQ08	START	ORIGIN	PLNGRP	SPACER
MOVE	NDIFU1	NDIFU2	NDIFU3	MMOVER
FINDER	GETPUT			

The master control of the program is the PDQ08 routine. This routine governs the general flow of the calculation depending on the type of problem and the various options selected by the user. Looping required for feedbacks is performed by this routine although the logic and strategy for such processes reside in other overlays. This routine also controls the overall loop on input cases and sub-cases. Program initialization is performed by the START routine. ORIGIN is used to allocate sufficient central memory storage for each primary and secondary overlay as each overlay is loaded. The remaining routines in this overlay are specialized utility routines used by various subroutines throughout the program.

INPUT (1,0)

INPCTL	MEXT	SAVER

Overall control of input processing is centered in the INPCTL routine. INPCTL calls a series of input processing subroutines in associated secondary overlays. The series of secondary overlays which are called is based on the type of problem, the options requested by the user, and input errors which may occur. INPCTL also initializes the labelled common blocks containing bit patterns, and assigns FTB unit numbers to be used for key internal files. MEXT is used when necessary to shift the file containing the input table-list to the permanent end of the FTB array in central memory to allow secondary overlays to be loaded at the temporary end of the blank common array. SAVER is used to move the table-list between central memory and disk.

CARD FILES (1,1)

RCARDS	NOTICE

RCARDS creates a file containing the card images from any input File Manager card files followed by the actual card input for the current case. NOTICE is a routine which prints user notices.

READ CARDS (1,2)

CNTINP

CNTINP retrieves the input table-list from the previous case (if any), deletes the cards which are deleted from case to case, calls the environmental routine CARDS to convert the card input, and saves the new input table-list. CNTINP also processes the cards which contain the main control parameters for the problem. These parameters are extensively checked to assure the consistency of the problem being defined. CNTINP also produces the one page edit of control parameters for the problem.

IN FILES (1,3)

IFILES

IFILES processes the following File Manager input files: concentrations, tablesets, pointwise flux, integrated flux, geometry, and quadrilateral figures. The files input are checked for consistency with the current problem, and the data from these files is stored in internal (FTB) files.

GEOMETRY (1,40)

GEOCRD	GMINPT	COMFIG	GETANG	LABFND
ZZGRID	TWISTR	AREAPL	EDZMSH	PICINP
DMYG				

This overlay processes quadrilateral geometry card input. GEOCRD is the control routine. GMINPT processes basic figure data including card series 05, 07, 7, 8, and 15. COMFIG processes compound figure data on card series 9. PICINP processes plot and printed picture edit requests from card series 0102. This overlay produces two files needed by the geometry generation routines, one containing basic figure data and one containing compound figure data. This overlay also produces an optional input edit.

BASICS (1,42)

BASCON	BASCFG	BFOVER	XYPNTS	PCKDWD

This overlay generates basic and auxiliary figures in quadrilateral geometry only. BASCON is the control routine. BASCFG constructs the basic figures and auxiliary figures, and stores each generated figure in a separate file.

COMPOUNDS (1,44)

SFCONT	DEFPNT	PNTSCN	OVRLAY	ANGLE1
ROWADJ	GBFFSF	GSFFBF	SHFTOR	

This overlay generates compound figures in quadrilateral geometry. SFCONT is the control routine. The description of each compound figure generated in this overlay is written into a separate file.

CHECKING (1,46)

CHKFIG

CHKFIG checks the solution figure in quadrilateral geometry to assure that a legal solution mesh has been generated. CHKFIG also rewrites the solution figure file to triangulate the mesh.

TRANSFORM (1,50)

FIGFLS PLAREA

FIGFLS reads the solution figure file in quadrilateral geometry and writes two auxiliary files containing geometry information which are used by the blocking routines. PLAREA compares the calculated planar region areas with the input planar region areas (if any).

MEASURE (1,52)

DSTORT DSTCAL DIADST MSHHST GRAPHG
TRIIND ANGLER

This overlay calculates and edits the quadrilateral distortion indicators. DSTORT is the control and editing routine. DSTCAL reads the solution figure file and calculates the distortion indicators.

DRAWING (1,54)

PLTFIG PLOTER RTSQD1 RTSQD2 LTSQDG
RTOFD1 RTOFD2 LTOFD1 LTOFD2 RTANGH
RTANGV PICEDT PICROW PICCOL DIAGNL
GATHER

This overlay produces plots and printed picture edits for quadrilateral geometry figures. The overlay reads the figure files. PLTFIG is the overall control routine and the plotting control. A buffer for the plotting file (which is a system file) is created using ENTFIL and deleted using DELFIL. PICEDT is the printed picture edit control.

GEOMETRY (1,5)

GEOCNT GEOMIN DMY2A

This overlay processes card input geometry data for rectangular and hexagonal geometry. GEOCNT is the control routine. GEOMIN processes card series 05, 15, 16, 17, 7, 8, and 9. Basic figure data, super figure data, and final figure overlay data are stored in separate internal files for use by the geometry generator. This overlay produces an optional input edit.

RECTANGLE (1,7)

RECMSH RECOVR DMY2B

This overlay generates the geometric solution space for a rectangular problem. RECMSH is the control routine for rectangular geometry generation. It computes planar region areas, stores the row and column mesh intervals, writes two auxilairy files containing geometric data used in blocking, and writes geometry file 4. RECOVR defines the geometry for each point in a single row. These routines also check that a legal grid has been described.

HEXAGON1 (1,11)

HEXMSH HEXOVR DMY2C

This overlay is the first of two overlays involved in contructing the solution grid for hexagonal geometry problems. HEXMSH is the control routine for hexagonal geometry generation. It computes planar region areas, writes an auxiliary file containing geometry information to be used in blocking, and writes an intermediate hexagonal geometry file which will be translated by the succeeding overlay. HEXOVR determines the geometry for a single row of the mesh. These routines also check that a legal hexagonal lattice has been described.

HEXAGON2 (1,13)

HEXFIL SIDE3

This is the second of two overlays involved in hexagonal geometry generation. HEXFIL reads the temporary geometry file written in the previous overlay and writes a canonical form hexagonal geometry file (this is the side and angle information to be written in geometry file 1). HEXFIL also writes an auxiliary file containing geometry information for use by the blocking overlay.

AXIAL DATA (1,15)
PICTURES (1,15)

PLMESH PICCAL RECPIC HEXPIC PCUNPC
OPTION DMY2D

This overlay is called for two different purposes. First, the subroutine PLMESH processes input axial mesh intervals and input planar region areas (card series 07 and 18 respectively). Second, the overlay produces the printed geometry picture edits for rectangular and hexagonal geometry. PICCAL is the control routine for the picture edits. RECPIC constructs the printed picture edits for rectangular (and cylindical) geometry. HEXPIC constructs the picture edits for hexagonal geometry.

MATERIALS (1,17)

CMPCRR DMY2E

CMPCRR processes and edits composition correspondence data, gross plane boundary data, and fine plane boundary data (card series 03, 060, and 061 respectively). The composition correspondence data is stored in a random file, so only a single configuration (or a single plane) need be held in central memory.

BLOCKING (1,21)

BLKCNT GBLOK1 GBLOK2 FBSCAN BLKFIL
FBAREA GBAREA SCAN SKTRAN BLKEQU
NEWCNC CONEXP

This overlay determines the set of transverse gross and fine blocks for the problem in all geometries. Additionaly, this overlay performs concentration expansion if requested. BLKCNT is the control and editing routine for blocking. GBLOK1 performs position independent blocking for two-dimensional rectangular, and all hexagonal and quadrilateral geometry problems. GBLOK2 performs rectangular blocking for cylindrical geometry, and also blocks all one-dimensional problems. The overlay reads two auxiliary geometry files written by the geomtry generation overlays, writes geometry files 2 and 3, and also writes the block numbers into geometry file 1. BLKCNT also serves as the control routine for concentration expansion. This calculation reads the old and

new geometry files, deduces the old block to new block transformation, and expands the old concentration file into a new concentration file based on the expansion definition.

HARMONY (1,23)

DPLIN1	CHANE	FILER	PRID	INPID
NUCHN	CHLIST	INDEX1	PACK1	STOVFL
NUCON	UNFIT	UNPK1	OVLAY	PRERC1
OVERC	NC1C2	ITYPEC	NPACK2	TABCTL
CDTABS	MORDER	NPK2A	BUCKIN	REQTAB
MSKSCH	UNPK2	PROVER	INDEX2	DPLIN2
ARATIO	FBNUCS	DMY3		

This overlay processes HARMONY input data. There are two major control routines in the overlay, namely DPLIN1 and DPLIN2, and each is called separately from INPCTL. DPLIN1 processes and edits all HARMONY card input data, including nuclide IDs, chains, chain lists, initial nuclide concentrations, tables, table overlay controls, tableset assignments, buckling, and area ratios (card series 3, 09, 10, 14, 11, 4, 12, 13, 08, 19, and 02). DPLIN1 creates a series of internal HARMONY data files used by several of the succeeding calculational overlays. Additionally, temporary files which are used by DPLIN2 are written. DPLIN2 reads these DPLIN1 files and a possible input table-set file, and also writes a series of internal HARMONY data files which are later used by several of the calculational segments.

FEEDBACKS (1,25)

SCHINP	THINPT	THGEOM	ERPRNT	MODCHK
PUTAWY	SRTCHK	FLUIDP	DMY4	

This overlay processes all card input for feedbacks. SCHINP processes all of the card input for the poison search, movable fuel search, fast rod search, one-dimesional multiple configuration searches, and xenon feedback. THINPT processes thermal feedback card input data. FLUIDP uses the HOH routines (see Reference 15) to set up an internal file containing water property tables for thermal feedback problems.

SYNTHESIS (1,27)

SIN1	SIN2	SIN3	SIN4	INTSCH
SEARCH	PARKIN	EXPAND	IAND	IOR
TMAP	INPEDT	SIN7	DMY32	

This overlay processes synthesis card input data and synthesis File Manager data. SIN1 is the control routine for processing and editing synthesis input. SIN1 processes the synthesis control information and also reads a possible input File Manager synthesis integral library file. SIN7 reads the input File Manager trial functions and writes each into an internal FTB file. The overlay writes a file containing a list of the trial function integrals which are required.

EDIT SETS (1,30)

SLICER	DISINP	EDTINP	REDINP	DMYEE

The routines in this overlay perform several separate input processing functions. This overlay is called from several places in INPCTL. SLICER manipulates the internal files and control indicators to change a 3-D explicit problem into a 2-D problem at a specified plane. DISINP processes display edit and blockwise edit input on card series 02 and 0103 respectively. EDTINP processes edit set, plane grouping, and axial edit card input on card series 011 - 016. REDINP processes block collapsing card input on card series 017 - 019 and 062.

REDUCTION (1,31)

REDUCE	RADCOL	REWRTE	RADAVG	RADSUM
AXIAVG	AXISUM	LIBSUM	RARAVG	AARAVG
NDIFFF				

This overlay performs the optional transverse and axial gross block collapsing based on a user defined scheme. REDUCE is the control and editing routine for block collapsing. The overlay rewrites geometry files 1, 2, 3, and 4, the gross and fine block integrated flux files, the gross and fine block concentration files, the synthesis integral library file, and the area ratio file. The gross block files are collapsed either axially or in the radial direction by either volume averaging or summing. The fine block files are reordered. Upon exit from this overlay, all internal files have been transformed to be consistent with the new (collapsed) geometry.

SUBCASES (1,32)
END INPUT (1,32)

SUBCAS	CASENN	PREPOS	EXPCON	FACGET
FBTRAN	EXPFLX	DMY2F		

This overlay contains routines performing various input processing tasks, and is called from several places in INPCTL. SUBCAS processes card input for sub-case data (series 2XX) if any. CASENN is the control routine for sub-case execution, resetting the data required by a sub-case and producing the edit of control information for each sub-case. PREPOS checks for the existence of proper File Manager directives for each File Manager file to be written. EXPCON writes the concentration file; this routine also processes and utilizes possible composition replacement data. EXPFLX writes the pointwise flux guess file for each group.

CHECKLIST (1,33)

CHKLST	LINEUP

CHKLST prints the input checklist (descriptions of all input cards). This overlay is called only when the program has been executed with no card input, and is not part of the normal input processing.

X-SECTIONS (3,0)

SIGMA	TABLES	STORE1	STORE2	INTERP
STORE4	DECOD2	DECOD1	INTRP	STORE3
ENCOD1	ENCOD2	REGCMP	GEOMWD	LCHECK
SIGMAS	MACDIF			

This overlay calculates the macroscopic data for all gross blocks. The overlay reads the concentration file and HARMONY data files and writes the macroscopic data file and kappa sigma fission file. SIGMA is the overall control routine. SIGMAS is the control routine for DATALINK problems only, and produces four macroscopic data files (reference and three feedback conditions).

CONFIGURE (5,0)
AXIAL MOVE (5,0)
SEARCH (5,0)
ROD SEARCH (5,0)

CNFEED	MOVFUL	MOVER	MOVING	IHIGHT
CMPSHF	IMPLYZ	MINT2	NONINC	ZIPED
CURPT	MXMOVE	MOVZIP	ZIPSCH	ZIPCED

This overlay performs the logic involved in the operation of the various control searches. Different subroutines in this overlay are called from various places in the PDQ08 routine in the root overlay depending on the type of search being done and the function to be performed. CNFEED contains the logic which determines the search strategy for the movable fuel search, fast rod-search, and poison search. MOVFUL accomplishes the required moves in 3-D and R-Z control searches, altering the necessary files which may include geometry files, concentration files, macroscopic data file, kappa sigma fission file, and composition correspondences. MINT2 rewrites the macro-weighted flux integral file for the fast rod-search. ZIPSCH is the control routine for the one-dimensional multiple configuration search.

SYNTHESIS (7,0)

SYNTH	CNTRCT	EXPGEO	MULT1

This overlay is the control for the calculation of the trial function product integrals and the weighting of these integrals by the macroscopic data to be used in the synthesis spatial calculation. The actual calculations are performed in the two associated secondary overlays. SYNTH serves as the overall control routine.

FLUX INT. (7,1)

SINT1	PROWXY	PROWHF	CONVEC	SUMVEC
SUMPRD	PRDIFV	PRDIFH	SCPLNG	HEXSUM
HXINT2	PRDIFT	PRDVEC	ISORT	INTCMP
QSSCRB	GEOPRC	PROWQ	QUINT1	QUINT2
QUDSM1	QUDSM2	UNPKR4	MULTQ	MULTN
COMBNQ	SUMSQ	PRDVCT	DIFVEC	INTCMQ
DMY161				

This overlay calculates the synthesis trial function product integrals. SINT1 writes a file containing the newly calculated trial function integrals, reading geometry file 1, the trial function files, and a file containing descriptions of the integrals to be computed. PROWXY is the control for the integration over one row of the mesh in rectangular geometry; PROWHF is the control for integration in hexagonal geometry; PROWQ is the control for integration in quadrilateral geometry. The computed integrals are written into a file which is then combined with a possible input synthesis library file to produce a set of files by trial function zone containing the sorted product integrals.

MACRO WT. (7,2)

MINT1	MTOUT	DBLMNT	ALIGNR	DMY162

MINT1 combines the macroscopic data and the trial function product integrals to create a file containing macroscopic integrals. MINT1 reads the macroscopic data file and the trial function product integral files and writes the macro-weighted integral file. An auxiliary macroscopic data file is written by this overlay when a residual calculation has been requested. Several auxiliary macro-weighted integral files are written when a fast rod-search is being done.

MIX COEFF. (11,0)

MIXCNT	MTRMPY	MTRSUB	SCAMTR	SCMADD
SCAMT3	MTRMP3	MTRVEC	VECVEC	INVRT
CALMTR	ITER	MNFR		

This overlay performs the synthesis spatial calculation, reading the macro-weighted integrals, and generating an eigenvalue and a set of mixing coefficients. MIXCNT is responsible for the overall control of the iteration, sets up the storage allocation, performs editing, and checks for convergence. The overlay reads the macro-weighted integral file, and writes an axial mixing coefficient file.

MATRICES (12,0)

COEFQ	SORTQ	SETCHI	CSCRIB	TRANSC
ROWMAC	FACTOR	ROT90	DCPL1	DCPL2
HVDCPL	FRCPL1	FRCPL2	NORML	DWGHTG
CONSTV	DOVERA	SIGCPL	INVERS	ROT180

This overlay produces the factored and normalized coefficient matrices for an explicit spatial calculation in quadrilateral geometry, reading geometry file 1 and the macroscopic data file, and writing three coefficient files for each energy group. Auxiliary files are created from both the geometry and macroscopic data files for use only in this overlay. COEFQ is the overall control routine.

COEFF. (13,0)

COEF	SORT	NORM

This overlay is the control for the calculation of the factored and normalized coefficient matrices for the explicit spatial calculation in rectangular and hexagonal geometries. The overlay reads geometry file 1 and the macroscopic data file, and writes three coefficient files for each energy group. COEF is reponsible for the overall control of the calculation and allocation of storage. COEF also writes an auxiliary geometry file in hexagonal geometry. COEF calls one of the two associated secondary overlays depending on geometry type. Auxiliary files are created from both the hexagonal geometry and macroscopic data files for use only in this overlay.

RECTANGLE (13,1)

COFROW	DELINT	SIGINT	DMY51

This overlay computes coefficients for rectangular geometry. COFROW is the control routine for the calculation of coefficients for a single row of the rectangular grid.

HEXAGON (13,2)

HEXROW	HEXDEL	HEXSIG	DMY52

This overlay computes coefficients for hexagonal geometry. HEXROW is the control routine for the calculation of coefficients for a single row of the hexagonal grid.

OMEGA (15,0)

OMEGA	WNNERS	WNVERT	WLLOC1	WLLOC2
WLLOC3	WLLOC4	WLLOC5	WCANDO	WNIT3D
WNDSTK	WAST3D	WUDGER	WCRIBR	WNPRNT
STRATG	WCPLNG	WSUBST	WRESID	WRELAX
SCPROD				

This overlay reads the coefficient matrix files and calculates the eigenvalues of the Gauss-Seidel iteration matrices for use in the explicit spatial calculation. OMEGA is the overall control routine. WNNERS controls the inner iterations for one sweep of the mesh. WNVERT is the control routine for inversion one line of the mesh.

ITERATION (17,0)

ITERAT	INITSC	GRPSRC	INNERS	OUTERS
EXTRAP	INVERT	TOTRUE	ALLOC1	ALLOC2
ALLOC3	ALLOC4	ALLOC5	MONFOR	PREDCT
INIT3D	ENDSTK	LAST3D	FUDGER	SCRIBR
INPRNT	DELCPL	CPLING	SUBST	RESID
RELAX				

This overlay performs the explicit spatial calculation for all geometries. The coefficient matrix files and pointwise flux guess files are read, and the pointwise solution flux files are rewritten. ITERAT is the overall control routine. INNERS controls the inner iterations for one sweep of the grid. INVERT is the control for the inversion of one line of the mesh.

FLUX/POWER (20,0)

POWCON	FLXCON	COMCON	COMBIN	PNTSYN
AXINT	PTHRE	MIXINT	FLXIN2	GETFAC
INTCON	ONEDIM	ETODSK	TWODRC	RECT3D
CONPLN	ADDECS	DMPDPL	TWODHX	HXGL3D
NEWGFL	CONT2D	DSKUNZ	UNTSET	QUAD2D
QUAD3D	FINPOW	GROSPW		

This overlay calculates the integrated flux over gross and fine depletion blocks for each energy group. The overlay also calculates gross and fine block power. POWCON is the overall control routine. POWCON calls FLXCON, which is the control routine for synthesis flux integration and also for generation of pointwise flux in synthesis problems. The integration of the pointwise flux in explicit problems is controlled by INTCON, which calls separate routines to perform the integration for one-dimensional problems, and each of two- and three-dimensional rectangular, hexagonal, and quadrilateral problems. Gross block power is written by GROSPW, which reads the gross block integrated flux and gross block kappa sigma fission files. Fine block power is written by FINPOW, which reads the fine block integrated flux, fine block concentrations, and gross block kappa sigma fission files.

MACRO EDIT (21,0)
INTEGRALS (21,0)

INTEDT	JCHECK	FINDRG	SIGEDT	RECINT
EDFLUX	EDKSF	EDSIGA	KINFIN	KEFFEC
INDBUC	DEPBUC	AVERAG	EDFLWT	EDITAL
AXIALE	DEDUCP	GRAPHA	GETFCT	

This overlay is called to (1) perform editing of volume-weighted macroscopic data, or (2) perform editing associated with integrals of the flux and macroscopic data. The overlay reads the macroscopic data file and integrated flux files and writes the edit integrals into a file for possible saving in a File Manager file. The edits in this overlay are produced over the user defined edit sets, plane groupings, and axial edits. INTEDT is the overall

control routine. SIGEDT controls the editing of the volume-weighted macroscopic data. EDITAL controls the outputing of the integral quantities.

DEPLETION (23,0)

DEPLET	PACKER	STORE5	INTVAL	DOINTR
DECOD4	DECOD3	INTPRT	ENCOD3	ENCOD4
RATES1	DEPLT1	DEPLT2	EDITRT	EDITNS
DOEDTN	DOEDTR	WDGEOM	KCHECK	CMPREG
AXIALC	TELLER	FBCHNS	FBDPLT	DEDUCC
GRAPHC	COLCOM			

This overlay performs gross and fine block depletion for any number of time intervals, and performs all editing of microscopic data and average nuclide concentrations that may be requested. This segment also edits collection and combination data. The overlay reads the gross and fine block integrated flux files, reads the gross and fine block concentration files, and reads the HARMONY data files. The gross and fine block concentration files are rewritten to contain the end-of-timestep number densities. The overlay also writes a set of integral files containing nuclide power, absorption rates, fission rates, and integrals of volume and nuclide concentrations, used for possible File Manager saving. The overall control routine for this calculation is the DEPLET routine.

N(T0) EDIT (24,0)
N(T1) EDIT (24,0)
POWER EDIT (24,0)

EDTCAL	CNTEDT	EXPD1D	ONDEDT	BALOON
TNTEDT	EDT1ID	DSP1PG	GRAPHM	MAXPOW
BLKCTL	SORTGM	FBEDIT	BUILDR	REFORM
CTLDIS	DISCTL	DISPLA	DISEDT	LINSET
SHOWIT	GETDAT	ONEPLN	BORDER	MAXMIN
HEXDIS	HEXEDT	MAXHEX	SINPLN	PKCHEV
PAGPRT	COUNTP	RSTEST	BOUND1	BOUND2
HBORDR	NOROW1	NOROW2	EDGEA	EDGEB
UPKPR1	ISTORA	IUNPK1	LNWRT1	UPKPR2
ISTORB	IUNPK2	LNWRT2		

This overlay edits certain data by mesh element. The overlay is called in several places in the PDQ08 routine in the root overlay to edit beginning-of-timestep gross and fine block concentrations, end-of-timestep gross and fine concentrations, and gross and fine block power. The form of the edits produced may be meshwise edits, heirarchical edits, or display edits. The overlay reads the geometry files, the gross and fine block concentration files, and the gross and fine block power files. EDTCAL is the overall control routine for mesh editing. CNTEDT is the control routine for editing by mesh element. BLKCTL is the control routine for heirarchical edits. CTLDIS is the control routine for display edits.

POINT EDIT (25,0)

EDTCON	NUMPIC	FINDB	PTPART	FIXFOR
PNTFLX	AXEDIT	EDWRIT	GRAPHZ	

This overlay produces edits for pointwise results. These edits include synthesis axial mixing cofficients and fractional flux plots, pointwise flux, partition power, pointwise average power and pointwise peak power. The pointwise flux files and kappa sigma fission files are read and a partition power file may be written (for possible editing or saving in an output File Manager file). The overall control routine is EDTCON. There are two associated secondary overlays, one for 1-D and 2-D problems and the second for 3-D problems.

1-D EDIT (25,1)
2-D EDIT (25,1)

POWER1	POWER2	EDIT1D	POWER3	POWER4
RMAX2	DMY101			

The routines in this overlay are used to edit pointwise results in 1-D and 2-D problems. The control routine is EDTCON in the associated primary overlay.

3-D EDIT (25,2)

POWER5	POWER6	RMAX3	DMY102

The routines in this overlay are used to edit pointwise results in 3-D problems. The control routine is EDTCON in the associated primary overlay.

RESIDUALS (26,0)

ERRCNT	RESIDL	EDTERR	PLOTER	GRAPH1
GRAPHN	REORDR	CONVCT	VCTMPY	ACCRES
EDTERA	ALIGNF			

This overlay performs the optional synthesis residuals calculation and edits the results via printer plots. ERRCNT is the control routine. RESIDL is the calculational routine, which reads the mixing coefficient file, trial function product integral files, and a macroscopic data file.

OUT FILES (27,0)

OFILES	FILFLX	FILCNC	FILPPW	FILITS
FILGEO	FILBPW	FILINF	FILMCF	FILILB
FILBAV	FILFIG	SAVPRT		

File Manager files which are to be output are written by this overlay. OFILES is the control routine. SAVPRT is the editing routine. The remaining routines each write one particular File Manager file reading the appropriate internal FTB file(s).

DATA LINK (30,0)

LNKCNT	DTALNK	MATRAN	BLTCOL	ADDER
DITCOL	POWER	MTSUB	FILR	

This overlay writes the File Manager DATALINK file. LNKCNT is the control routine.

THERMAL FB (31,0)

THFCON	GETTHD	INLETH	THSTOR	CALCT3
DOTEMP	ENTHLP	BLKINV	POLVAL	GEOMDO
IMPREG	IMPCMP	UPDATH	PRNTTH	AXIALT
DEDUCT	GRAPHT			

This overlay performs the thermal feedback calculation. THFCON is the control routine. The major calculational routine is DOTEMP, which calculates new values of moderator density, moderator temperature, and fuel temperature based on the latest spatial flux calculation. This overlay reads the HARMONY data files and a T-H data file, reads the gross block power file, reads and rewrites the concentration file, and writes a file of T-H integrals (for possible saving by File Manager).

XENON FB (33,0)

XENCON	FILMIC	FILGAM	FILINT	GETNUC
DOXEIN	DECOD5	FIGREG	EDITXE	EQUIXE
INTPRE	DECOD6	ENCOD5	ENCOD6	MCHECK
GETCMP	AXIALX	DEDUCX	GRAPHX	

This overlay performs the xenon feedback calculation for determining extrapolated equilibrium xenon and iodine concentrations. XENCON is the control routine. The overlay reads the gross block integrated flux file, reads the HARMONY data files, and reads and rewrites the concentration file.

APPENDIX D: SAMPLE PROBLEMS

This appendix contains three sample problems which indicate a few of the problem options available and the printed output obtained from such problems. In each problem, the input data is listed so that the user may reproduce these examples by running a problem utilizing the listed data.

The first sample problem is a two - dimensional rectangular geometry depletion problem. This problem includes an edit by mesh element of the fine block concentrations for one nuclide both before and after depletion. Some input edits are included to show the form of such edits. The depletion performs five thermal - flux normalization passes, each for a very short depletion interval simply to show the results of such a calculation. Several integrated nuclide quantities are edited. The pointwise and meshwise power is edited as is the pointwise flux for a subset of the energy groups.

The second sample problem is a small three - dimensional problem with temperature feedback. The special program option to supress page ejections is used to compress all editing. No input edits are included (the default condition) and the flux - weighted integration data is restricted to print a subset of the data. Thermal - hydraulic results are edited. This problem utilizes sub-cases to run the identical problem at two different power levels.

The third sample problem is a three case problem. The geometry of this problem is three - dimensional rectangular and is a combination of explicit and synthesis cases. The first case is an explicit solution with the number of outer iterations restricted arbitrarily to five. This case is run only to obtain a pointwise flux file, the planes of which are utilized as trial functions in the second case which is the synthesis problem. A pointwise flux file is generated and saved in the synthesis case and then used as a flux guess for the third case which obtains a converged explicit solution. Various output files are written, both sectioned and non-sectioned files. The special program option to supress page ejections is used to compress all editing. An edit and printer plot of the maximum power by plane is included in the first two cases. All integration editing is supressed in this problem. In the synthesis case, the mixing coefficients are printed and the fractional flux contributions are printer plotted. The synthesis residuals are calculated and edited in the second case.

```
          $$$$$$$$$$$$$$$$$$$$ /BEGIN/ CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$
          = SAMPLE PROBLEM FOR PDQ-8 DEPLETION
           *
          *** MASTER CONTROL INPUT
           *
0001      010001,2,0,4,1,1,1,1,9,9,-2,11,13,1,0,0
0002      010002,1,1,1,1
0003      010003,11+1,25-2
0004      010004,75165+0,248175+0,0+0,0+0
           *
          *** POINTWISE EDIT REQUESTS
           *
0005      010005,0,11,0,13,0,0,0,0,1,1
0006      010006,1,6,1,12,0,0,1,1,1
0007      010007,1,6,1,12
           *
          *** MASTER DEPLETION DEFINITIONS
           *
0008      010008,0+0,5+2,1+2,15994+5
           *
          *** PICTURE EDIT REQUESTS
           *
0009      010009,0,1
           *
          *** INPUT SUMMARY EDIT REQUESTS
           *
0010      010010,0,/4/1
           *
          *** ISOTOPIC INTEGRATION EDITS
           *
0011      010110,POWER NUC,UFUEL,U 238,U 236,(),EMPTY,XE135
0012      010120,ABSORP,UFUEL,U 238,U 236
0013      010140,ATOM UFUEL,UFUEL,(),VOLFUEL,ND-6,ND-7
0014      010190,FOUR,4.0,THREE,3.0,PI,3.14159,FOURTEEN,14.0
0015      010111,18,20
0016      010121,18,20,29,6,7
0017      010131,18,20
0018      010141,-18,-19,-20,18,19,20,24,25,26,27,28,29,6,7
           *
          *** POINTWISE ISOTOPIC EDIT REQUESTS
           *
0019      010151,-18
0020      010161,-18
           *
          *** ISOTOPIC COMBINATION EDITS
           *
0021      010191,POW/ABS,POWER NUC,(/),ABSORP,ZERO,ABSORP,(-),ABSORP
0022      010192,UNITY,POWER NUC,(/),POWER NUC
0023      010193,14*UNITY,FOURTEEN,(*),UNITY,PI+UNITY,PI,(+),UNITY
0024      010194,4**3,FOUR,(**),THREE
0025      010195,CONC UFUEL,ATOM UFUEL,(/),VOLFUEL
           *
          *** INTEGRATION EDIT-SET DESCRIPTIONS
```

```
          *
0026      014001,1,0,1,-9
          *
          *** MESH SPACINGS
          *
0027      050101,795+0,1,18055+1,2,36101+1,3,10833+1,6,1016+1,7,3175+0,8
0028      050102,52917+0,11
0029      050201,9944+0,1,18631+1,2,3175+0,3,7455+0,4,1905+0,5,1204+1,6
0030      050202,1905+0,7,11303+1,8,22606+1,10,56515+0,12,9525-1,13
          *
          *** FINAL FIGURE LAYDOWN
          *
0031      170001,01,010,0,0,0,0
          *
          *** FINE BLOCKING REGION DEFINITIONS
          *
0032      150001,8,9
          *
          *** DEFAULT CHANNEL BIASES
          *
0033      160000,1
          *
          *** DEFAULT CHANNEL/TRACK IDENTIFICATIONS
          *
0034      700000,1
          *
          *** BASIC FIGURE DEFINITIONS
          *
0035      801000,11,13,01,0,02
0036      801001,4,0,6,0,1,  5,6,11,0,2,  3,0,1,1,13,  9,1,4,1,12,  8,4,6,1,12
0037      801002,7,1,4,4,5,  6,4,6,4,5,  7,1,4,12,13,  6,4,6,12,13, 2,6,7,2,13
0038      801003,1,7,11,2,13
          *
          *** HARMONY INPUT
          *
          *** BUCKLING
          *
0039      080001,2-2,5,0+0,7,2-2,9
          *
          *** CHAIN LISTS
          *
0040      090001,0,5,1,7,2,9
0041      090101,6
0042      090201,1,2,3,4,5,7,8
          *
          *** INITIAL CONCENTRATIONS
          *
0043      100061,29,26253-2
0044      100071,29,26253-2
0045      100081,18,27991-3,20,19778-4,6,1+1
0046      100091,18,62441-3,20,44121-4,7,1+1
          *
          *** TABLE SET ASSIGNMENTS
```

```
          *
0047      110001,1,1,2,2,3,3,4,4,5,5,6,6,7,7,9,9
          *
          *** TABLE OVERLAYS
          *
0048      112101,7,29,6,-6
0049      112201,7,29,6,-6
0050      115401,8,2,18,20,26,27,28,8,-8
0051      115402,8,4,18,20,8,-8
          *
          *** DEFINITION OF MASKS
          *
0052      120100,1,1,0
0053      120111,18,1,1+1
0054      120200,1,4,0
0055      120211,29,1,1+1,5+0,1+0,0+0
          *
          *** FUNCTION TABLE DEFINITIONS
          *
0056      130010,5,18,2,4,1,0,18,4
0057      130020,5,20,2,4,1,0,20,4
0058      130030,5,26,2,4,1,0
0059      130040,5,27,2,4,1,0
0060      130050,5,28,2,4,1,0
0061      130011,116506+1
0062      130021,11431+1
0063      130031,124082+1
0064      130041,127765+1
0065      130051,114553+1
0066      130060,4,29,1,3,3,0
0067      130070,4,29,1,4,3,0
0068      130080,4,29,2,3,3,0
0069      130090,4,29,2,4,3,0
0070      130100,4,29,1,3,3,0
0071      130110,4,29,1,4,3,0
0072      130120,4,29,2,3,3,0
0073      130130,4,29,2,4,3,0
0074      130061,275715537+2,20852877+2,325525044+1,-392833834+1
0075      130071,189838621+4,16665308+4,135776392+4,120900722+4
0076      130081,129856313+3,136716537+3,1436119938+3,1455269873+3
0077      130091,1159398544+4,1433229964+4,1744933892+4,1840208738+4
0078      130101,257453243+2,190788322+2,179432788+1,-523450018+1
0079      130111,162857578+4,144658245+4,129131913+4,12411991+4
0080      130121,1215216165+3,127599871+3,1349436217+3,1374349598+3
0081      130131,1069615282+4,1296683283+4,1571085796+4,1659494153+4
          *
          *** MASTER NUMERIC IDENTIFICATION OF NUCLIDES
          *
0082      300001,-18,19,-20,25,27,24,26,28,29,6,7
          *
          *** MASTER LIST OF ATOMIC WEIGHTS BY NUCLIDE
          *
0083      300301,235.,236.,238.,1.,1.,1.,1.,1.,1.,1.,1.
```

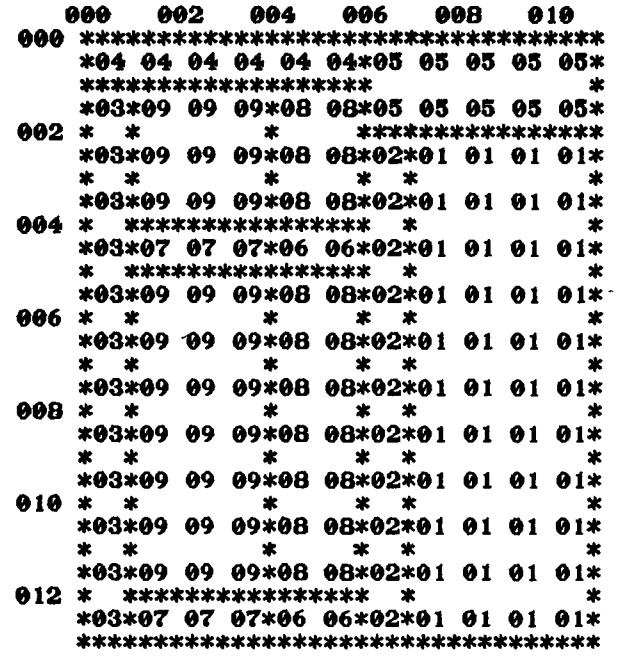
```
          *
         *** MASTER ALPHANUMERIC IDENTIFICATION OF NUCLIDES
          *
0084     300501,UFUEL,U 236,U 238,I 135,XE135,PM149,SM149,
0085     300502,FP 1,B-10,ND-6,ND-7,
          *
         *** DEPLETION CHAIN DEFINITIONS
          *
0086     301000,2,1,500.
0087     301011,18,0,0.
0088     301021,19,0,1-09,2,18,1+1
0089     302000,1,1,1000.
0090     302011,20,0,0.
0091     303000,2,2,2000.
0092     303011,25,0,288-4,5,18,.06
0093     303021,27,0,211-4,3,25,1+1,5,18,3-2,5,20,3-2
0094     304000,2,2,3000.
0095     304011,24,0,385-5,5,18,14-1,5,20,14-1
0096     304021,26,0,0+0,1,24,1+1
0097     305000,1,2,4000.
0098     305011,28,0,0+0,4,28,0+0,5,18,1+1
0099     306000,1,1,50.
0100     306011,29,0,0+0
0101     307000,1,1,4000.
0102     307011,6,0,0+0,4,6,0+0
0103     308000,1,1,4000.
0104     308011,7,0,0+0,4,7,0+0
          *
         *** TABLESET DEFINITIONS
          *
         *** MASTER MACRO, MASTER MICRO, AND FUNCTION TABLE USE DEFINITION
          *
0105     401000,1
0106     401001,NON-DEPLETABLE COMP. 1
0107     401100,2557173+1,1161-2,86973-1
0108     401200,1313644+1,1-4,120506+0
0109     401300,7383812+0,769-3,122577+0
0110     401400,2534006+0,1178-1,0+0
0111     402000,2
0112     402001,NON-DEPL. 2
0113     402100,224481+1,1723-2,56966-1
0114     402200,1131894+1,486-3,57258-1
0115     402300,9121025+0,1592-2,57858-1
0116     402400,4272003+0,8247-2,0+0
0117     403000,3
0118     403001,ND 3
0119     403100,2171213+1,1804-2,47127-1,0+0,0+0
0120     403200,1093854+1,617-3,40083-1,0+0,0+0
0121     403300,9845120+0,16-2,40139-1,0+0,0+0
0122     403400,5287002+0,1124-1,0+0,0+0,0+0
0123     404000,4
0124     404100,2122374+1,1817-2,40193-1
0125     404200,1072099+1,702-3,28965-1
```

```
0126      404300,1040113+1,1546-2,28618-1
0127      404400,6265005+0,6582-2,0+0
0128      405000,5
0129      405100,2107081+1,1812-2,37979-1
0130      405200,1065996+1,727-3,25608-1
0131      405300,1058473+1,1518-2,25132-1
0132      405400,1871292+0,6371-2,0+0
0133      406000,7
0134      406001,B-10 COMP 7
0135      406100,.0133333333,0+0,0+0
0136      406200,.0133333333,0+0,0+0
0137      406300,171379-1,242585-3,0+0
0138      406400,4540866667-1,-412601-2,0+0
0139      406101,29,0+0,42711309l+0,0+0
0140      406201,29,0+0,217929379+1,0+0
0141      406601,2,10,11,12,13
0142      407000,6
0143      407001,B-10 COMP 6
0144      407100,.0133333333,0+0,0+0
0145      407200,.0133333333,0+0,0+0
0146      407300,1728143333-1,544919-3,0+0
0147      407400,7190666667-1,109639-1,0+0
0148      407601,2,6,7,8,9
0149      408000,9
0150      408001,COMP 9
0151      408100,0+0,0+0,0+0
0152      408200,0+0,0+0,0+0
0153      408300,0+0,0+0,0+0
0154      408400,0+0,0+0,0+0
0155      408101,6,14906+0,17465-2,53928-1
0156      408201,6,29605+0,51557-3,51973-1
0157      408301,6,356+0,153-2,52438-1
0158      408401,6,59577+0,646-2,0+0
0159      408102,7,14789+0,17362-2,53809-1
0160      408202,7,29399+0,50188-3,51988-1
0161      408302,7,35430+0,16139-2,52376-1
0162      408402,7,51796+0,55710-2,0+0
0163      408103,18,567+1,1245+1,1306+1,1117+1,2769919427+1,31675-10
0164      408203,18,9476+1,2073+1,-77+0,1625+1,248+1,31675-10
0165      408303,18,9900+1,3400+2,-165+2,22358+2,2459969585+1,31675-10
0166      408403,18,31152+3,2896+3,0+0,2437+3,2470004103+1,31875-10
0167      408104,20,5046+1,41+0,156+1,344+0,2703488372+1,31717-10
0168      408204,20,904+1,23+0,-55-1
0169      408304,20,2+1,23+2,-11+2
0170      408404,20,11275+2,1258+1,0+0
0171      408405,26,4522+5,4522+5,0+0
0172      408406,27,1275+7,1275+7,0+0
0173      408407,28,4652+2,4652+2,0+0
0174      409000,8
0175      409001,C FOR 8 ONLY
0176      409601,1,1,2,3,4,5
          $$$$$$$$$$$$$$$$$$$$ //END// CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$
          ..........
```

P R O B L E M I N P U T D E S C R I P T I O N

PROGRAM IDENTIFICATION	PROGRAM(VERSION-DATE)	PDQ08(WAPD-TM-1266)	COMPUTER	CDC-7600
SPATIAL DESCRIPTION	ITERATION SOLUTION	EIGENVALUE	ADJOINT SOLUTION	NO
FEW-GROUP DESCRIPTION	NUMBER OF GROUPS	4	FAST GROUP	P-1
	THERMAL GROUPS	1	SOLUTION GROUPS	4
GEOMETRY PARAMETERS	DIMENSIONALITY, TYPE	2-D RECTANGULAR	BLOCK MESH TYPE	GROSS/FINE
	COMPOSITIONS	REGIONS (1 TO 1)	INPUT MESH UNITS	CENTIMETERS
	LARGEST FINAL FIGURE	1	LARGEST PLANAR REGION	9
	LARGEST COMPOSITION	9	COLUMN BOUNDARY	11
	ROW BOUNDARY	13	PLANE BOUNDARY	1
	MESH ELEMENTS	143	MESH POINTS	168
	MESH GROUP-POINTS	672	SOLUTION POINTS	168
	NON-SOLUTION POINTS	0	SOLUTION GROUP-POINTS	672
BOUNDARY CONDITIONS	COLUMN 0	ZERO CURRENT	COLUMN 11	ZERO CURRENT
	ROW 0	ZERO CURRENT	ROW 13	ZERO CURRENT
ITERATION PARAMETERS	INPUT EIGENVALUE	110000+01	CONVERGENCE PARAMETER	250000-02
	CHI(GROUP 1)	751650+00	CHI(GROUP 2)	248175+00
	CHI(GROUP 3)	000000+00	CHI(GROUP 4)	000000+00
DEPLETION PARAMETERS	BEGIN-TIME	000000+00 HOURS	END-TIME	500000+02 HOURS
	DEPLETION INTERVAL	500000+02 HOURS	POWER LEVEL	159940+05 WATTS
DATA STORAGE ALLOCATIONS	CENTRAL MEMORY	31199 WORDS	EXTENDED MEMORY	98304 WORDS
BLOCKING COUNTS	TOTAL GROSS BLOCKS	9	TOTAL FINE BLOCKS	50

REGION PICTURE



C A R D - I N P U T N U C L I D E C O N C E N T R A T I O N E D I T

COMPOSITION	UFUEL DENSITY	U 236 DENSITY	U 238 DENSITY	I 135 DENSITY	XE135 DENSITY	PM149 DENSITY	SM149 DENSITY	FP 1 DENSITY
8	2799100-03	0000000+00	1977800-04	0000000+00	0000000+00	0000000+00	0000000+00	0000000+00
9	6244100-03	0000000+00	4412100-04	0000000+00	0000000+00	0000000+00	0000000+00	0000000+00

C A R D - I N P U T N U C L I D E C O N C E N T R A T I O N E D I T

COMPOSITION	B-10 DENSITY	ND-6 DENSITY	ND-7 DENSITY
6	2625300-02	0000000+00	0000000+00
7	2625300-02	0000000+00	0000000+00
8	0000000+00	1000000+01	0000000+00
9	0000000+00	0000000+00	1000000+01

H A R M O N Y - I N P U T E D I T

NUCLIDE IDENTIFICATIONS
(NEGATIVE ID DESIGNATES A FINE BLOCK NUCLIDE)

-18 = UFUEL	19 = U 236	-20 = U 238	25 = I 135	27 = XE135	24 = PM149
26 = SM149	28 = FP 1	29 = B-10	6 = ND-6	7 = ND-7	

AREA-RATIOS FOR COMPOSITIONS 1 - 9

(001) 100000+01 100000+01 100000+01 100000+01 100000+01 100000+01 100000+01 100000+01 100000+01

TABLE SET ..... IDENTIFICATION

1 ..... NON-DEPLETABLE COMP. 1
2 ..... NON-DEPL. 2
3 ..... ND 3
4 .....
5 .....
7 ..... B-10 COMP 7
6 ..... B-10 COMP 6
9 ..... COMP 9
8 ..... G FOR 8 ONLY

TABLE USAGE BY COMPOSITION

COMP.	TABLE SET		GROUP	NUCLIDE	TYPE	ORDER	TABLE NO.
1	1	MASTER MACRO					32767
2	2	MASTER MACRO					32766
3	3	MASTER MACRO					32765
4	4	MASTER MACRO					32764
5	5	MASTER MACRO					32763
6	6	MASTER MACRO					32754
6	7	MASTER MICRO	1	29			32761
6	7	MASTER MICRO	2	29			32760
6	6	INTERP MICRO	3	29	1	3	32753
6	6	INTERP MICRO	4	29	1	3	32752
6	6	INTERP MICRO	3	29	2	3	32751
6	6	INTERP MICRO	4	29	2	3	32750
7	7	MASTER MACRO					32762

COMP.	TABLE SET		GROUP	NUCLIDE	TYPE	ORDER	TABLE NO.
7	7	MASTER MICRO	1	29			32761
7	7	MASTER MICRO	2	29			32760
7	7	INTERP MICRO	3	29	1	3	32758
7	7	INTERP MICRO	4	29	1	3	32757
7	7	INTERP MICRO	3	29	2	3	32756
7	7	INTERP MICRO	4	29	2	3	32755
8	9	MASTER MACRO					32749
8	9	MASTER MICRO	1	6			32748
8	9	MASTER MICRO	1	7			32747
8	9	MASTER MICRO	1	18			32746
8	9	MASTER MICRO	1	20			32745
8	9	MASTER MICRO	2	6			32744
8	9	MASTER MICRO	2	7			32743
8	9	MASTER MICRO	2	18			32742
8	9	MASTER MICRO	2	20			32741
8	9	MASTER MICRO	3	6			32740
8	9	MASTER MICRO	3	7			32739
8	9	MASTER MICRO	3	18			32738
8	9	MASTER MICRO	3	20			32737
8	9	MASTER MICRO	4	6			32736
8	9	MASTER MICRO	4	7			32735
8	9	MASTER MICRO	4	18			32734
8	9	MASTER MICRO	4	20			32733
8	9	MASTER MICRO	4	26			32732
8	9	MASTER MICRO	4	27			32731
8	9	MASTER MICRO	4	28			32730
8	8	INTERP G	4	18	2	1	32728
8	8	INTERP G	4	20	2	1	32727
8	8	INTERP G	4	26	2	1	32726
8	8	INTERP G	4	27	2	1	32725
8	8	INTERP G	4	28	2	1	32724
8	8	INTERP G	4	18	4	1	32728
8	8	INTERP G	4	20	4	1	32727
9	9	MASTER MACRO					32749
9	9	MASTER MICRO	1	6			32748
9	9	MASTER MICRO	1	7			32747
9	9	MASTER MICRO	1	18			32746
9	9	MASTER MICRO	1	20			32745
9	9	MASTER MICRO	2	6			32744
9	9	MASTER MICRO	2	7			32743
9	9	MASTER MICRO	2	18			32742
9	9	MASTER MICRO	2	20			32741
9	9	MASTER MICRO	3	6			32740
9	9	MASTER MICRO	3	7			32739
9	9	MASTER MICRO	3	18			32738
9	9	MASTER MICRO	3	20			32737
9	9	MASTER MICRO	4	6			32736
9	9	MASTER MICRO	4	7			32735

COMP.	TABLE SET		GROUP	NUCLIDE TYPE	ORDER TABLE NO.
9	9	MASTER MICRO	4	18	32734
9	9	MASTER MICRO	4	20	32733
9	9	MASTER MICRO	4	26	32732
9	9	MASTER MICRO	4	27	32731
9	9	MASTER MICRO	4	28	32730

E D I T - S E T D A T A E D I T

EDIT SET	1	FIGURE	001	EDIT SET	2	FIGURE	001	EDIT SET	3	FIGURE	001
		REGION	001			REGION	002			REGION	003
EDIT SET	4	FIGURE	001	EDIT SET	5	FIGURE	001	EDIT SET	6	FIGURE	001
		REGION	004			REGION	005			REGION	006
EDIT SET	7	FIGURE	001	EDIT SET	8	FIGURE	001	EDIT SET	9	FIGURE	001
		REGION	007			REGION	008			REGION	009

UFUEL FINE BLOCK CONCENTRATION AT 0. HOURS PLANE 0 - 1

	1	2	3	4	5	6	
1	624410-03	624410-03	624410-03	279910-03	279910-03		1
2	624410-03	624410-03	624410-03	279910-03	279910-03		2
3	624410-03	624410-03	624410-03	279910-03	279910-03		3
4	000000+00	000000+00	000000+00	000000+00	000000+00		4
5	624410-03	624410-03	624410-03	279910-03	279910-03		5
6	624410-03	624410-03	624410-03	279910-03	279910-03		6
7	624410-03	624410-03	624410-03	279910-03	279910-03		7
8	624410-03	624410-03	624410-03	279910-03	279910-03		8
9	624410-03	624410-03	624410-03	279910-03	279910-03		9
10	624410-03	624410-03	624410-03	279910-03	279910-03		10
11	624410-03	624410-03	624410-03	279910-03	279910-03		11
12	1	2	3	4	5	6	12

M A C R O S C O P I C D A T A E D I T

VOLUME-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	25571730+01	11610000-02	86973000-01	00000000+00	00000000+00	20000000-02
2	22448100+01	17230000-02	56966000-01	00000000+00	00000000+00	20000000-02
3	21712130+01	18040000-02	47127000-01	00000000+00	00000000+00	20000000-02
4	21223740+01	18170000-02	40193000-01	00000000+00	00000000+00	20000000-02
5	21070810+01	18120000-02	37979000-01	00000000+00	00000000+00	20000000-02
6	25000000+02	11213000-02	00000000+00	00000000+00	00000000+00	00000000+00
7	25000000+02	11213000-02	00000000+00	00000000+00	00000000+00	00000000+00
8	22112120+01	21030969-02	54324416-01	88443508-03	10119280-13	20000000-02
9	21979997+01	25316801-02	54693308-01	19729571-02	22573623-13	20000000-02

VOLUME-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	13136440+01	10000000-04	12050600+00	00000000+00	00000000+00	20000000-02
2	11318940+01	48600000-03	57258000-01	00000000+00	00000000+00	20000000-02
3	10938540+01	61700000-03	40083000-01	00000000+00	00000000+00	20000000-02
4	10720990+01	70200000-03	28965000-01	00000000+00	00000000+00	20000000-02
5	10659960+01	72700000-03	25608000-01	00000000+00	00000000+00	20000000-02
6	25000000+02	57213000-02	00000000+00	00000000+00	00000000+00	00000000+00
7	25000000+02	57213000-02	00000000+00	00000000+00	00000000+00	00000000+00
8	11152702+01	11003724-02	51756382-01	11280373-02	14407493-13	20000000-02
9	11099798+01	18064298-02	51504778-01	25163723-02	32139553-13	20000000-02

VOLUME-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	73838120+00	76900000-03	12257700+00	00000000+00	00000000+00	20000000-02
2	91210250+00	15920000-02	57858000-01	00000000+00	00000000+00	20000000-02
3	98451290+00	16000000-02	40139000-01	00000000+00	00000000+00	20000000-02
4	10401130+01	15460000-02	28618000-01	00000000+00	00000000+00	20000000-02
5	10584730+01	15180000-02	25132000-01	00000000+00	00000000+00	20000000-02
6	37175398+01	34145670+00	00000000+00	00000000+00	00000000+00	00000000+00
7	39341997+01	31927328+00	00000000+00	00000000+00	00000000+00	00000000+00
8	92899505+00	11501834-01	47601927-01	15395059-01	19822936-12	20000000-02
9	92446244+00	23858623-01	41587904-01	34342550-01	44220070-12	20000000-02

VOLUME-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	25340060+00	11780000-01	00000000+00	00000000+00	00000000+00	20000000-02
2	42720030+00	82470000-02	00000000+00	00000000+00	00000000+00	20000000-02
3	52870020+00	11240000-01	00000000+00	00000000+00	00000000+00	20000000-02
4	62650050+00	65820000-02	00000000+00	00000000+00	00000000+00	20000000-02
5	18712920+00	63710000-02	00000000+00	00000000+00	00000000+00	20000000-02
6	65931660-01	30547329+01	00000000+00	00000000+00	00000000+00	00000000+00
7	77144267-01	28039350+01	00000000+00	00000000+00	00000000+00	00000000+00
8	48790681+00	10093046+00	00000000+00	19629982+00	25332172-11	20000000-02
9	46752544+00	18645564+00	00000000+00	37585736+00	48503779-11	20000000-02

S P A T I A L - I T E R A T I O N R E S U L T S

```
GROUP 1    PASS 1    RHO = 9975280+00    OMEGA(  8) = 1905271+01    SIGMA = 9000000+00    DELTA( 37) = 7500000-01
GROUP 1    PASS 2    RHO = 9979216+00    OMEGA( 16) = 1912797+01    SIGMA = 9753098+00    DELTA( 41) = 7500000-01
GROUP 1    PASS 3    RHO = 9981110+00    OMEGA( 24) = 1916696+01    SIGMA = 9942594+00    DELTA( 42) = 7500000-01
GROUP 1    PASS 4    RHO = 9982469+00    OMEGA( 32) = 1919625+01    SIGMA = 9966382+00    DELTA( 44) = 7500000-01

GROUP 2    PASS 1    RHO = 9977083+00    OMEGA(  8) = 1908631+01    SIGMA = 9000000+00    DELTA( 39) = 7500000-01
GROUP 2    PASS 2    RHO = 9981992+00    OMEGA( 16) = 1918582+01    SIGMA = 9647563+00    DELTA( 43) = 7500000-01
GROUP 2    PASS 3    RHO = 9983539+00    OMEGA( 24) = 1922020+01    SIGMA = 9935982+00    DELTA( 45) = 7500000-01
GROUP 2    PASS 4    RHO = 9985022+00    OMEGA( 32) = 1925480+01    SIGMA = 9977680+00    DELTA( 48) = 7500000-01

GROUP 3    PASS 1    RHO = 9877833+00    OMEGA(  8) = 1800943+01    SIGMA = 9000000+00    DELTA( 17) = 7500000-01
GROUP 3    PASS 2    RHO = 9901230+00    OMEGA( 16) = 1819202+01    SIGMA = 9860810+00    DELTA( 19) = 7500000-01
GROUP 3    PASS 3    RHO = 9920523+00    OMEGA( 24) = 1836295+01    SIGMA = 9936864+00    DELTA( 21) = 7500000-01
GROUP 3    PASS 4    RHO = 9925532+00    OMEGA( 32) = 1841121+01    SIGMA = 9904423+00    DELTA( 22) = 7500000-01

GROUP 4    PASS 1    RHO = 9258559+00    OMEGA(  8) = 1571963+01    SIGMA = 8658001+00    DELTA(  7) = 7500000-01
GROUP 4    PASS 2    RHO = 9507556+00    OMEGA( 16) = 1636781+01    SIGMA = 9995000+00    DELTA(  9) = 7500000-01
GROUP 4    PASS 3    RHO = 9580745+00    OMEGA( 24) = 1660085+01    SIGMA = 9995000+00    DELTA( 10) = 7500000-01
GROUP 4    PASS 4    RHO = 9579443+00    OMEGA( 32) = 1659648+01    SIGMA = 9979484+00    DELTA( 10) = 7500000-01

GROUP 1    IT. = 44    R(1) = 2798558+01    DELTA = 9214890-02
GROUP 2    IT. = 48    R(1) = 4132017+01    DELTA = 8614180-02
GROUP 3    IT. = 22    R(1) = 4102625+01    DELTA = 8050698-02
GROUP 4    IT. = 10    R(1) = 7737981+01    DELTA = 1010663-01

SIG/I = 0000000+00    MAX. = 3623040+01    GAMMA = 2853839+01    RATIO(  0) = 1000000+01
SIG/O = 0000000+00    MIN. = 3313392+00    PT/AV = 2343858+01    EPS.(  1) = 2583510+01    LAMBDA = 101103117+01

GROUP 1    IT. = 44    R(1) = 9634616+00    DELTA = 3921174-02
GROUP 2    IT. = 48    R(1) = 7961543+00    DELTA = 5979887-02
GROUP 3    IT. = 22    R(1) = 7462290+00    DELTA = 6721878-02
GROUP 4    IT. = 10    R(1) = 1011868+01    DELTA = 1087171-01

SIG/I = 1758679+00    MAX. = 1224878+01    GAMMA = 1050331+01    RATIO(  0) = 1000000+01
SIG/O = 1068520+00    MIN. = 1025744+01    PT/AV = 2253208+01    EPS.(  2) = 1534589+00    LAMBDA = 106191692+01

GROUP 1    IT. = 44    R(1) = 1702091+00    DELTA = 7051698-02
GROUP 2    IT. = 48    R(1) = 2089690+00    DELTA = 8936851-02
GROUP 3    IT. = 22    R(1) = 2352558+00    DELTA = 7757485-02
GROUP 4    IT. = 10    R(1) = 3051960+00    DELTA = 1125760-01

SIG/I = 2652533+00    MAX. = 1132597+01    GAMMA = 1026939+01    RATIO(  0) = 1000000+01
SIG/O = 4231042+00    MIN. = 1100697+01    PT/AV = 1390445+01    EPS.(  3) = 3858077-01    LAMBDA = 109052346+01

GROUP 1    IT. = 44    R(1) = 1641413-01    DELTA = 9355827-02
GROUP 2    IT. = 48    R(1) = 1855666-01    DELTA = 1873940-01
GROUP 3    IT. = 22    R(1) = 3329226-01    DELTA = 8893935-02
GROUP 4    IT. = 10    R(1) = 4536950-01    DELTA = 1103397-01

SIG/I = 1307537+00    MAX. = 1102892+01    GAMMA = 1003759+01    RATIO(  0) = 1000000+01
SIG/O = 1636824+00    MIN. = 1094477+01    PT/AV = 1688746+01    EPS.(  4) = 7554361-02    LAMBDA = 109462321+01
```

```
GROUP 1    IT. = 44    R(1) = 3811600-02    DELTA = 7878791-02
GROUP 2    IT. = 48    R(1) = 3701268-02    DELTA = 1873101-01
GROUP 3    IT. = 22    R(1) = 5936475-02    DELTA = 9113703-02
GROUP 4    IT. = 10    R(1) = 7908230-02    DELTA = 1114866-01

SIG/I = 1825680+00    MAX. = 1097023+01    GAMMA = 1000669+01    RATIO( 0) = 1000000+01
SIG/O = 1952520+00    MIN. = 1095104+01    PT/AV = 1746958+01    EPS.(  5) = 1522479-02        LAMBDA = 109535505+01

ITERATIONS  5 ...EIGENVALUE = 109535505+01 ..REACTIVITY(PERCENTAGE) = 870540146+01 ......DOMINANCE = 116289778+00
LEVELS ..FLUX NORMALIZATION = 347208761+14 .....POWER NORMALIZATION = 208854617+12 ...POWER VOLUME = 962078472+02
```

I N T E G R A T I O N E D I T S

EDIT SET	VOLUME	FLUX INTEGRALS FOLLOWED BY FLUX AVERAGES GROUP 1	2	3	4
1	181453155+02	135623020+16	173770829+16	164068045+16	312998384+16
		747427182+14	957662210+14	904189543+14	172495421+15
2	967745080+01	787610642+15	100976909+16	870466316+15	108250495+16
		813861686+14	104342466+15	899478937+14	111858482+15
3	905357925+01	870015984+15	115420561+16	826594972+15	228993170+15
		960963570+14	127486112+15	913003520+14	252931093+14
4	940752120+01	842173238+15	115039667+16	856197117+15	369347741+15
		895212692+14	122284781+15	910119784+14	392608991+14
5	834678607+01	634129308+15	892569434+15	757616897+15	936324776+15
		759728718+14	106935703+15	907674991+14	112177881+15
6	619105950+00	549683395+14	713384606+14	536800738+14	262155497+14
		887866439+14	115228194+15	867057954+14	423442057+14
7	185706067+01	177424953+15	229971270+15	160697774+15	291222813+14
		955407412+14	123836164+15	865334001+14	156819223+14
8	240544598+02	215365262+16	276434604+16	214746179+16	144869239+16
		895323626+14	114920312+15	892749954+14	602255215+14
9	721533874+02	700225098+16	905699641+16	646380420+16	175849889+16
		970467394+14	125524203+15	895842099+14	243716748+14

INTEGRATED POWER EDIT

EDIT SET	POWER FRACTION	RELATIVE POWER DENSITY	GROUP FRACTION OF EDIT-SET POWER GROUP 1	2	3	4
8	259920169+00	103957270+01	524237609-02	958040211-02	102399153+00	882778069+00
9	740079831+00	986807272+00	133537514-01	245916899-01	241474879+00	720579680+00

INTEGRATED ABSORPTION EDIT

EDIT SET	GROUP FRACTION OF TOTAL ABSORPTION FOLLOWED BY GROUP FRACTION OF EDIT-SET ABSORPTION ABSORP. FRACT.	GROUP 1	2	3	4
1	396810230-01	157284595-02	173579100-04	126029119-02	368305279-01
		396372330-01	437436051-03	317605520-01	928164779+00
2	121475838-01	135555584-02	490206311-03	138425338-02	891756831-02
		111590573+00	403542233-01	113952980+00	734102224+00
3	617127231-02	156777712-02	711359122-03	132109272-02	257104334-02
		254044392+00	115269443+00	214071371+00	416614794+00
4	608581263-02	152854040-02	806687426-03	132222026-02	242836454-02
		251164551+00	132552130+00	217262729+00	399020589+00
5	890349339-02	114777451-02	648182019-03	114879353-02	595874333-02
		128912828+00	728008648-01	129027280+00	669259027+00
6	987716078-01	615679931-04	407698404-03	183091970-01	799931444-01
		623336953-03	412768824-02	185369029+00	809879946+00
7	134329795+00	198727093-03	131428291-02	512498974-01	815668874-01
		147939698-02	978400150-02	381522934+00	607213668+00
8	178291155+00	452434278-02	303845383-02	246724967-01	146055861+00
		253761483-01	170420896-01	138383178+00	819198584+00

9	515618257+00	177078997-01	168427762-01	154047312+00	327520269+00	
		343430424-01	316954956-01	298762330+00	635199132+00	

TOTAL GROUP-INDEPENDENT BUCKLING, K INFINITY, AND K EFFECTIVE EDITS

EDIT SET	GP. IND. BUCK.	SUM	K INFINITY FOLLOWED BY K EFFECTIVE GROUP 1	2	3	4
8	567175464-02	177095246+01	117812321-01	207397982-01	247862575+00	149056886+01
		109535505+01	647021636-02	105923679-01	112301030+00	965991441+00
9	623916532-02	175771734+01	259147835-01	456236802-01	490014430+00	119616445+01
		109535505+01	164566847-01	271485183-01	264428202+00	787321650+00

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

EDIT SET	D	SIGMA A	GROUP 1 SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	25571730+01	11610000-02	86973000-01	00000000+00	00000000+00	-36465404-01
2	22448100+01	17230000-02	56966000-01	00000000+00	00000000+00	-28144306-01
3	21712130+01	18040000-02	47127000-01	00000000+00	00000000+00	-24536250-01
4	21223740+01	18170000-02	40193000-01	00000000+00	00000000+00	-21793872-01
5	21070810+01	18120000-02	37979000-01	00000000+00	00000000+00	-20884419-01
6	25000000+02	11213000-02	00000000+00	00000000+00	00000000+00	-44852000-04
7	25000000+02	11213000-02	00000000+00	00000000+00	00000000+00	-44852000-04
8	22112120+01	21030969-02	54324416-01	88443508-03	10119280-13	18946878-01
9	21979997+01	25316801-02	54693308-01	19729571-02	22573623-13	12963031-01

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA

EDIT SET	D	SIGMA A	GROUP 1 SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	13136440+01	10000000-04	12050600+00	00000000+00	00000000+00	-42068795-01
2	11318940+01	48600000-03	57258000-01	00000000+00	00000000+00	-13759972-01
3	10938540+01	61700000-03	40083000-01	00000000+00	00000000+00	-67324925-02
4	10720990+01	70200000-03	28965000-01	00000000+00	00000000+00	-22264983-02
5	10659960+01	72700000-03	25608000-01	00000000+00	00000000+00	-13927526-02
6	25000000+02	57213000-02	00000000+00	00000000+00	00000000+00	-22885200-03
7	25000000+02	57213000-02	00000000+00	00000000+00	00000000+00	-22885200-03
8	11152702+01	11003724-02	51756382-01	11280373-02	14407493-13	12252956-01
9	11099798+01	18064298-02	51504778-01	25163723-02	32139553-13	87903272-02

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	73838120+00	76900000-03	12257700+00	00000000+00	00000000+00	38053726-02
2	91210250+00	15920000-02	57858000-01	00000000+00	00000000+00	56429264-02
3	98451290+00	16000000-02	40139000-01	00000000+00	00000000+00	12454253-01
4	10401130+01	15460000-02	28618000-01	00000000+00	00000000+00	64161240-02
5	10584730+01	15180000-02	25132000-01	00000000+00	00000000+00	13250669-02
6	37175398+01	34145670+00	00000000+00	00000000+00	00000000+00	-91850179-01
7	39341997+01	31927328+00	00000000+00	00000000+00	00000000+00	-81153299-01
8	92899505+00	11501834-01	47601927-01	15395050-01	19822936-12	60950529-02
9	92446244+00	23858623-01	41587904-01	34342550-01	44220070-12	52704760-02

FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	25340060+00	11780000-01	00000000+00	00000000+00	00000000+00	20507381+00
2	42720030+00	82470000-02	00000000+00	00000000+00	00000000+00	87601775-01
3	52870020+00	11240000-01	00000000+00	00000000+00	00000000+00	25078874+00
4	62650050+00	65820000-02	00000000+00	00000000+00	00000000+00	93384321-01
5	18712920+00	63710000-02	00000000+00	00000000+00	00000000+00	72623744-01
6	65931660-01	30547329+01	00000000+00	00000000+00	00000000+00	-46331806+02
7	77144267-01	28039350+01	00000000+00	00000000+00	00000000+00	-36346641+02
8	48790681+00	10093046+00	00000000+00	19629982+00	25332172-11	-64241365-01
9	46752544+00	18645564+00	00000000+00	37585736+00	48503779-11	-73843913-01

D E P L E T I O N D E S C R I P T I O N

DEPLETION WILL BE DONE FROM 0. HOURS TO 50.00 HOURS AT A POWER LEVEL OF 159940000+05 WATTS

5 PASSES WILL BE MADE THROUGH THE DEPLETION MESH EACH PASS DEPLETING FOR 10.00 HOURS

BETWEEN EACH PASS THE THERMAL FLUX WILL BE RENORMALIZED TO MAINTAIN A CONSTANT POWER LEVEL

DURING A PASS THROUGH THE MESH CROSS-SECTIONS WILL BE EVALUATED AND CHAINS WILL BE SOLVED IN DISCRETE STEPS AS FOLLOWS

COMPOSITION	NO. OF STEPS	LENGTH OF EACH STEP (HOURS)
1	(NON-DEPLETING)	
2	(NON-DEPLETING)	
3	(NON-DEPLETING)	
4	(NON-DEPLETING)	
5	(NON-DEPLETING)	
6	1	10.00
7	1	10.00
8	1	10.00
9	1	10.00

ALL NUCLIDES WILL BE DEPLETED OVER GROSS BLOCKS VIA THE ABOVE SCHEME

IN ADDITION, THE FOLLOWING NUCLIDES WILL BE DEPLETED OVER FINE BLOCKS VIA THE ABOVE SCHEME

UFUEL U 238

NUCLIDE COLLECTIONS AT 0. HOURS
(COLLECTION VALUE = COLLECTION NAME)

15994000+05 = POWER NUC 00000000+00 = EMPTY 63991378+15 = ABSORP 51786380+23 = ATOM UFUEL
96207847+26 = VOLFUEL

ALGEBRAIC COMBINATIONS OF NUCLIDE COLLECTIONS AT 0. HOURS
(COMBINATION VALUE = COMBINATION NAME)

24993992-10 = POW/ABS 00000000+00 = ZERO 10000000+01 = UNITY 14000000+02 = 14*UNITY
41415900+01 = PI+UNITY 64000000+02 = 4**3 53827606-03 = CONC UFUEL

NUCLIDE POWER FRACTIONS AT 0. HOURS

EDIT SET	NUCLIDE	TOTAL FRACTION	GROUP 1 FRACTION	GROUP 2 FRACTION	GROUP 3 FRACTION	GROUP 4 FRACTION
8	UFUEL	99988821+00	51305839-02	95804021-02	10239915+00	88277807+00
	U 238	11179220-03	11179220-03	00000000+00	00000000+00	00000000+00
9	UFUEL	99971523+00	13068979-01	24591690-01	24147488+00	72057968+00
	U 238	28477241-03	28477241-03	00000000+00	00000000+00	00000000+00

NUCLIDE INTEGRATED ABSORPTION RATES AT 0. HOURS

EDIT SET	NUCLIDE	TOTAL ABSORPTION	GROUP 1 ABSORPTION	GROUP 2 ABSORPTION	GROUP 3 ABSORPTION	GROUP 4 ABSORPTION
6	B-10	98564032+14	61635999+11	40814873+12	18300169+14	79794077+14
7	B-10	13455935+15	19894660+12	13157346+13	51267523+14	81777142+14
8	UFUEL	15960924+15	75052199+12	16040213+13	20437265+14	13681743+15
	U 238	10481087+13	17463926+11	12574844+11	97686748+12	41202486+11
	ND-6	17830738+14	37613543+13	14252139+13	32856165+13	93585528+13
9	UFUEL	47238089+15	54434830+13	11723394+14	13722618+15	31798784+15
	U 238	68755396+13	12666799+12	91908860+11	65593586+13	97604106+11
	ND-7	36931364+14	12157308+14	45455254+13	10431934+14	97965973+13

NUCLIDE INTEGRATED FISSION RATES AT 0. HOURS

EDIT SET	NUCLIDE	TOTAL FISSION	GROUP 1 FISSION	GROUP 2 FISSION	GROUP 3 FISSION	GROUP 4 FISSION
8	UFUEL	13050267+15	67335989+12	12573732+13	13439305+14	11513263+15
	U 238	14652660+11	14652660+11	00000000+00	00000000+00	00000000+00
9	UFUEL	37190050+15	48838318+13	91898286+13	90238318+14	26758852+15
	U 238	10627753+12	10627753+12	00000000+00	00000000+00	00000000+00

THERMAL-FLUX NORMALIZATION	INTERVAL
34720876+14	FROM 0. TO 10.00 HOURS
34743691+14	FROM 10.00 TO 20.00 HOURS
34766527+14	FROM 20.00 TO 30.00 HOURS
34789386+14	FROM 30.00 TO 40.00 HOURS
34812265+14	FROM 40.00 TO 50.00 HOURS

NUCLIDE CONCENTRATIONS AT 50.00 HOURS

EDIT SET	UFUEL LOADING	U 236 LOADING	U 238 LOADING	UFUEL DENSITY	U 236 DENSITY	U 238 DENSITY	PM149 DENSITY	I 135 DENSITY
8	26160644-02	20506507-05	18793361-03	27871684-03	21755162-06	19770158-04	98534798-08	11223836-07
9	17546715-01	70853291-05	12575693-02	62323163-03	25059335-06	44103851-04	93730208-08	10679462-07

NUCLIDE CONCENTRATIONS AT 50.00 HOURS

EDIT SET	SM149 DENSITY	XE135 DENSITY	FP 1 DENSITY	B-10 DENSITY	ND-6 DENSITY	ND-7 DENSITY
6	00000000+00	00000000+00	00000000+00	25967271-02	00000000+00	00000000+00
7	00000000+00	00000000+00	00000000+00	26122729-02	00000000+00	00000000+00
8	31044002-08	28371086-08	97560211-06	00000000+00	10000000+01	00000000+00
9	33790180-08	61418801-08	92777630-06	00000000+00	00000000+00	10000000+01

UFUEL FINE BLOCK CONCENTRATION AT 50.00 HOURS PLANE 0 - 1

	1	2	3	4	5	6	
1	623163-03	623143-03	622912-03	278965-03	278706-03		1
2	623322-03	623337-03	623127-03	279067-03	278748-03		2
3	623429-03	623464-03	623285-03	279168-03	278817-03		3
4	000000+00	000000+00	000000+00	000000+00	000000+00		4
5	623431-03	623451-03	623220-03	279085-03	278677-03		5
6	623334-03	623322-03	623027-03	278936-03	278498-03		6
7	623286-03	623256-03	622927-03	278862-03	278409-03		7
8	623233-03	623184-03	622816-03	278779-03	278306-03		8
9	623280-03	623241-03	622893-03	278829-03	278354-03		9
10	623379-03	623367-03	623074-03	278956-03	278493-03		10
11	623469-03	623482-03	623242-03	279085-03	278636-03		11
12	1	2	3	4	5	6	12

FINE BLOCK MESH POWER EDIT PLANE 0 - 1

	1	2	3	4	5	6	
1	104717+01	106600+01	127377+01	816304+00	104936+01		1
2	905922+00	893712+00	108203+01	725189+00	101198+01		2
3	811142+00	780804+00	941105+00	634859+00	949793+00		3
4	000000+00	000000+00	000000+00	000000+00	000000+00		4
5	808532+00	791793+00	999120+00	709404+00	107582+01		5
6	894091+00	906252+00	117098+01	842950+00	123655+01		6
7	937079+00	964805+00	125998+01	908843+00	131615+01		7
8	983223+00	102873+01	135930+01	982896+00	140852+01		8
9	941628+00	978026+00	129057+01	938813+00	136606+01		9
10	854328+00	866254+00	112936+01	824883+00	124153+01		10
11	774363+00	764098+00	980103+00	709705+00	111272+01		11
12	1	2	3	4	5	6	12

MAXIMUM FINE BLOCK POWER IS 140852+01 IN FIGURE 1, REGION 8, CHANNEL 6, TRACK 9

PARTITION POWER EDIT

ROW	COLUMN	TOP LEFT	TOP RIGHT	BOTTOM LEFT	BOTTOM RIGHT
1	4	0000+00	0000+00	1562+01	7952+00
2	4	1256+01	6360+00	1256+01	6360+00
3	4	1175+01	5938+00	1175+01	5938+00
4	4	9386+00	4707+00	0000+00	0000+00
5	4	0000+00	0000+00	9593+00	4815+00
6	4	1335+01	6774+00	1335+01	6774+00
7	4	1379+01	6999+00	1379+01	6999+00
8	4	1550+01	7889+00	1550+01	7889+00
9	4	1618+01	8246+00	1618+01	8246+00
10	4	1393+01	7073+00	1393+01	7073+00
11	4	1237+01	6264+00	1237+01	6264+00
12	4	1031+01	5188+00	0000+00	0000+00

POINTWISE AVERAGE POWER

	1	2	3	4	5	6
1	120604+01	112018+01	129561+01	117836+01	976599+00	118011+01
2	996177+00	866274+00	981946+00	946000+00	857434+00	118329+01
3	949894+00	811341+00	915288+00	884325+00	813558+00	119365+01
4	822405+00	660928+00	735657+00	704646+00	661415+00	113055+01
5	815900+00	647439+00	730770+00	720431+00	697172+00	116546+01
6	952769+00	818021+00	970943+00	100642+01	981501+00	145915+01
7	968476+00	837096+00	998946+00	103922+01	101302+01	149252+01
8	103231+01	910429+00	111275+01	116929+01	113355+01	162549+01
9	105503+01	935115+00	115662+01	122137+01	118453+01	169052+01
10	950857+00	825507+00	994861+00	104996+01	103888+01	155032+01
11	888962+00	751986+00	892662+00	931811+00	927033+00	144990+01
12	804403+00	652099+00	759645+00	774834+00	766604+00	130734+01

POINTWISE FLUX - GROUP 3

	0	1	2	3	4	5	6	7	8	9
0	922571+14	921681+14	915551+14	905163+14	905642+14	906937+14	908120+14	909164+14	909444+14	909831+14
1	920791+14	919350+14	912168+14	901557+14	902782+14	904947+14	906761+14	908439+14	908879+14	909471+14
2	905363+14	902449+14	890090+14	878412+14	881975+14	888117+14	896155+14	903856+14	905790+14	908030+14
3	902118+14	898029+14	884003+14	872122+14	875813+14	882577+14	892656+14	903170+14	906063+14	908778+14
4	895200+14	885578+14	866769+14	854502+14	858055+14	865904+14	881561+14	900414+14	904562+14	908196+14
5	895125+14	885665+14	866807+14	854515+14	858061+14	865912+14	881566+14	900231+14	904389+14	908022+14
6	910105+14	906825+14	894054+14	881442+14	884252+14	889366+14	896627+14	903932+14	905851+14	907334+14
7	912358+14	909514+14	897424+14	884772+14	887401+14	892072+14	898336+14	904448+14	906077+14	907251+14
8	924058+14	921938+14	912316+14	899422+14	900767+14	902965+14	905075+14	906814+14	907171+14	906831+14
9	930611+14	928570+14	919412+14	905516+14	905719+14	906286+14	906312+14	906029+14	905744+14	904574+14
10	913000+14	910074+14	897059+14	882056+14	883767+14	887450+14	892584+14	897276+14	898374+14	898821+14
11	906713+14	901545+14	885651+14	870460+14	872355+14	877132+14	885758+14	894664+14	896583+14	897770+14
12	901879+14	890992+14	871564+14	856412+14	858169+14	863690+14	876941+14	892731+14	895470+14	897218+14
13	901768+14	890663+14	871248+14	856103+14	857844+14	863356+14	876593+14	892687+14	895445+14	897205+14

POINTWISE FLUX - GROUP 3

	10	11
0	910077+14	910162+14
1	909835+14	909957+14
2	909229+14	909601+14
3	910048+14	910417+14
4	909727+14	910137+14
5	909528+14	909927+14
6	907781+14	907857+14
7	907536+14	907561+14
8	906260+14	906010+14
9	903499+14	903080+14
10	898640+14	898505+14
11	897914+14	897870+14
12	897571+14	897580+14
13	897562+14	897573+14

POINTWISE FLUX - GROUP 4

	0	1	2	3	4	5	6	7	8	9
0	339225+14	333787+14	312446+14	380722+14	468626+14	580729+14	701690+14	100853+15	108126+15	117606+15
1	328994+14	316927+14	288088+14	349524+14	440877+14	560107+14	693899+14	102022+15	109844+15	120097+15
2	264773+14	246450+14	203000+14	244064+14	337979+14	483163+14	696814+14	111398+15	124177+15	141102+15
3	252237+14	230978+14	184727+14	221798+14	310744+14	454795+14	703873+14	111900+15	127645+15	146653+15
4	224654+14	188388+14	134751+14	161867+14	231391+14	356240+14	663209+14	114941+15	133671+15	156122+15
5	222242+14	186149+14	130124+14	160190+14	238497+14	379704+14	686120+14	116361+15	135376+15	158307+15
6	250190+14	230986+14	185901+14	239793+14	364817+14	564406+14	877884+14	129467+15	147766+15	170559+15
7	254278+14	236102+14	192102+14	249051+14	379286+14	584870+14	899663+14	131209+15	149426+15	172172+15
8	274196+14	256726+14	215721+14	286532+14	436557+14	663054+14	986426+14	139350+15	157348+15	179850+15
9	281476+14	263783+14	223399+14	300869+14	459461+14	696177+14	102898+15	144283+15	162465+15	185197+15
10	247285+14	229847+14	188007+14	247767+14	384326+14	602121+14	938008+14	137535+15	156691+15	180736+15
11	232045+14	209436+14	163900+14	213876+14	332171+14	529536+14	872551+14	134674+15	154703+15	179585+15
12	219396+14	181436+14	130999+14	169650+14	262777+14	425310+14	779516+14	132395+15	153380+15	178935+15
13	219053+14	174910+14	112521+14	145740+14	221734+14	352326+14	761099+14	132334+15	153349+15	178919+15

POINTWISE FLUX - GROUP 4

	10	11
0	123442+15	125412+15
1	126423+15	128560+15
2	151436+15	154898+15
3	157859+15	161571+15
4	169132+15	173400+15
5	171604+15	175965+15
6	184065+15	188537+15
7	185676+15	190151+15
8	193243+15	197688+15
9	198729+15	203221+15
10	195074+15	199836+15
11	194308+15	199181+15
12	193915+15	198856+15
13	193904+15	198847+15

```
* * * * * * * * * * * * * * * *
*                               *
*  E N D  O F  O U T P U T      *
*                               *
* * * * * * * * * * * * * * * *
```

PDQ08(WAPD-TM-1266)

```
          $$$$$$$$$$$$$$$$$$$$$$ /BEGIN/ CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$$$
          = 3-D PDQ TEST PROBLEM
0001      010001,2,0,2,1,0,1,9,5,5,-2,14,14,4,0,1
0002      010002,0,1,0,1,0,0
0003      010003,0.936,1-3
0004      010004,1+1,0+0
0005      010008,...,1.,1+8
0006      010036,5,99,73,72,99,18,1,1-2,1-1,   $TRYS,IDC,IDRHO,IDTM, ETC
0007      011000,1,1,1,1,1,1,9,5            $LIMIT EDITS
0008      011001,1,-9,0,1,-5
0009      012001,1,-8,0,1,-3
0010      015001,1,-4                    $EDIT ALL PLANES
0011      015011,0,-1                      $EDIT PLANE1
0012      015021,1,-2                      $EDIT PLANE2
0013      015031,2,-3                      $EDIT PLANE3
0014      015041,3,-4                      $EDIT PLANE4
0015      050101,4+1,3,1+1,5,3+1,7,1+1,9,3+1,11,1+1,13,3+1.14
0016      050201,1+1,1,3+1,2
0017      070001,15+2,4
0018      801000,14,14,1,0,1
0019      801001,5,0,14,0,14,4,7,14,3,14,4,3,14,7,14
0020      802000,4,4,2,-2,0,2,-2
0021      802001,3,0,4,0,4          $ C
0022      802101,2,0,4,0,4          $ B
0023      802201,1,0,4,0,4          $ A
0024      170001,9,010,00,00,0,0
0025      170002,1,020,08,04,0,0
0026      170003,2,020,12,04,0,0
0027      170004,3,020,04,08,0,0
0028      170005,4,021,08,08,0,0
0029      170006,5,022,12,08,0,0
0030      170007,6,020,04,12,0,0
0031      170008,7,022,08,12,0,0
0032      170009,8,021,12,12,0,0
0033      060001,1,2,3,4
0034      090001,1,3,0,5
0035      090101,1,2,3,4,5,6,7,8,9,10,11
0036      110001,1,1,2,2,3,3,4,4,5,5
0037      300001,1,2,3,5,6,18,20,29,99,72,73
0038      300501,HYDROGEN,OXYGEN,ZIRC,STEEL,IRON,U-235,U-238,SOLBOR
0039      300502,T-FUEL,T-MOD,RHO-MOD
0040      301000,1,1,25+4
0041      301011,01,0,0+0,4,01,0+0
0042      302000,1,1,25+4
0043      302011,02,0,0+0,4,02,0+0
0044      303000,1,1,25+4
0045      303011,03,0,0+0,4,03,0+0
0046      304000,1,1,25+4
0047      304011,05,0,0+0,4,05,0+0
0048      305000,1,1,25+4
0049      305011,06,0,0+0,4,06,0+0
0050      306000,1,1,25+4
0051      306011,18,0,0+0,4,18,0+0
```

```
0052      307000,1,1,25+4
0053      307011,20,0,0+0,4,20,0+0
0054      308000,1,1,25+4
0055      308011,29,0,0+0,4,29,0+0
0056      309000,1,1,25+4
0057      309011,99,0,0+0,4,99,0+0
0058      310000,1,1,25+4
0059      310011,72,0,0+0,4,72,0+0
0060      311000,1,1,25+4
0061      311011,73,0,0+0,4,73,0+0
0062      401000,01
0063      401001,A FUEL
0064      401100,0+0,0+0,0+0
0065      401200,0+0,0+0,0+0
0066      401101,18,206569+2,133832+2,252993-2,898511+1,247111+1,3206-10
0067      401102,20,844385+1,946878+0,216691-2,113505+0,268821+1,3181-10
0068      401103,29,522903+2,498606+2,184096-1
0069      401104,01,21116+1,43580-2,57489-0
0070      401105,02,32309+1,26459-2,15402-1
0071      401106,03,60485+1,54513-1,45743-2
0072      401107,05,56420+1,49959-1,72499-2
0073      401108,06,55737+1,99436-1,71267-2
0074      401109,73,1589+0,2144-2,2774-1,2853-3,2471+1,3206-10
0075      401110,99,0+0,-270-4,-210-4
0076      401201,18,251229+3,303868+3,000000+0,257117+3,244200+1,3206-10
0077      401202,20,917810+1,135554+1,000000+0
0078      401203,29,170018+4,213659+4,000000+0
0079      401204,01,21228+2,18537-0,0+0
0080      401205,02,37056+1,93016-4,0+0
0081      401206,03,61403+1,95110-1,0+0
0082      401207,05,11953+2,15852+1,0+0
0083      401208,06,12201+2,13368+1,0+0
0084      401209,73,1085+1,3978-1,0000-0,7691-2,2442+1,3206-10
0085      401210,99,0+0,0+0,0+0
0086      402000,02
0087      402001,B FUEL
0088      402100,0+0,0+0,0+0
0089      402200,0+0,0+0,0+0
0090      402101,18,204740+2,132067+2,248715-2,887795+1,247131+1,3206-10
0091      402102,20,842739+1,938914+0,212765-2,113917+0,268738+1,3181-10
0092      402103,29,516552+2,492285+2,180846-1
0093      402104,01,21349+1,43021-2,56656-0
0094      402105,02,32303+1,26435-2,15142-1
0095      402106,03,60458+1,54472-1,44943-2
0096      402107,05,56214+1,49441-1,71000-2
0097      402108,06,55516+1,99181-1,69767-2
0098      402109,73,1591+0,2264-2,2782-1,3184-3,2471+1,3206-10
0099      402110,99,0+0,-270-4,-210-4
0100      402201,18,248087+3,299398+3,000000+0,253299+3,244200+1,3206-10
0101      402202,20,913060+1,133747+1,000000+0
0102      402203,29,168943+4,212730+4,000000+0
0103      402204,01,21119+2,18453-0,0-0
0104      402205,02,37000+1,92181-4,0-0
```

```
0105      402206,03,61390+1,94361-1,0-0
0106      402207,05,11940+2,15727+1,0-0
0107      402208,06,12190+2,13263+1,0-0
0108      402209,73,1082+1,4107-1,0000-0,9074-2,2442+1,3206-10
0109      402210,99,0+0,0+0,0+0
0110      403000,03
0111      403001,C FUEL
0112      403100,0+0,0+0,0+0
0113      403200,0+0,0+0,0+0
0114      403101,18,203523+2,130900+2,247531-2,881060+1,247143+1,3206-10
0115      403102,20,839650+1,913406+0,211629-2,114136+0,268683+1,3181-10
0116      403103,29,514687+2,490429+2,179994-1
0117      403104,01,21586+1,42909-2,56564-0
0118      403105,02,32301+1,26407-2,15109-1
0119      403106,03,60439+1,54413-1,44829-2
0120      403107,05,56125+1,49320-1,70727-2
0121      403108,06,55425+1,99148-1,69493-2
0122      403109,73,1592+0,2159-2,2804-1,3491-3,2471+1,3206-10
0123      403110,99,0+0,-270-4,-210-4
0124      403201,18,245584+3,296629+3,000000+0,250950+3,244200+1,3206-10
0125      403202,20,909083+1,132612+1,000000+0
0126      403203,29,168372+4,212389+4,000000+0
0127      403204,01,21100+2,18455-0,0+0
0128      403205,02,36763+1,91870-4,0+0
0129      403206,03,61388+1,94134-1,0+0
0130      403207,05,11936+2,15689+1,0+0
0131      403208,06,12187+2,13231+1,0+0
0132      403209,73,1083+1,3621-1,0000-0,1086-1,2442+1,3206-10
0133      403210,99,0+0,0+0,0+0
0134      404000,4
0135      404001,SHROUD
0136      404100,0.87770,.00446266,.00114328
0137      404200,0.30092,.0708,0+0
0138      405000,5
0139      405001,REFLECTOR
0140      405100,1.40398,.000791834,.0365214
0141      405200,0.24701,.0286603,0+0
0142      100011,01,299462-1,02,280626-1,03,418570-2,05,114076-2,06,565840-4
0143      100012,18,165654-3,20,637909-2,29,915855-5
0144      100021,01,299462-1,02,280626-1,03,418570-2,05,114076-2,06,565840-4
0145      100022,18,185531-3,20,635943-2,29,915855-5
0146      100031,01,299462-1,02,280626-1,03,418570-2,05,114076-2,06,565840-4
0147      100032,18,205409-3,20,633977-2,29,915855-5
          * TH DATA
0148      500001,2250.,.035,.965,4+6,100.,.023,1.,1.,1.,1.,2.,1.,0.0
0149      500002,.03,0.,0.    $PRESS,FW,FM,W,K1,A,D1,D2, ...
0150      500011,1.07 $A(N)
0151      500012,0.0 $B(N)
0152      500013,.0003333  $C(N) FROM PDQ5 TH RPT
0153      500014,0.0 $D(N)
0154      510001,.191,.,522.,1 $F,FLOW RATIO,TIN,TRK NO=REGION=COMP
0155      510002,.238,.,522.,2 $F,FLOW RATIO,TIN,TRK NO=REGION=COMP
0156      510003,.571,.,522.,3 $F,FLOW RATIO,TIN,TRK NO=REGION=COMP
```

```
0157    510004,1.00,.,522.,4 $F,FLOW RATIO,TIN,TRK NO=REGION=COMP
0158    510005,1.00,.,522.,5 $F,FLOW RATIO,TIN,TRK NO=REGION=COMP
0159    520001,55.1,.56,.56,.32,.,56.,1          $AH,AF,VC,VF,AY,LZ,COMP FUEL A
0160    520002,55.1,.56,.56,.32,.,56.,2          $AH,AF,VC,VF,AY,LZ,COMP FUEL B
0161    520003,55.1,.56,.56,.32,.,56.,3          $AH,AF,VC,VF,AY,LZ,COMP FUEL C
0162    520004,1.0,1.0,1.0,0.0,0.0,1.0,4 $ AN,AF,VC,VF,ETC.
0163    520005,1.0,1.0,1.0,0.0,0.0,1.0,5 $ AN,AF,VC,VF,ETC.
0164    530001,.191,.162,.162,.000,00,1 $RS,R1,R2,R3,FF,COMP
0165    530002,.191,.162,.162,.000,00,2 $RS,R1,R2,R3,FF,COMP
0166    530003,.191,.162,.162,.000,00,3 $RS,R1,R2,R3,FF,COMP
0167    530004,.000,.000,.000,.000,-1,4 $RS,R1,R2,R3,FF,COMP
0168    530005,.000,.000,.000,.000,-1,5 $RS,R1,R2,R3,FF,COMP
0169    540001,1,1,5  $ (RR,TT,C)I..  GAP K,FUEL K,COMP
0170    550101,.0299462,5  $NH
0171    550201,547+3,5   $TM REF
0172    550301,1096+4,5   $TF REF
0173    560111,.,1+60        $RR TABLE ...HEAT FLUX  FOR GAP K
0174    560121,.,1+60        $RR TABLE ...FISSION    FOR GAP K
0175    560131,1+11,1+11,1+11,1+11     $GAP CONDUCTANCE VS INDEP VARS
0176    570111,.,1+60        $TT TABLE ...HEAT FLUX  FOR FUEL K
0177    570121,.,1+60        $TT TABLE ...FISSION    FOR FUELK
0178    570131,2.88,2.88,2.88,2.88     $UO2 K VS INDEP VARS
        * END PDQ TH DATA
        * SUB-CASE DATA
0179    010008,...,1.,1+9
0180    201001,5MW,15MW
0181    203001,.05,.15
0182    206001,/2/10
        = 3-D PDQ T-H TEST
        * END SUB-CASE DATA
0183    2000,60,0 $ REDUCE PAPER OUTPUT
        $$$$$$$$$$$$$$$$$$$$$ //END// CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$$
        ..........
```

//

P R O B L E M I N P U T D E S C R I P T I O N

PROGRAM IDENTIFICATION	PROGRAM(VERSION-DATE)	PDQ08(WAPD-TM-1266)	COMPUTER	CDC-7600
SPATIAL DESCRIPTION	ITERATION SOLUTION	EIGENVALUE	ADJOINT SOLUTION	NO
FEW-GROUP DESCRIPTION	NUMBER OF GROUPS	2	FAST GROUP	P-1
	THERMAL GROUPS	1	SOLUTION GROUPS	2
GEOMETRY PARAMETERS	DIMENSIONALITY, TYPE	3-D RECTANGULAR	BLOCK MESH TYPE	GROSS ONLY
	COMPOSITIONS	REGIONS (1 TO 1)	INPUT MESH UNITS	INCHES
	LARGEST FINAL FIGURE	9	LARGEST PLANAR REGION	5
	LARGEST COMPOSITION	5	COLUMN BOUNDARY	14
	ROW BOUNDARY	14	PLANE BOUNDARY	4
	MESH ELEMENTS	784	MESH POINTS	1125
	MESH GROUP-POINTS	2250	SOLUTION POINTS	588

	NON-SOLUTION POINTS - 537	SOLUTION GROUP-POINTS - 1176	
BOUNDARY CONDITIONS	COLUMN 0 - ZERO FLUX	COLUMN 14 - ZERO CURRENT	
	ROW 0 - ZERO FLUX	ROW 14 - ZERO CURRENT	
	PLANE 0 - ZERO FLUX	PLANE 4 - ZERO FLUX	
ITERATION PARAMETERS	INPUT EIGENVALUE - 936000+00	CONVERGENCE PARAMETER - 100000-03	
	CHI(GROUP 1) - 100000+01	CHI(GROUP 2) - 000000+00	
DEPLETION PARAMETERS	BEGIN-TIME - 000000+00 HOURS	END-TIME - 000000+00 HOURS	
	DEPLETION INTERVAL - 000000+00 HOURS	POWER LEVEL - 100000+09 WATTS	
DATA STORAGE ALLOCATIONS	CENTRAL MEMORY - 31202 WORDS	EXTENDED MEMORY - 131072 WORDS	
BLOCKING COUNTS	TOTAL GROSS BLOCKS - 40	TOTAL FINE BLOCKS - 0	
	GROSS BLOCKS / PLANE - 10	FINE BLOCKS / PLANE - 0	
	GROSS BLOCK PLANES - 4	FINE BLOCK PLANES - 0	

S U B - C A S E D E S C R I P T I O N

SUB-CASE 1 OF 2
SUB-CASE IDENTIFICATION - 5MW

CONFIGURATION - 0

FLUX GUESS - PREVIOUS

CONTROL FEEDBACK - NO
TEMPERATURE FEEDBACK - YES
XENON FEEDBACK - NO

CONCENTRATION REPLACEMENT - NO

DEPLETION PATH - SPATIAL / DEPLETE
INITIAL TIME (EFPH) - 000000+00
DEPLETION INTERVAL (HOURS) - 000000+00
DEPLETION INTERVAL (EFPH) - 000000+00

POWER FRACTION - 500000-01
POWER LEVEL - 500000+07

S P A T I A L - I T E R A T I O N R E S U L T S

GROUP 1	PASS 1	RHO = 7028154+00	OMEGA(8) = 1294376+01	SIGMA = 6955840+00	DELTA(3) = 1000000+00
GROUP 1	PASS 2	RHO = 7091093+00	OMEGA(16) = 1299256+01	SIGMA = 9521766+00	DELTA(3) = 1000000+00
GROUP 1	PASS 3	RHO = 7104704+00	OMEGA(24) = 1300323+01	SIGMA = 9371805+00	DELTA(3) = 1000000+00
GROUP 2	PASS 1	RHO = 2633463+00	OMEGA(8) = 1076261+01	SIGMA = 2622515+00	DELTA(1) = 1000000+00

```
GROUP 1    IT. =  3   R(1) = 3260321+03   DELTA = 2796019+00
GROUP 2    IT. =  3   R(1) = 1028448+03   DELTA = 1473403-01

SIG/I = 0000000+00   MAX. = 3560391+01   GAMMA = 3485342+01   RATIO( 0) = 1000000+01
SIG/O = 0000000+00   MIN. = 2656378+00   PT/AV = 2482799+01   EPS.(  1) = 3400364+01        LAMBDA = 809112955+00

GROUP 1    IT. =  3   R(1) = 6605579+02   DELTA = 1962891+00
GROUP 2    IT. =  3   R(1) = 1614272+02   DELTA = 5463266-02

SIG/I = 1989060+00   MAX. = 1196575+01   GAMMA = 1132235+01   RATIO( 0) = 1000000+01
SIG/O = 2246298+00   MIN. = 7013709+00   PT/AV = 1967122+01   EPS.(  2) = 3061535+00        LAMBDA = 916106277+00

GROUP 1    IT. =  3   R(1) = 2991415+02   DELTA = 2030481+00
GROUP 2    IT. =  3   R(1) = 8114537+01   DELTA = 6816215-02

SIG/I = 4558139+00   MAX. = 1026394+01   GAMMA = 1012821+01   RATIO( 0) = 1000000+01
SIG/O = 4183818+00   MIN. = 7645986+00   PT/AV = 2888403+01   EPS.(  3) = 1759473+00        LAMBDA = 927851602+00

GROUP 1    IT. =  3   R(1) = 2004024+02   DELTA = 2189251+00
GROUP 2    IT. =  3   R(1) = 5523361+01   DELTA = 6920148-02

SIG/I = 6706673+00   MAX. = 1003053+01   GAMMA = 1003563+01   RATIO( 1) = 1000000+01
SIG/O = 6996188+00   MIN. = 8231764+00   PT/AV = 2740886+01   EPS.(  4) = 1159647+00        LAMBDA = 931157781+00

GROUP 1    IT. =  3   R(1) = 1271715+02   DELTA = 2317417+00
GROUP 2    IT. =  3   R(1) = 3411416+01   DELTA = 6410996-02

SIG/I = 7380027+00   MAX. = 9897905+00   GAMMA = 1002672+01   RATIO( 2) = 7392744+00
SIG/O = 7566340+00   MIN. = 8763448+00   PT/AV = 2209099+01   EPS.(  5) = 6137371-01        LAMBDA = 933646109+00

GROUP 1    IT. =  3   R(1) = 7261029+01   DELTA = 2398133+00
GROUP 2    IT. =  3   R(1) = 1883228+01   DELTA = 5980460-02

SIG/I = 7667451+00   MAX. = 9722707+00   GAMMA = 1001715+01   RATIO( 3) = 4876339+00
SIG/O = 7771506+00   MIN. = 9124238+00   PT/AV = 2459950+01   EPS.(  6) = 3958638-01        LAMBDA = 935247588+00

GROUP 1    IT. =  3   R(1) = 4670270+01   DELTA = 2525431+00
GROUP 2    IT. =  3   R(1) = 1229724+01   DELTA = 6048843-02

SIG/I = 7805720+00   MAX. = 9590269+00   GAMMA = 1000697+01   RATIO( 1) = 3603490+00
SIG/O = 7885170+00   MIN. = 9205745+00   PT/AV = 2365478+01   EPS.(  7) = 2471138-01        LAMBDA = 935899559+00

GROUP 1    IT. =  3   R(1) = 3491190+01   DELTA = 2639486+00
GROUP 2    IT. =  3   R(1) = 9343689+00   DELTA = 6128038-02

SIG/I = 8339747+00   MAX. = 9518146+00   GAMMA = 1000267+01   RATIO( 2) = 7168999+00
SIG/O = 8396586+00   MIN. = 9234652+00   PT/AV = 2117883+01   EPS.(  8) = 1673366-01        LAMBDA = 936149393+00

GROUP 1    IT. =  3   R(1) = 2308493+01   DELTA = 2820708+00
GROUP 2    IT. =  3   R(1) = 6284788+00   DELTA = 6144343-02

SIG/I = 8545993+00   MAX. = 9446412+00   GAMMA = 1000197+01   RATIO( 3) = 4878078+00
```

SIG/O = 8597520+00 MIN. = 9283958+00 PT/AV = 1664432+01 EPS.(9) = 8872345-02 LAMBDA = 936333728+00

ITERATIONS 9 ...EIGENVALUE = 936333728+00 ..REACTIVITY(PERCENTAGE) =-679952775+01 ......DOMINANCE = 838443698+00
LEVELS ..FLUX NORMALIZATION = 134901853+14 .....POWER NORMALIZATION = 891337531+12 ...POWER VOLUME = 330365192+06

//

PLANE GROUPING 1
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	62817630+03	52793732+03	18274723-01	12948064-05	27834545+05
2	57642992+03	53376531+03	17146068-01	00000000+00	19906215+05
3	59264101+03	53718150+03	12758842-01	00000000+00	25886561+05
4	57644824+03	53376933+03	17140954-01	00000000+00	19912893+05
5	67120566+03	56949553+03	-33593792-01	00000000+00	35430184+05
6	70227991+03	58545368+03	-61359563-01	00000000+00	38961632+05
7	59267233+03	53718830+03	12750109-01	00000000+00	25898024+05
8	70229952+03	58546246+03	-61376294-01	00000000+00	38967429+05
9	71558155+03	58465370+03	-59964984-01	13600670-03	47875269+05

PLANE GROUPING 2
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	56717251+03	52280436+03	30268826-01	00000000+00	14962322+05
2	54639851+03	52343865+03	30048846-01	00000000+00	10698013+05
3	55373126+03	52387120+03	29530614-01	00000000+00	13914502+05
4	54640876+03	52343926+03	30048121-01	00000000+00	10702508+05
5	58319231+03	52814513+03	24437967-01	00000000+00	19046657+05
6	59677283+03	53031050+03	21660857-01	00000000+00	20944941+05
7	55374854+03	52387222+03	29529393-01	00000000+00	13922084+05
8	59678576+03	53031187+03	21659057-01	00000000+00	20948588+05
9	60454759+03	53020163+03	21803162-01	00000000+00	25739575+05

PLANE GROUPING 3
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	63224091+03	52526353+03	25207497-01	00000000+00	34182941+05
2	58058005+03	52816516+03	24414215-01	00000000+00	24448915+05
3	59806629+03	52993239+03	22155280-01	00000000+00	31792069+05
4	58059964+03	52816746+03	24411494-01	00000000+00	24456994+05
5	67218632+03	54712524+03	-17394947-03	00000000+00	43509726+05
6	70674328+03	55627810+03	-12724809-01	00000000+00	47844719+05

7	59809977+03	52993606+03	22150474-01	00000000+00	31805999+05
8	70677094+03	55628356+03	-12732199-01	00000000+00	47851882+05
9	72423455+03	55580847+03	-12088497-01	00000000+00	58786514+05

PLANE GROUPING 4
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	64456638+03	52831399+03	17755235-01	38844193-05	34270656+05
2	58686027+03	53437501+03	16376093-01	00000000+00	24510316+05
3	60617680+03	53797143+03	11745348-01	00000000+00	31872591+05
4	58688103+03	53437917+03	16370716-01	00000000+00	24518086+05
5	69696384+03	57263086+03	-36291391-01	00000000+00	43621947+05
6	72254093+03	59008433+03	-64179323-01	00000000+00	47969978+05
7	60621252+03	53797855+03	11736216-01	00000000+00	31885995+05
8	72255069+03	59009423+03	-64195110-01	00000000+00	47976849+05
9	73811145+03	58916944+03	-63039508-01	40802010-03	58943115+05

PLANE GROUPING 5
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	60772162+03	53025571+03	11861438-01	00000000+00	15050038+05
2	56184944+03	53882858+03	10647897-01	00000000+00	10759414+05
3	57367995+03	54376321+03	43758988-02	00000000+00	13995025+05
4	56186404+03	53883425+03	10640651-01	00000000+00	10763600+05
5	64446682+03	59017009+03	-64316035-01	00000000+00	19158878+05
6	67755551+03	61286201+03	-10717456+00	00000000+00	21070199+05
7	57370469+03	54377292+03	43636358-02	00000000+00	14002079+05
8	67757693+03	61287399+03	-10720157+00	00000000+00	21073555+05
9	68439865+03	61175889+03	-10476695+00	00000000+00	25896176+05

MAXIMUM RELATIVE ERROR OF FUEL TEMPERATURE ---------- = 83958144+00
TOTAL FLOW IN FUELED TRACKS ---------- = 39137776+06

//

S P A T I A L - I T E R A T I O N R E S U L T S

SIG/I = 0000000+00 MAX. = 9368646+00 GAMMA = 9921063+00 RATIO(0) = 1000000+01
SIG/O = 0000000+00 MIN. = 9187998+00 PT/AV = 1640715+01 EPS.(1) = 1516805-01 LAMBDA = 932950859+00

SIG/I = 4404458+00 MAX. = 9368046+00 GAMMA = 9995646+00 RATIO(0) = 1000000+01
SIG/O = 4208612+00 MIN. = 9258636+00 PT/AV = 1833667+01 EPS.(2) = 7164316-02 LAMBDA = 932544647+00

ITERATIONS 2 ...EIGENVALUE = 932544647+00 ..REACTIVITY(PERCENTAGE) =-723347166+01 .....DOMINANCE = 378273101+00
LEVELS ..FLUX NORMALIZATION = 135523405+14 .....POWER NORMALIZATION = 895444315+12 ...POWER VOLUME = 330365192+06

PLANE GROUPING 1
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	62824890+03	52793931+03	18264769-01	27471595-05	27863875+05
2	57645254+03	53376184+03	17150048-01	00000000+00	19918312+05
3	59270308+03	53718440+03	12755118-01	00000000+00	25914083+05
4	57646678+03	53376497+03	17146062-01	00000000+00	19923502+05
5	67133803+03	56951409+03	-33625490-01	00000000+00	35469079+05
6	70237047+03	58548753+03	-61452484-01	22221168-04	39008797+05
7	59272785+03	53718979+03	12748191-01	00000000+00	25923144+05
8	70238433+03	58549361+03	-61466082-01	24724087-04	39012891+05
9	71582594+03	58474058+03	-60175333-01	19467162-03	47979324+05

PLANE GROUPING 2
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	56691265+03	52279995+03	30277378-01	00000000+00	14874330+05
2	54623499+03	52342901+03	30060408-01	00000000+00	10626288+05
3	55353444+03	52385959+03	29544519-01	00000000+00	13828159+05
4	54624308+03	52342949+03	30059835-01	00000000+00	10629840+05
5	58284616+03	52811030+03	24479263-01	00000000+00	18938710+05
6	59637627+03	53026825+03	21716080-01	00000000+00	20833017+05
7	55354830+03	52386041+03	29543539-01	00000000+00	13834240+05
8	59638547+03	53026923+03	21714799-01	00000000+00	20835613+05
9	60417984+03	53016665+03	21848892-01	00000000+00	25624116+05

PLANE GROUPING 3
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	63250280+03	52526042+03	25214071-01	00000000+00	34281749+05
2	58068093+03	52815296+03	24428688-01	00000000+00	24501593+05
3	59823668+03	52992127+03	22169828-01	00000000+00	31876696+05
4	58069613+03	52815475+03	24426557-01	00000000+00	24507855+05
5	67254154+03	54709983+03	-13865978-03	00000000+00	43641738+05
6	70721964+03	55625355+03	-12691562-01	00000000+00	48003524+05
7	59826315+03	52992419+03	22166000-01	00000000+00	31887703+05
8	70723911+03	55625741+03	-12696792-01	00000000+00	48008563+05
9	72496732+03	55581531+03	-12097781-01	00000000+00	59040036+05

PLANE GROUPING 4
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	64476405+03	52831902+03	17735358-01	82414786-05	34358852+05
2	58697798+03	53437703+03	16373489-01	00000000+00	24564352+05
3	60636774+03	53798167+03	11732228-01	00000000+00	31957093+05
4	58699405+03	53438026+03	16369302-01	00000000+00	24570361+05
5	69732847+03	57267611+03	-36357143-01	00000000+00	43734554+05
6	72272163+03	59015804+03	-64349213-01	66663503-04	48097243+05
7	60639589+03	53798731+03	11724989-01	00000000+00	31967644+05
8	72272851+03	59016468+03	-64365697-01	74172262-04	48102086+05
9	73841559+03	58929808+03	-63383627-01	58401486-03	59157579+05

PLANE GROUPING 5
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	60747983+03	53025986+03	11844878-01	00000000+00	14951026+05
2	56169871+03	53882853+03	10647969-01	00000000+00	10688991+05
3	57350482+03	54377319+03	43632978-02	00000000+00	13908458+05
4	56171016+03	53883294+03	10642326-01	00000000+00	10692290+05
5	64414407+03	59021064+03	-64380668-01	00000000+00	19030945+05
6	67717015+03	61292502+03	-10731668+00	00000000+00	20925625+05
7	57352450+03	54378088+03	43535841-02	00000000+00	13914084+05
8	67718538+03	61293348+03	-10733576+00	00000000+00	20928024+05
9	68409491+03	61190027+03	-10504459+00	00000000+00	25740358+05

MAXIMUM RELATIVE ERROR OF FUEL TEMPERATURE ---------- = 30931472-03

TEMPERATURE-FEEDBACK CONVERGED

//

S P A T I A L - I T E R A T I O N R E S U L T S

SIG/I = 0000000+00	MAX. = 9363019+00	GAMMA = 1000121+01	RATIO(0) = 1000000+01	
SIG/O = 0000000+00	MIN. = 9283450+00	PT/AV = 1258224+01	EPS.(1) = 4465459-02	LAMBDA = 932139443+00
SIG/I = 7805720+00	MAX. = 9367231+00	GAMMA = 1000523+01	RATIO(1) = 1000000+01	
SIG/O = 9285736+00	MIN. = 9297607+00	PT/AV = 1333119+01	EPS.(2) = 4391931-02	LAMBDA = 932627109+00
SIG/I = 9124615+00	MAX. = 9358801+00	GAMMA = 1000101+01	RATIO(2) = 3520453+00	
SIG/O = 9117453+00	MIN. = 9301043+00	PT/AV = 1187582+01	EPS.(3) = 3387103-02	LAMBDA = 932720877+00
SIG/I = 9162685+00	MAX. = 9350769+00	GAMMA = 1000022+01	RATIO(1) = 2633658+00	
SIG/O = 9160081+00	MIN. = 9306037+00	PT/AV = 1097536+01	EPS.(4) = 2504280-02	LAMBDA = 932741045+00

```
SIG/I = 9185162+00   MAX. = 9347818+00   GAMMA = 1000031+01   RATIO( 2) = 9710644+00
SIG/O = 9185219+00   MIN. = 9309578+00   PT/AV = 1096282+01   EPS.(  5) = 2156978-02        LAMBDA = 932769838+00

SIG/I = 9185356+00   MAX. = 9341125+00   GAMMA = 1000017+01   RATIO( 3) = 9655038+00
SIG/O = 9185313+00   MIN. = 9315205+00   PT/AV = 1049467+01   EPS.(  6) = 1422264-02        LAMBDA = 932785838+00

SIG/I = 9185438+00   MAX. = 9336367+00   GAMMA = 1000017+01   RATIO( 4) = 9560305+00
SIG/O = 9185415+00   MIN. = 9319990+00   PT/AV = 1066505+01   EPS.(  7) = 8954801-03        LAMBDA = 932801429+00

SIG/I = 9185399+00   MAX. = 9333112+00   GAMMA = 1000008+01   RATIO( 5) = 9447255+00
SIG/O = 9185393+00   MIN. = 9323085+00   PT/AV = 1073319+01   EPS.(  8) = 5388494-03        LAMBDA = 932808524+00

SIG/I = 9185472+00   MAX. = 9330968+00   GAMMA = 1000001+01   RATIO( 6) = 9316067+00
SIG/O = 9185479+00   MIN. = 9324983+00   PT/AV = 1118708+01   EPS.(  9) = 3335772-03        LAMBDA = 932809438+00

SIG/I = 9185661+00   MAX. = 9329820+00   GAMMA = 1000002+01   RATIO( 7) = 9176483+00
SIG/O = 9185703+00   MIN. = 9326230+00   PT/AV = 1137318+01   EPS.( 10) = 2021306-03        LAMBDA = 932811545+00

SIG/I = 9186162+00   MAX. = 9329112+00   GAMMA = 9999996+00   RATIO( 8) = 9002377+00
SIG/O = 9186206+00   MIN. = 9326880+00   PT/AV = 1237191+01   EPS.( 11) = 1321440-03        LAMBDA = 932811217+00

SIG/I = 9186944+00   MAX. = 9328725+00   GAMMA = 1000000+01   RATIO( 9) = 8807200+00
SIG/O = 9187025+00   MIN. = 9327325+00   PT/AV = 1305747+01   EPS.( 12) = 8474225-04        LAMBDA = 932811508+00

ITERATIONS 12 ...EIGENVALUE = 932811508+00 ..REACTIVITY(PERCENTAGE) =-720279405+01 ......DOMINANCE = 909660498+00
LEVELS ..FLUX NORMALIZATION = 136199967+14 .....POWER NORMALIZATION = 899914565+12 ...POWER VOLUME = 330365192+06
```

//

I N T E G R A T I O N E D I T S

PLANE GROUPING 1
FLUX INTEGRALS FOLLOWED BY FLUX AVERAGES

EDIT SET	VOLUME	GROUP 1	2
1	803052890+06	127312123+20	296951054+19
		158535166+14	369777705+13

PLANE GROUPING 1
INTEGRATED POWER EDIT

EDIT SET	POWER FRACTION	RELATIVE POWER DENSITY	GROUP FRACTION OF EDIT-SET POWER GROUP 1	2
1	853896937+00	351281752+00	208708359+00	791291641+00

PLANE GROUPING 1
INTEGRATED ABSORPTION EDIT

EDIT SET	GROUP FRACTION OF TOTAL ABSORPTION FOLLOWED BY GROUP FRACTION OF EDIT-SET ABSORPTION ABSORP. FRACT. GROUP 1	2
1	853769994+00 280450030+00	573319964+00

328484290+00 671515710+00

PLANE GROUPING 1
TOTAL GROUP-INDEPENDENT BUCKLING, K INFINITY, AND K EFFECTIVE EDITS

EDIT SET	GP. IND. BUCK.	SUM	K INFINITY FOLLOWED BY K EFFECTIVE GROUP 1	2
1	434411314-03	954492044+00	205312627+00	749179417+00
		932811508+00	200979484+00	731832024+00

PLANE GROUPING 1
FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	13509967+01	88685385-02	18167875-01	55509170-02	69991539-13	43146550-03

PLANE GROUPING 1
FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 2

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	34258777+00	77728184-01	00000000+00	86658129-01	11376984-11	47616221-03

//

S U B - C A S E D E S C R I P T I O N

SUB-CASE 2 OF 2
SUB-CASE IDENTIFICATION - 15MW

CONFIGURATION - 0

FLUX GUESS - PREVIOUS

CONTROL FEEDBACK - NO
TEMPERATURE FEEDBACK - YES
XENON FEEDBACK - NO

CONCENTRATION REPLACEMENT - NO

DEPLETION PATH - SPATIAL / DEPLETE
INITIAL TIME (EFPH) - 000000+00
DEPLETION INTERVAL (HOURS) - 000000+00
DEPLETION INTERVAL (EFPH) - 000000+00

POWER FRACTION - 150000+00
POWER LEVEL - 150000+08

//

S P A T I A L - I T E R A T I O N R E S U L T S

```
GROUP 1    PASS 1    RHO = 7009167+00    OMEGA(  8) = 1292921+01    SIGMA = 6938469+00    DELTA(  3) = 1000000+00
GROUP 1    PASS 2    RHO = 7072209+00    OMEGA( 16) = 1297782+01    SIGMA = 9532413+00    DELTA(  3) = 1000000+00
GROUP 1    PASS 3    RHO = 7086198+00    OMEGA( 24) = 1298873+01    SIGMA = 9382215+00    DELTA(  3) = 1000000+00

GROUP 2    PASS 1    RHO = 2633467+00    OMEGA(  8) = 1076261+01    SIGMA = 2622521+00    DELTA(  1) = 1000000+00

GROUP 1   IT. =  3   R(1) = 1224446+01   DELTA = 3563001+00
GROUP 2   IT. =  3   R(1) = 3560312+00   DELTA = 5437947-02

SIG/I = 0000000+00   MAX. = 9309522+00   GAMMA = 9970102+00   RATIO( 0) = 1000000+01
SIG/O = 0000000+00   MIN. = 9302094+00   PT/AV = 1057855+01   EPS.(  1) = 3170276-02        LAMBDA = 933167829+00

GROUP 1   IT. =  3   R(1) = 1774679+00   DELTA = 1429657+00
GROUP 2   IT. =  3   R(1) = 4424499-01   DELTA = 7267339-02

SIG/I = 1434334+00   MAX. = 9325548+00   GAMMA = 9996078+00   RATIO( 0) = 1000000+01
SIG/O = 1359757+00   MIN. = 9319293+00   PT/AV = 2291438+01   EPS.(  2) = 9353536-03        LAMBDA = 932801842+00

ITERATIONS  2 ...EIGENVALUE = 932801842+00 ..REACTIVITY(PERCENTAGE) =-720390494+01 ......DOMINANCE = 482593709-01
LEVELS ..FLUX NORMALIZATION = 409992041+14 .....POWER NORMALIZATION = 902980664+12 ...POWER VOLUME = 330365192+06
```

//

PLANE GROUPING 1
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	75122181+03	53118029+03	-39971912-01	36158696-01	84079911+05
2	68441807+03	55611098+03	-13296454-01	00000000+00	60045135+05
3	73249301+03	56567788+03	-27693527-01	00000000+00	78154667+05
4	68441998+03	55611136+03	-13296996-01	00000000+00	60045853+05
5	80619018+03	61994988+03	-35481231+00	30487227+00	10704936+06
6	82141888+03	62869952+03	-51735371+00	51773039+00	11781838+06
7	73249622+03	56567852+03	-27694513-01	00000000+00	78155877+05
8	82141908+03	62869955+03	-51735433+00	51773125+00	11781852+06
9	85989070+03	62858164+03	-51024231+00	50770354+00	14503692+06

PLANE GROUPING 2
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	65169785+03	52423272+03	27406764-01	00000000+00	43158138+05
2	59220677+03	52614215+03	26818354-01	00000000+00	30801549+05
3	61336696+03	52739204+03	25331663-01	00000000+00	40095883+05
4	59220762+03	52614220+03	26818295-01	00000000+00	30801919+05

5	69741744+03	53905422+03	10359402-01	00000000+00	54961246+05
6	73639609+03	54524633+03	24420892-02	00000000+00	60510809+05
7	61336843+03	52739212+03	25331559-01	00000000+00	40096530+05
8	73639640+03	54524636+03	24420425-02	00000000+00	60510898+05
9	75927190+03	54497231+03	28247479-02	00000000+00	74496404+05

PLANE GROUPING 3
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	77759197+03	52954288+03	-68070397-03	11210176-01	10441686+06
2	69906215+03	53959516+03	96684326-02	00000000+00	74541643+05
3	75216029+03	54478195+03	30907413-02	00000000+00	97029444+05
4	69906419+03	53959536+03	96681743-02	00000000+00	74542505+05
5	84286157+03	59060441+03	-10890492+00	55909674-01	13295784+06
6	86180877+03	60692357+03	-24083845+00	19280213+00	14636459+06
7	75216380+03	54478230+03	30902680-02	00000000+00	97030930+05
8	86180903+03	60692365+03	-24083896+00	19280262+00	14636477+06
9	90959588+03	60652608+03	-23253357+00	18267066+00	18019207+06

PLANE GROUPING 4
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	78908686+03	53207044+03	-46208461-01	37942940-01	10454097+06
2	71747870+03	55843597+03	-15638028-01	00000000+00	74666923+05
3	77528928+03	56871359+03	-30564607-01	00000000+00	97184053+05
4	71748101+03	55843640+03	-15638598-01	00000000+00	74667814+05
5	84305347+03	63968871+03	-38075776+00	30228162+00	13309361+06
6	86196169+03	65270069+03	-57572742+00	55788494+00	14647281+06
7	77529310+03	56871427+03	-30565601-01	00000000+00	97185545+05
8	86196193+03	65270069+03	-57572830+00	55788629+00	14647298+06
9	90975928+03	65270069+03	-56722321+00	54486422+00	18030777+06

PLANE GROUPING 5
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	68698661+03	53199115+03	-73026572-01	59322973-01	43281899+05
2	63671336+03	57100297+03	-33919767-01	00000000+00	30926840+05
3	67002946+03	58475637+03	-55606716-01	00000000+00	40250503+05
4	63671475+03	57100352+03	-33920563-01	00000000+00	30927239+05
5	73265551+03	65270069+03	-57477423+00	55642552+00	55096626+05
6	74048617+03	65270069+03	-73549527+00	80250411+00	60617748+05
7	67003175+03	58475729+03	-55608207-01	00000000+00	40251156+05

8	74048628+03	65270069+03	-73549574+00	80250482+00	60617827+05
9	76031693+03	65270069+03	-73097015+00	79557574+00	74610919+05

MAXIMUM RELATIVE ERROR OF FUEL TEMPERATURE ---------- = 70902346-01
TOTAL FLOW IN FUELED TRACKS ---------- = 39137776+06

//

S P A T I A L - I T E R A T I O N R E S U L T S

SIG/I = 0000000+00 MAX. = 9462165+00 GAMMA = 1007570+01 RATIO(0) = 1000000+01
SIG/O = 0000000+00 MIN. = 9252531+00 PT/AV = 1717901+01 EPS.(1) = 1421212-01 LAMBDA = 932957164+00

SIG/I = 1758720+00 MAX. = 9368804+00 GAMMA = 1000763+01 RATIO(0) = 1000000+01
SIG/O = 1443385+00 MIN. = 9321961+00 PT/AV = 2892411+01 EPS.(2) = 3439536-02 LAMBDA = 933669024+00

ITERATIONS 2 ...EIGENVALUE = 933669024+00 ..REACTIVITY(PERCENTAGE) =-710433502+01 ......DOMINANCE = 843021743-01
LEVELS ..FLUX NORMALIZATION = 409987213+14 .....POWER NORMALIZATION = 902970030+12 ...POWER VOLUME = 330365192+06

//

PLANE GROUPING 1
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	75133324+03	53119818+03	-39929583-01	36087552-01	84053854+05
2	68496078+03	55621230+03	-13439616-01	00000000+00	60252542+05
3	73312887+03	56579535+03	-27877731-01	00000000+00	78398693+05
4	68495982+03	55621216+03	-13439415-01	00000000+00	60252156+05
5	80592781+03	61999392+03	-35468283+00	30460467+00	10686409+06
6	82077049+03	62873189+03	-51652999+00	51648587+00	11736004+06
7	73312586+03	56579487+03	-27876973-01	00000000+00	78397500+05
8	82077039+03	62873199+03	-51653085+00	51648695+00	11735997+06
9	85901323+03	62861737+03	-50929796+00	50627859+00	14441621+06

PLANE GROUPING 2
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	65191939+03	52423620+03	27399627-01	00000000+00	43236307+05
2	59237441+03	52615205+03	26806563-01	00000000+00	30875161+05
3	61357856+03	52740454+03	25316813-01	00000000+00	40188853+05
4	59237443+03	52615205+03	26806561-01	00000000+00	30875171+05
5	69772182+03	53908330+03	10322235-01	00000000+00	55057232+05
6	73663793+03	54527236+03	24057513-02	00000000+00	60579769+05
7	61357813+03	52740451+03	25316843-01	00000000+00	40188664+05
8	73663886+03	54527246+03	24056110-02	00000000+00	60580035+05
9	75955752+03	54499974+03	27864384-02	00000000+00	74586926+05

PLANE GROUPING 3
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	77786643+03	52955017+03	-69856898-03	11211172-01	10451479+06
2	69960270+03	53964292+03	96074725-02	00000000+00	74772647+05
3	75281531+03	54484083+03	30084639-02	00000000+00	97309806+05
4	69960198+03	53964288+03	96075207-02	00000000+00	74772327+05
5	84295204+03	59065820+03	-10925178+00	56247575-01	13302185+06
6	86152645+03	60691862+03	-24065064+00	19256459+00	14616480+06
7	75281277+03	54484065+03	30087257-02	00000000+00	97308701+05
8	86152692+03	60691883+03	-24065181+00	19256569+00	14616513+06
9	90920521+03	60651976+03	-23229789+00	18237261+00	17991546+06

PLANE GROUPING 4
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	78914611+03	53209108+03	-46137628-01	37843961-01	10445792+06
2	71817008+03	55854753+03	-15788172-01	00000000+00	74941192+05
3	77608868+03	56883868+03	-30748538-01	00000000+00	97503563+05
4	71816869+03	55854738+03	-15787968-01	00000000+00	74940608+05
5	84257731+03	63969577+03	-38065860+00	30211486+00	13275673+06
6	86092499+03	65270069+03	-57449215+00	55599363+00	14573916+06
7	77608460+03	56883818+03	-30747799-01	00000000+00	97501868+05
8	86092466+03	65270069+03	-57449335+00	55599546+00	14573892+06
9	90835815+03	65270069+03	-56580888+00	54269875+00	17931569+06

PLANE GROUPING 5
WEIGHTED THERMAL-HYDRAULIC RESULTS AT 0. HOURS

EDIT SET	FUEL TEMPERATURE (DEG. F)	MODERATOR TEMPERATURE (DEG. F)	MODERATOR DENSITY (FRACT. CHANGE)	VAPOR (VOL. FRACT.)	HEAT FLUX (BTU/HR.-SQ. FT.)
1	68698719+03	53201726+03	-72952553-01	59207523-01	43188857+05
2	63710956+03	57115254+03	-34138147-01	00000000+00	31043787+05
3	67048262+03	58493281+03	-55893119-01	00000000+00	40382711+05
4	63710879+03	57115230+03	-34137797-01	00000000+00	31043533+05
5	73225409+03	65270069+03	-57413811+00	55545156+00	54813680+05
6	73986002+03	65270069+03	-73444717+00	80089937+00	60176164+05
7	67048020+03	58493202+03	-55891845-01	00000000+00	40381931+05
8	73985959+03	65270069+03	-73444738+00	80089969+00	60175866+05
9	75947633+03	65270069+03	-72978711+00	79376439+00	74017491+05

MAXIMUM RELATIVE ERROR OF FUEL TEMPERATURE ---------- = 51194885-03

TEMPERATURE-FEEDBACK CONVERGED

//

S P A T I A L - I T E R A T I O N R E S U L T S

SIG/I = 0000000+00	MAX. = 9350586+00	GAMMA = 9999391+00	RATIO(0) = 1000000+01		
SIG/O = 0000000+00	MIN. = 9319512+00	PT/AV = 2692362+01	EPS.(1) = 1941816-02	LAMBDA = 933764364+00	
SIG/I = 8043594+00	MAX. = 9344138+00	GAMMA = 9998492+00	RATIO(1) = 1000000+01		
SIG/O = 8291358+00	MIN. = 9320184+00	PT/AV = 2874595+01	EPS.(2) = 1719186-02	LAMBDA = 933623520+00	
SIG/I = 8300197+00	MAX. = 9341603+00	GAMMA = 9999824+00	RATIO(2) = 8464777+00		
SIG/O = 8354313+00	MIN. = 9324669+00	PT/AV = 2737066+01	EPS.(3) = 1221301-02	LAMBDA = 933607128+00	
SIG/I = 8698969+00	MAX. = 9340603+00	GAMMA = 1000009+01	RATIO(1) = 4462563+00		
SIG/O = 8757896+00	MIN. = 9329477+00	PT/AV = 2208285+01	EPS.(4) = 7155154-03	LAMBDA = 933615735+00	
SIG/I = 9417821+00	MAX. = 9339847+00	GAMMA = 9999981+00	RATIO(2) = 4184051+00		
SIG/O = 9438899+00	MIN. = 9330754+00	PT/AV = 1959231+01	EPS.(5) = 5768994-03	LAMBDA = 933613984+00	
SIG/I = 9483408+00	MAX. = 9339186+00	GAMMA = 1000003+01	RATIO(1) = 2981051+00		
SIG/O = 9492843+00	MIN. = 9332416+00	PT/AV = 1610086+01	EPS.(6) = 4019916-03	LAMBDA = 933616916+00	
SIG/I = 9561422+00	MAX. = 9338915+00	GAMMA = 9999999+00	RATIO(2) = 8428250+00		
SIG/O = 9559962+00	MIN. = 9332758+00	PT/AV = 1584035+01	EPS.(7) = 3652636-03	LAMBDA = 933616815+00	
SIG/I = 9562646+00	MAX. = 9338442+00	GAMMA = 1000001+01	RATIO(3) = 8240641+00		
SIG/O = 9561936+00	MIN. = 9333403+00	PT/AV = 1585408+01	EPS.(8) = 2969101-03	LAMBDA = 933617534+00	
SIG/I = 9564828+00	MAX. = 9338010+00	GAMMA = 1000001+01	RATIO(4) = 7882255+00		
SIG/O = 9564650+00	MIN. = 9334088+00	PT/AV = 1578318+01	EPS.(9) = 2242556-03	LAMBDA = 933618127+00	
SIG/I = 9567547+00	MAX. = 9337593+00	GAMMA = 9999999+00	RATIO(5) = 7417986+00		
SIG/O = 9567392+00	MIN. = 9334727+00	PT/AV = 1474855+01	EPS.(10) = 1556502-03	LAMBDA = 933618029+00	
SIG/I = 9569538+00	MAX. = 9337255+00	GAMMA = 1000000+01	RATIO(6) = 7008564+00		
SIG/O = 9569360+00	MIN. = 9335147+00	PT/AV = 1465393+01	EPS.(11) = 1149054-03	LAMBDA = 933618255+00	
SIG/I = 9570807+00	MAX. = 9336998+00	GAMMA = 1000000+01	RATIO(7) = 6683101+00		
SIG/O = 9570634+00	MIN. = 9335413+00	PT/AV = 1489328+01	EPS.(12) = 8740362-04	LAMBDA = 933618232+00	

ITERATIONS 12 ...EIGENVALUE = 933618232+00 ..REACTIVITY(PERCENTAGE) =-711016192+01 .....DOMINANCE = 952311845+00
LEVELS ..FLUX NORMALIZATION = 409915348+14 .....POWER NORMALIZATION = 902811753+12 ...POWER VOLUME = 330365192+06

//

I N T E G R A T I O N E D I T S

PLANE GROUPING 1
FLUX INTEGRALS FOLLOWED BY FLUX AVERAGES

EDIT SET	VOLUME	GROUP 1	2
1	803052890+06	384508729+20	890436577+19
		478808723+14	110881436+14

PLANE GROUPING 1
INTEGRATED POWER EDIT

EDIT SET	POWER FRACTION	RELATIVE POWER DENSITY	GROUP FRACTION OF EDIT-SET POWER GROUP 1	2
1	852220572+00	350592118+00	210332633+00	789667367+00

PLANE GROUPING 1
INTEGRATED ABSORPTION EDIT

EDIT SET	GROUP FRACTION OF TOTAL ABSORPTION FOLLOWED BY GROUP FRACTION OF EDIT-SET ABSORPTION ABSORP. FRACT.	GROUP 1	2
1	852038804+00	280624789+00	571414015+00
		329356818+00	670643182+00

PLANE GROUPING 1
TOTAL GROUP-INDEPENDENT BUCKLING, K INFINITY, AND K EFFECTIVE EDITS

EDIT SET	GP. IND. BUCK.	SUM	K INFINITY FOLLOWED BY K EFFECTIVE GROUP 1	2
1	433757144-03	955581863+00	207188739+00	748393124+00
		933618232+00	202708969+00	730909263+00

PLANE GROUPING 1
FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 1

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	13564276+01	88055149-02	17961920-01	55459111-02	69926812-13	43610677-03

PLANE GROUPING 1
FLUX-WEIGHTED AVERAGE MACROSCOPIC DATA
GROUP 2

EDIT SET	D	SIGMA A	SIGMA R	NU SIGMA F	K SIGMA F	BUCKLING
1	34466350+00	77425287-01	00000000+00	86350849-01	11336643-11	40026624-03

```
* * * * * * * * * * * * * * * *
*                             *
*  E N D  O F  O U T P U T    *
*                             *
* * * * * * * * * * * * * * * *
```

PDQ08(WAPD-TM-1266)

```
        $$$$$$$$$$$$$$$$$$$$$$ /BEGIN/ CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$$$
        * PDQ08 3-D EXPLICIT VS. KAPLAN SYNTHESIS COMPARISON
0001    5,5
0002    010002,0,0,1,1,0,0
0003    010003,1.18093,9-3
0004    010004,1+1,0+0
0005    010012,-1
0006    010013,-1
0007    010014,-1
0008    010015,-1
0009    010021,(),(),(),/2/SECTION1,/4/SECTION2,()
0010    010022,/10/1
0011    011000,/8/0
0012    011001,1,0,1,2
0013    011001,1,0,1,-5
0014    014001,1,0,1,-5
0015    015001,0,-11
0016    030001,1,1,1,2,2,5
0017    030031,1,2,1,2,3,5
0018    030081,1,3,1,2,1,5
0019    050011,10+2,6
0020    050021,0.5,2
0021    060001,1,2,3,4,5,6,7,8,9,10,11
0022    070001,10+2,11
0023    110001,1,1,2,2,3,3
0024    170001,1,10,0,0,0,0
0025    401000,1
0026    401100,135+1,15-1,6-2,2-1,1.
0027    401200,5+0,38+0,0+0,75+0,2.
0028    402000,2
0029    402100,125+1,7-2,13-1,5-3,3.
0030    402200,65+0,7-1,0+0,1+0,4.
0031    403000,3
0032    403100,145+1,20-1,8-2,3-1,5.
0033    403200,68+0,25+0,0+0,42+0,6.
0034    150000,1
0035    150000
0036    150001,1,2,3,4,5
0037    160000,1
0038    700000,1
0039    800100,6,2,1,0,2
0040    800101,1,0,3,0,2,2,3,6,0,2
0041    800102,3,4,5,0,2,4,5,6,0,2
        =EXPLICIT-1 3-D
0042    010001,2,0,2,+1,1,1,1,5,3,2,6,2,11,0,0 $ EXPLICIT
0044    010006,0,1,0,1,3,9,0,0,-3
0045    2000,60,0
        $$$$$$$$$$$$$$$$$$$$$$ //END// CARD INPUT DATA FOR CASE    1 $$$$$$$$$$$$$$$$$$$$$$
        ///////
```

//

P R O B L E M I N P U T D E S C R I P T I O N

PROGRAM IDENTIFICATION	PROGRAM(VERSION-DATE)	PDQ08(WAPD-TM-1266)	COMPUTER - CDC-7600
SPATIAL DESCRIPTION	ITERATION SOLUTION	EIGENVALUE	ADJOINT SOLUTION - NO
FEW-GROUP DESCRIPTION	NUMBER OF GROUPS	2	FAST GROUP - P-1
	THERMAL GROUPS	1	SOLUTION GROUPS - 2
GEOMETRY PARAMETERS	DIMENSIONALITY, TYPE	3-D RECTANGULAR	BLOCK MESH TYPE - GROSS/FINE
	COMPOSITIONS	REGIONS	INPUT MESH UNITS - CENTIMETERS
	LARGEST FINAL FIGURE	1	LARGEST PLANAR REGION - 5
	LARGEST COMPOSITION	3	COLUMN BOUNDARY - 6
	ROW BOUNDARY	2	PLANE BOUNDARY - 11
	MESH ELEMENTS	132	MESH POINTS - 252
	MESH GROUP-POINTS	504	SOLUTION POINTS - 150
	NON-SOLUTION POINTS	102	SOLUTION GROUP-POINTS - 300
BOUNDARY CONDITIONS	COLUMN 0	ZERO FLUX	COLUMN 6 - ZERO FLUX
	ROW 0	ZERO CURRENT	ROW 2 - ZERO CURRENT
	PLANE 0	ZERO FLUX	PLANE 11 - ZERO FLUX
ITERATION PARAMETERS	INPUT EIGENVALUE	118093+01	CONVERGENCE PARAMETER - 900000-03
	CHI(GROUP 1)	100000+01	CHI(GROUP 2) - 000000+00
DATA STORAGE ALLOCATIONS	CENTRAL MEMORY	31199 WORDS	EXTENDED MEMORY - 131072 WORDS
BLOCKING COUNTS	TOTAL GROSS BLOCKS	44	TOTAL FINE BLOCKS - 132
	GROSS BLOCKS / PLANE	4	FINE BLOCKS / PLANE - 12
	GROSS BLOCK PLANES	11	FINE BLOCK PLANES - 11

S P A T I A L - I T E R A T I O N R E S U L T S

```
GROUP 1    PASS 1    RHO = 9942695+00    OMEGA(  8) = 1859255+01    SIGMA = 9000000+00    DELTA( 40) = 1000000+00
GROUP 1    PASS 2    RHO = 9943048+00    OMEGA( 16) = 1859658+01    SIGMA = 9954886+00    DELTA( 40) = 1000000+00
GROUP 1    PASS 3    RHO = 9949038+00    OMEGA( 24) = 1866738+01    SIGMA = 9955068+00    DELTA( 43) = 1000000+00

GROUP 2    PASS 1    RHO = 9427354+00    OMEGA(  8) = 1613814+01    SIGMA = 9000000+00    DELTA( 10) = 1000000+00
GROUP 2    PASS 2    RHO = 9560804+00    OMEGA( 16) = 1653480+01    SIGMA = 9995000+00    DELTA( 12) = 1000000+00
GROUP 2    PASS 3    RHO = 9665903+00    OMEGA( 24) = 1690927+01    SIGMA = 9803717+00    DELTA( 14) = 1000000+00

GROUP 1   IT. = 43   R(1) = 2894201+02   DELTA = 9284704-01
GROUP 2   IT. = 14   R(1) = 1570643+02   DELTA = 1836947-01

SIG/I = 0000000+00   MAX. = 2273536+02   GAMMA = 1246499+02   RATIO( 0) = 1000000+01
SIG/O = 0000000+00   MIN. = 2403766+00   PT/AV = 6226180+01   EPS.(  1) = 2026862+02        LAMBDA = 106896263+01

GROUP 1   IT. = 43   R(1) = 7301009+01   DELTA = 3187724-01
GROUP 2   IT. = 14   R(1) = 1373289+01   DELTA = 7098543-01
```

```
SIG/I = 2256065+00   MAX. = 1408321+01   GAMMA = 1035741+01   RATIO( 0) = 1000000+01
SIG/O = 1652870+00   MIN. = 8042575+00   PT/AV = 1806782+01   EPS.(  2) = 2735906+00        LAMBDA = 110716839+01

GROUP 1    IT. = 43   R(1) = 4337988+01   DELTA = 3764078-01
GROUP 2    IT. = 14   R(1) = 1051993+01   DELTA = 7378790-01

SIG/I = 6008479+00   MAX. = 1328023+01   GAMMA = 1027877+01   RATIO( 0) = 1000000+01
SIG/O = 7313750+00   MIN. = 8598364+00   PT/AV = 2264854+01   EPS.(  3) = 2444542+00        LAMBDA = 113803342+01

GROUP 1    IT. = 43   R(1) = 3066574+01   DELTA = 3035277-01
GROUP 2    IT. = 14   R(1) = 7816148+00   DELTA = 7558671-01

SIG/I = 7089633+00   MAX. = 1281905+01   GAMMA = 1015385+01   RATIO( 0) = 1000000+01
SIG/O = 7381710+00   MIN. = 9001585+00   PT/AV = 2825432+01   EPS.(  4) = 2210074+00        LAMBDA = 115554176+01

GROUP 1    IT. = 43   R(1) = 2218234+01   DELTA = 2577512-01
GROUP 2    IT. = 14   R(1) = 5913800+00   DELTA = 7496916-01

SIG/I = 7254313+00   MAX. = 1251103+01   GAMMA = 1008593+01   RATIO( 1) = 1000000+01
SIG/O = 7482153+00   MIN. = 9378232+00   PT/AV = 3371865+01   EPS.(  5) = 1953274+00        LAMBDA = 116547176+01

ITERATIONS  5 ...EIGENVALUE = 116547176+01 ..REACTIVITY(PERCENTAGE) = 141978355+02 ......DOMINANCE = 694923619+00
LEVELS ..FLUX NORMALIZATION = 316287831-01 .....POWER NORMALIZATION = 316287831-01 ...POWER VOLUME = 660000000+04
```

//

GROSS PLANE	POINT PLANES	RADIAL MAXIMUM GROSS POWER	LOCATION FIGURE	LOCATION REGION
4	003-004	236362+01	1	2
5	004-005	270751+01	1	2
6	005-006	295725+01	1	2
7	006-007	322107+01	1	2
8	007-008	345664+01	1	2
9	008-009	190562+01	1	1

AXIAL SHAPE OF RADIAL MAXIMUM — GROSS POWER

```
XXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
X
```

MAXIMUM GROSS BLOCK POWER IS 345664+01 IN GROSS BLOCK PLANE 8 (PLANES 007-008), FIGURE 1, REGION 2

FINE PLANE	POINT PLANES	RADIAL MAXIMUM FINE POWER	LOCATION FIGURE	LOCATION REGION	LOCATION CHANNEL	LOCATION TRACK
4	003-004	236362+01	1	2	4	1
5	004-005	270751+01	1	2	4	1
6	005-006	295725+01	1	2	4	1
7	006-007	322107+01	1	2	4	1
8	007-008	345664+01	1	2	4	1
9	008-009	300453+01	1	1	3	1

AXIAL SHAPE OF RADIAL MAXIMUM — FINE POWER

```
X
XXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

MAXIMUM FINE BLOCK POWER IS 345664+01 IN FINE BLOCK PLANE 8 (PLANES 007-008), FIGURE 1, REGION 2
CHANNEL 4, TRACK 1

//

O U T P U T F I L I N G

```
POINTWISE FLUX.....OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM FLUX ,T=220,V=001,S=POINTFLUX ) -      511  WORDS

PARTITION POWER.....OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM PPWR ,T=222,V=001,S=PARTPOWER ) -     1036  WORDS

FINE BLOCK POWER.....OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM POWR ,T=255,V=001,S=FINEPOWER ) -       75  WORDS


  EDIT INTEGRAL.....SECTION - (SECTION IDENTIFICATION = 224 ,  SIZE =      572  WORDS)
  GEOMETRY.....SECTION - (SECTION IDENTIFICATION = 251 ,  SIZE =      172  WORDS)
S E C T I O N E D.....OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION ONE  ,T=250,V=001,S=SECTION1  ) -      744  WORDS


  CROSS BLOCK POWER.....SECTION - (SECTION IDENTIFICATION = 254 ,  SIZE =       28  WORDS)


  INTEGRATED FLUX.....SECTION - (SECTION IDENTIFICATION = 253 ,  SIZE =      276  WORDS)
S E C T I O N E D.....OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION TWO  ,T=250,V=001,S=SECTION2  ) -      304  WORDS
                                                                                                 --------
                                                TOTAL AMOUNT OF DATA IN THESE OUTPUT FILES -     2670  WORDS
```

```
        $$$$$$$$$$$$$$$$$$$$$$ /BEGIN/ CARD INPUT DATA FOR CASE   2 $$$$$$$$$$$$$$$$$$$$$$
        =SYNTHESIS1 WITH 3-D EXPLICIT FOR TRIAL FUNCTIONS
0001    010005,0,1,0,1,0,11,1,1
0002    010006,0,1,0,1,0,11,0,0,-3
0003    600000,1  $  DO SYNTHESIS RESIDUAL CALCULATION
0004    600001,4,4
0005    600002,11
0006    660004,123,(),4,(),3,()
0007    600010,1
0008    600011,1,1,5,2,9,3,6,4
0009    601001,1,(),2,(),3,(),123,()
0010    602001,1,(),2,(),3,(),123,()
0011    600002,6,11
0012    010001,5,0,2,+1,1,1,1,5,3,2,6,2,11,0,0 $ SYNTHESIS
        $$$$$$$$$$$$$$$$$$$$$$ //END// CARD INPUT DATA FOR CASE   2 $$$$$$$$$$$$$$$$$$$$$$
        ///////
```

//

P R O B L E M I N P U T D E S C R I P T I O N

PROGRAM IDENTIFICATION	PROGRAM(VERSION-DATE) - PDQ08(WAPD-TM-1266)	COMPUTER - CDC-7600
SPATIAL DESCRIPTION	ITERATION SOLUTION - SYNTHESIS	ADJOINT SOLUTION - NO
FEW-GROUP DESCRIPTION	NUMBER OF GROUPS - 2	FAST GROUP - P-1
	THERMAL GROUPS - 1	SOLUTION GROUPS - 2
GEOMETRY PARAMETERS	DIMENSIONALITY, TYPE - 3-D RECTANGULAR	BLOCK MESH TYPE - GROSS/FINE
	COMPOSITIONS - REGIONS	INPUT MESH UNITS - CENTIMETERS
	LARGEST FINAL FIGURE - 1	LARGEST PLANAR REGION - 5
	LARGEST COMPOSITION - 3	COLUMN BOUNDARY - 6
	ROW BOUNDARY - 2	PLANE BOUNDARY - 11
	MESH ELEMENTS - 132	MESH POINTS - 252
	MESH GROUP-POINTS - 504	SOLUTION POINTS - 150
	NON-SOLUTION POINTS - 102	SOLUTION GROUP-POINTS - 300
BOUNDARY CONDITIONS	COLUMN 0 - ZERO FLUX	COLUMN 6 - ZERO FLUX
	ROW 0 - ZERO CURRENT	ROW 2 - ZERO CURRENT
	PLANE 0 - ZERO FLUX	PLANE 11 - ZERO FLUX
ITERATION PARAMETERS	INPUT EIGENVALUE - 118093+01	CONVERGENCE PARAMETER - 900000-03
	CHI(GROUP 1) - 100000+01	CHI(GROUP 2) - 000000+00
DATA STORAGE ALLOCATIONS	CENTRAL MEMORY - 31199 WORDS	EXTENDED MEMORY - 131072 WORDS
INPUT FILES	GEOMETRY - (P=IEAF,I=SAMPLE SECTION ONE ,T=250,V=001,S=SECTION1 ,SECTION=251)	
COMPOSITION DATA	CORRESPONDENCES - FILE INPUT	
BLOCKING COUNTS	TOTAL GROSS BLOCKS - 44	TOTAL FINE BLOCKS - 132
	GROSS BLOCKS / PLANE - 4	FINE BLOCKS / PLANE - 12

```
-   GROSS BLOCK PLANES -        11            -   FINE BLOCK PLANES -        11            -
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

//

S Y N T H E S I S   T R I A L - F U N C T I O N   D E S C R I P T I O N

```
- - - - - - - - - - - - - - - - - - - - - - - - -
-   TRIAL-FUNCTION ZONE 01   (PLANES 000-006)   -
-                          -                    -
-     FIRST  GROUP         -     SECOND GROUP   -
-                          -                    -
- VERS  0,TENT-FUNCT,2**- VERS  0,TENT-FUNCT,2**-
-                          -                    -
- VERS  1,POINTFLUX ,1   - VERS  1,POINTFLUX ,2 -
-                          -                    -
- VERS  2,POINTFLUX ,1   - VERS  2,POINTFLUX ,2 -
-                          -                    -
- VERS  3,POINTFLUX ,1   - VERS  3,POINTFLUX ,2 -
-                          -                    -
- VERS123,POINTFLUX ,1   - VERS123,POINTFLUX ,2 -
-                          -                    -
- - - - - - - - - - - - - - - - - - - - - - - - -
-   TRIAL-FUNCTION ZONE 02   (PLANES 006-011)   -
-                          -                    -
-     FIRST  GROUP         -     SECOND GROUP   -
-                          -                    -
- VERS  0,TENT-FUNCT,2**- VERS  0,TENT-FUNCT,2**-
-                          -                    -
- VERS  1,POINTFLUX ,1   - VERS  1,POINTFLUX ,2 -
-                          -                    -
- VERS  2,POINTFLUX ,1   - VERS  2,POINTFLUX ,2 -
-                          -                    -
- VERS  3,POINTFLUX ,1   - VERS  3,POINTFLUX ,2 -
-                          -                    -
- VERS123,POINTFLUX ,1   - VERS123,POINTFLUX ,2 -
-                          -                    -
- - - - - - - - - - - - - - - - - - - - - - - - -
```

**   SPECIAL FUNCTION ADDED FOR SYNTHESIS RESIDUAL CALCULATION
**   DELETED AS TRIAL AND WEIGHT FUNCTION

ALL (00083 OUT OF 00083) NEW SYNTHESIS TRIAL FUNCTION PRODUCT-INTEGRALS WILL BE CALCULATED

TRIAL FUNCTION PLANE-SLICES OBTAINED FROM INPUT THREE-DIMENSIONAL POINTWISE FLUX FILE - (VERS 1,POINTFLUX)
(VERS 1,POINTFLUX) = (P=IEAF,I=SAMPLE PROBLEM FLUX ,T=220,V=001,S=POINTFLUX)

PLANE 1 - (VERS 1,POINTFLUX) PLANE 5 - (VERS 2,POINTFLUX) PLANE 9 - (VERS 3,POINTFLUX)
PLANE 6 - (VERS 4,POINTFLUX)

DIFFERENCED TRIAL-FUNCTIONS

(VERS123,POINTFLUX) = (VERS 4,POINTFLUX) - (VERS 3,POINTFLUX)

//

S P A T I A L - I T E R A T I O N R E S U L T S

RATE/O = 0000000+00 MAX. = 1227971+01 MIN. = 9258196+00 EPS.(1) = 2601925+00 LAMBDA = 116126127+01

RATE/O = 3005736+00 MAX. = 1188148+01 MIN. = 1095867+01 EPS.(2) = 7820701-01 LAMBDA = 117996157+01

RATE/O = 2485296+00 MAX. = 1182848+01 MIN. = 1159895+01 EPS.(3) = 1943676-01 LAMBDA = 118089881+01

RATE/O = 2407471+00 MAX. = 1181431+01 MIN. = 1175905+01 EPS.(4) = 4679343-02 LAMBDA = 118095761+01

RATE/O = 2503325+00 MAX. = 1181076+01 MIN. = 1179692+01 EPS.(5) = 1171392-02 LAMBDA = 118096176+01

RATE/O = 2676272+00 MAX. = 1180993+01 MIN. = 1180623+01 EPS.(6) = 3134963-03 LAMBDA = 118096160+01

ITERATIONS 6 ...EIGENVALUE = 118096160+01 ..REACTIVITY(PERCENTAGE) = 153232418+02 ......DOMINANCE = 267627222+00
LEVELS ..FLUX NORMALIZATION = 352638533+02 .....POWER NORMALIZATION = 352638533+02 ...POWER VOLUME = 660000000+04

//

GROSS PLANE	POINT PLANES	RADIAL MAXIMUM GROSS POWER	LOCATION -- FIGURE	REGION	AXIAL SHAPE OF RADIAL MAXIMUM GROSS POWER
1	000-001	143233+00	1	2	X
2	001-002	455884+00	1	2	XXXXX
3	002-003	855235+00	1	2	XXXXXXXXXXX
4	003-004	219438+01	1	2	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
5	004-005	290407+01	1	2	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
6	005-006	341530+01	1	2	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
7	006-007	369091+01	1	2	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
8	007-008	368717+01	1	2	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
9	008-009	181872+01	1	1	XXXXXXXXXXXXXXXXXXXXXXXXXX
10	009-010	141112+01	1	1	XXXXXXXXXXXXXXXXXXX
11	010-011	527753+00	1	1	XXXXXX

MAXIMUM GROSS BLOCK POWER IS 369091+01 IN GROSS BLOCK PLANE 7 (PLANES 006-007), FIGURE 1, REGION 2

FINE PLANE	POINT PLANES	RADIAL MAXIMUM FINE POWER	LOCATION FIGURE	REGION	CHANNEL	TRACK	AXIAL SHAPE OF RADIAL MAXIMUM FINE POWER
1	000-001	143233+00	1	2	4	1	X
2	001-002	455884+00	1	2	4	1	XXXXX
3	002-003	855235+00	1	2	4	1	XXXXXXXXXXX
4	003-004	219438+01	1	2	4	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

5	004-005	290407+01	1	2	4	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
6	005-006	341530+01	1	2	4	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
7	006-007	369091+01	1	2	4	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
8	007-008	368717+01	1	2	4	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
9	008-009	288755+01	1	1	3	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10	009-010	216768+01	1	1	3	1	XXXXXXXXXXXXXXXXXXXXXXXXXXXX
11	010-011	801307+00	1	1	3	1	XXXXXXXXXX

MAXIMUM FINE BLOCK POWER IS 369091+01 IN FINE BLOCK PLANE 7 (PLANES 006-007), FIGURE 1, REGION 2
CHANNEL 4, TRACK 1

SYNTHESIS AXIAL MIXING-COEFFICIENTS GROUP 1

AXIAL

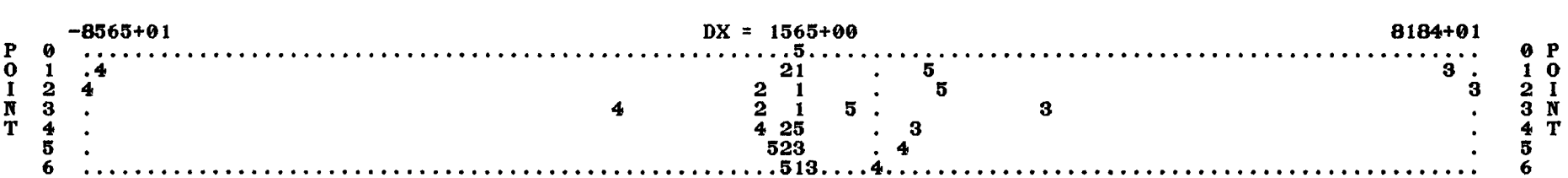
POINT	(ZONE 1) TRIAL FUNCTION POSITION 1	2	3	4	5
0	00000000+00	00000000+00	00000000+00	00000000+00	00000000+00
1	00000000+00	-37606374-04	13726850-02	-11380815-02	-13724071-02
2	00000000+00	-33393489-03	29809503-02	-24079512-02	-29816711-02
3	00000000+00	-63433683-03	17751775-02	-99655543-03	-17253188-02
4	00000000+00	-19934003-03	11764664-02	-28314832-03	-40483468-03
5	00000000+00	-15562976-03	34713192-05	97276297-03	94569683-03
6	00000000+00	-16880117-03	28927240-03	82944778-03	79598124-03

AXIAL

POINT	(ZONE 2) TRIAL FUNCTION POSITION 1	2	3	4	5
7	00000000+00	-20579006-03	20712684-02	-76444415-03	-90978896-03
8	00000000+00	-48684734-03	19699935-02	-66375263-03	-14921471-02
9	00000000+00	-36697139-03	19781593-02	-91684042-03	-19449954-02
10	00000000+00	-10237924-03	13345957-02	-74855885-03	-13302738-02
11	00000000+00	00000000+00	00000000+00	00000000+00	00000000+00

FRACTIONAL FLUX CONTRIBUTIONS FIRST GROUP

1 = (FIRST POSITION) 2 = (SECOND POSITION) 3 = (THIRD POSITION)
4 = (FOURTH POSITION) 5 = (FIFTH POSITION)



```
      -8565+01                                DX = 1565+00                                8184+01

      -1597+01                                DX = 3546-01                                2197+01
P  7  .....................4.....................2.1....5.....................................3.....  7 P
O  8  .                   4                     2  1    5                    .              3     .  8 O
I  9  .          4                              2  1       5                 .                 3  .  9 I
N 10  4                                           2 1          5            .                    3 10 N
T 11  ..........................................5.....................................................  11 T
      -1597+01                                DX = 3546-01                                2197+01
```

FRACTIONAL FLUX CONTRIBUTIONS FIRST GROUP

1 = (FIRST POSITION) 2 = (SECOND POSITION) 3 = (THIRD POSITION)
4 = (FOURTH POSITION) 5 = (FIFTH POSITION)

```
      -8565+01                                DX = 1565+00                                8184+01
P  0  ..................................................5.....................................  0 P
O  1  .4                                                21     .   5                        3 .  1 O
I  2  4                                                 2  1   .     5                      3    2 I
N  3  .                                    4            2  1   5 .           3              .  3 N
T  4  .                                                 4 25     .  3                        .  4 T
   5  .                                                   523    . 4                         .  5
   6  ..................................................513...4.....................................  6
   7  .                                                  4  215    .    3                     .  7
   8  .                                                   4 215    .   3                      .  8
   9  .                                                  4   21 5   .     3                  .  9
  10  .                                              4       21  5  .       3                .  10
  11  ..................................................5.....................................  11
      -8565+01                                DX = 1565+00                                8184+01
```

SYNTHESIS AXIAL MIXING-COEFFICIENTS GROUP 2

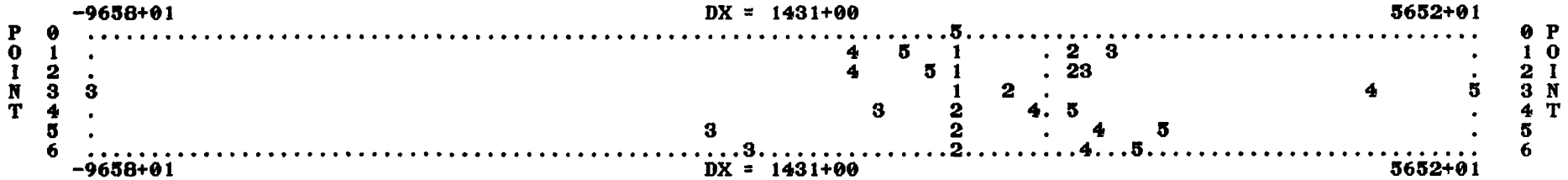
AXIAL POINT	(ZONE 1) TRIAL FUNCTION POSITION 1	2	3	4	5
0	00000000+00	00000000+00	00000000+00	00000000+00	00000000+00
1	00000000+00	66903671-03	28995641-03	-51332200-03	-18019328-03
2	00000000+00	14921108-02	49085025-03	-10810055-02	-22518548-03
3	00000000+00	63505138-03	-44648977-02	51079787-02	39643801-02
4	00000000+00	-67435645-05	-75836192-03	15538216-02	13850883-02
5	00000000+00	-13752789-04	-26861228-02	35189671-02	33336754-02
6	00000000+00	-14553856-04	-25169160-02	34820833-02	32923708-02

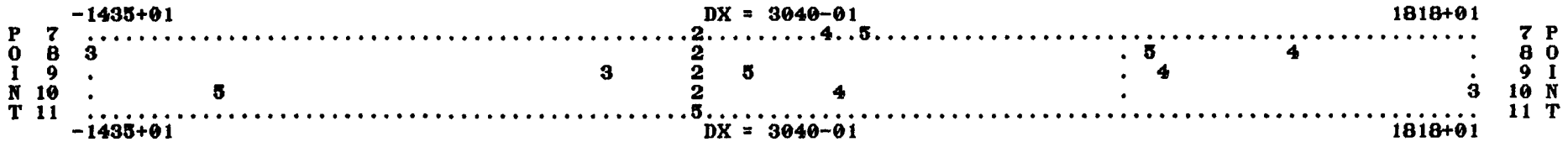
AXIAL POINT	(ZONE 2) TRIAL FUNCTION POSITION 1	2	3	4	5
7	00000000+00	-20636408-04	34524813-03	86967045-03	70171692-03
8	00000000+00	-26480407-04	-94501699-03	22063269-02	10600425-02

9	00000000+00	-51429449-05	-69839768-04	89264867-03	63968860-04
10	00000000+00	-12489841-04	35322003-03	15040768-03	-32951501-03
11	00000000+00	00000000+00	00000000+00	00000000+00	00000000+00

FRACTIONAL FLUX CONTRIBUTIONS SECOND GROUP

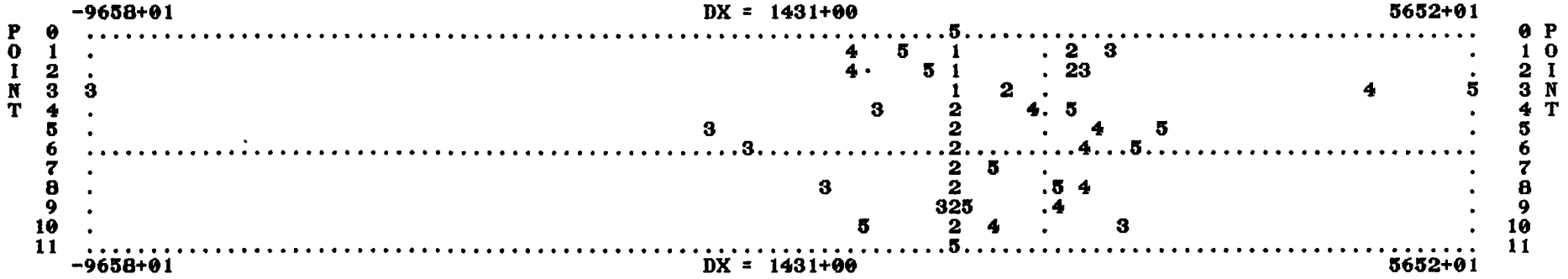
1 = (FIRST POSITION) 2 = (SECOND POSITION) 3 = (THIRD POSITION)
4 = (FOURTH POSITION) 5 = (FIFTH POSITION)





FRACTIONAL FLUX CONTRIBUTIONS SECOND GROUP

1 = (FIRST POSITION) 2 = (SECOND POSITION) 3 = (THIRD POSITION)
4 = (FOURTH POSITION) 5 = (FIFTH POSITION)



SYNTHESIS RESIDUALS - RELATIVE

```
           1 = (     FIRST   GROUP      )           2 = (     SECOND  GROUP      )

      0000+00                                          DX =  1051+00                                           1124+02
P  0  2....................................................................................................  0 P
O  1  .                                2                         1                                        .  1 O
I  2  .                                     2                           1                                 .  2 I
N  3  .                                   2                                                  1            .  3 N
T  4  .                    2                                                                            1 .  4 T
   5  .                           2                                                                        1  5
   6  ..........................2.........................................................................1  6
   7  .               2                                                                                1  .  7
   8  .          2                                                                   1                    .  8
   9  .    2                                                                  1                           .  9
  10  .         2                                                          1                              .  10
  11  2....................................................................................................  11
      0000+00                                          DX =  1051+00                                           1124+02
```

S Y N T H E S I S   R E S I D U A L S - R E L A T I V E

FIRST GROUP

```
  VALUE             0000+00                                   DX =  1159+00                             1124+02
0000+00  P  0  1............................................................................................  0 P
6668+01  O  1  .                                                     1                                    .  1 O
7468+01  I  2  .                                                           1                              .  2 I
9789+01  N  3  .                                                                              1           .  3 N
1101+02  T  4  .                                                                                        1 .  4 T
1124+02     5  .                                                                                           1  5
1121+02     6  ............................................................................................1  6
1090+02     7  .                                                                                       1  .  7
9785+01     8  .                                                                              1           .  8
8280+01     9  .                                                                 1                        .  9
7947+01    10  .                                                                1                         .  10
0000+00    11  1............................................................................................  11
  VALUE             0000+00                                   DX =  1159+00                             1124+02
```

S Y N T H E S I S   R E S I D U A L S - R E L A T I V E

SECOND GROUP

```
  VALUE             0000+00                                   DX =  4487-01                             4353+01
0000+00  P  0  2............................................................................................  0 P
3698+01  O  1  .                                                                            2             .  1 O
4353+01  I  2  .                                                                                           2  2 I
4086+01  N  3  .                                                                                  2       .  3 N
2367+01  T  4  .                                                 2                                        .  4 T
3136+01     5  .                                                                 2                        .  5
2921+01     6  .............................................................2..............................  6
1803+01     7  .                                    2                                                     .  7
1222+01     8  .                        2                                                                 .  8
```

```
 5566+00     9  .           2                                                                                   .  9
 1153+01    10  .                       2                                                                       . 10
 0000+00    11  2...............................................................................................  11
  VALUE         0000+00                                   DX = 4487-01                                   4353+01
```

S Y N T H E S I S   R E S I D U A L S - R E L A T I V E

TOTAL BY AXIAL POINT

```
  VALUE         0000+00                                   DX = 1036+00                                   1005+02
 0000+00  P  0  0...............................................................................................  0 P
 6169+01  O  1  .                                                        0                                      .  1 O
 6940+01  I  2  .                                                              0                                .  2 I
 8823+01  N  3  .                                                                              0                .  3 N
 9720+01  T  4  .                                                                                      0        .  4 T
 1005+02     5  .                                                                                         0        5
 9984+01     6  ........................................................................................0.  6
 9547+01     7  .                                                                                   0           .  7
 8609+01     8  .                                                                            0                  .  8
 7387+01     9  .                                                                  0                            .  9
 7166+01    10  .                                                                0                              . 10
 0000+00    11  0...............................................................................................  11
  VALUE         0000+00                                   DX = 1036+00                                   1005+02
```

SYNTHESIS RESIDUALS (RELATIVE) - TOTAL BY GROUP   9992+01   2317+01

SYNTHESIS RESIDUALS (RELATIVE) - TOTAL   OVERALL   8894+01

S Y N T H E S I S   R E S I D U A L S - A B S O L U T E

```
          1 = (     FIRST   GROUP     )              2 = (     SECOND GROUP     )

        0000+00                                      DX = 1308-01                                      1400+01
P   0   2..................................................................................................  0 P
O   1   .2       1                                                                                        .  1 O
I   2   . 2                1                                                                              .  2 I
N   3   .   2                                     1                                                       .  3 N
T   4   .  2                                                            1                                 .  4 T
    5   .    2                                                                              1             .  5
    6   ....2.............................................................................................1..  6
    7   .  2                                                                                               1  7
    8   . 2                                                                                      1        .  8
    9   .2                                                                       1                        .  9
   10   .2                                           1                                                    . 10
   11   2..................................................................................................  11
        0000+00                                      DX = 1308-01                                      1400+01
```

S Y N T H E S I S   R E S I D U A L S - A B S O L U T E

FIRST GROUP

```
 VALUE          0000+00                    DX = 1443-01                    1400+01
0000+00  P  0  1.....................................................................  0 P
1071+00  O  1  .  1                                                                .  1 O
2489+00  I  2  .     1                                                             .  2 I
5771+00  N  3  .        1                                                          .  3 N
9708+00  T  4  .           1                                                       .  4 T
1225+01     5  .              1                                                    .  5
1374+01     6  ..............................................................1....  6
1400+01     7  .                                                              1  .  7
1254+01     8  .                                                           1     .  8
9071+00     9  .                                                     1           .  9
5004+00    10  .                 1                                              .  10
0000+00    11  1.....................................................................  11
 VALUE          0000+00                    DX = 1443-01                    1400+01
```

S Y N T H E S I S R E S I D U A L S - A B S O L U T E

SECOND GROUP

```
 VALUE          0000+00                    DX = 6400-03                    6208-01
0000+00  P  0  2.....................................................................  0 P
1200-01  O  1  .        2                                                          .  1 O
2957-01  I  2  .           2                                                       .  2 I
4914-01  N  3  .                 2                                                 .  3 N
3673-01  T  4  .                    2                                              .  4 T
5898-01     5  .                                                        2          .  5
6208-01     6  ..............................................................2....  6
4059-01     7  .                       2                                         .  7
2494-01     8  .                    2                                            .  8
7976-02     9  .           2                                                       .  9
9433-02    10  .              2                                                    .  10
0000+00    11  2.....................................................................  11
 VALUE          0000+00                    DX = 6400-03                    6208-01
```

S Y N T H E S I S R E S I D U A L S - A B S O L U T E

TOTAL BY AXIAL POINT

```
 VALUE          0000+00                    DX = 1485-01                    1440+01
0000+00  P  0  0.....................................................................  0 P
1191+00  O  1  .     0                                                             .  1 O
2785+00  I  2  .        0                                                          .  2 I
6262+00  N  3  .           0                                                       .  3 N
1008+01  T  4  .              0                                                    .  4 T
1284+01     5  .                                                     0             .  5
1436+01     6  ..............................................................0....  6
1440+01     7  .                                                              0  .  7
1278+01     8  .                                                           0     .  8
```

```
 9151+00     9  .                                                  0                                          .  9
 5098+00    10  .                         0                                                                   . 10
 0000+00    11  0.........................................................................................  . 11
  VALUE         0000+00                                 DX = 1485-01                                   1440+01
```

SYNTHESIS RESIDUALS (ABSOLUTE) - TOTAL BY GROUP 8563+01 3314+00

SYNTHESIS RESIDUALS (ABSOLUTE) - TOTAL OVERALL 8894+01

//

O U T P U T   F I L I N G

```
POINTWISE FLUX................OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM FLUX ,T=220,V=002,S=POINTFLUX ) -      511  WORDS

PARTITION POWER...............OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM PPWR ,T=222,V=002,S=PARTPOWER ) -     1036  WORDS

FINE BLOCK POWER..............OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM POWR ,T=255,V=002,S=FINEPOWER ) -       75  WORDS


  EDIT INTEGRAL...................SECTION - (SECTION IDENTIFICATION = 224 ,  SIZE =      572  WORDS)
  GEOMETRY........................SECTION - (SECTION IDENTIFICATION = 251 ,  SIZE =      172  WORDS)
S E C T I O N E D.............OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION ONE  ,T=250,V=002,S=SECTION1  ) -      744  WORDS


  GROSS BLOCK POWER...............SECTION - (SECTION IDENTIFICATION = 254 ,  SIZE =       28  WORDS)
  INTEGRATED FLUX.................SECTION - (SECTION IDENTIFICATION = 253 ,  SIZE =      276  WORDS)
  SYNTHESIS MIXING COEFFICIENT....SECTION - (SECTION IDENTIFICATION = 229 ,  SIZE =      270  WORDS)
  SYNTHESIS INTEGRAL LIBRARY......SECTION - (SECTION IDENTIFICATION = 228 ,  SIZE =      502  WORDS)
S E C T I O N E D.............OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION TWO  ,T=250,V=002,S=SECTION2  ) -     1076  WORDS
                                                                                                        --------
                                                 TOTAL AMOUNT OF DATA IN THESE OUTPUT FILES -     3442  WORDS
```

```
          $$$$$$$$$$$$$$$$$$$$$$ /BEGIN/ CARD INPUT DATA FOR CASE    3 $$$$$$$$$$$$$$$$$$$$$$
          =EXPLICIT-2 3-D
0001      5
0002      010001,2,0,2,+1,1,1,1,5,3,2,6,2,11,0,0 $ EXPLICIT
          $$$$$$$$$$$$$$$$$$$$$$ //END// CARD INPUT DATA FOR CASE    3 $$$$$$$$$$$$$$$$$$$$$$
          .......
```

P R O B L E M I N P U T D E S C R I P T I O N

PROGRAM IDENTIFICATION	PROGRAM(VERSION-DATE)	PDQ08(WAPD-TM-1266)		COMPUTER	CDC-7600
SPATIAL DESCRIPTION	ITERATION SOLUTION	EIGENVALUE		ADJOINT SOLUTION	NO
FEW-GROUP DESCRIPTION	NUMBER OF GROUPS	2		FAST GROUP	P-1
	THERMAL GROUPS	1		SOLUTION GROUPS	2
GEOMETRY PARAMETERS	DIMENSIONALITY, TYPE	3-D RECTANGULAR		BLOCK MESH TYPE	GROSS/FINE
	COMPOSITIONS	REGIONS		INPUT MESH UNITS	CENTIMETERS
	LARGEST FINAL FIGURE	1		LARGEST PLANAR REGION	5
	LARGEST COMPOSITION	3		COLUMN BOUNDARY	6
	ROW BOUNDARY	2		PLANE BOUNDARY	11
	MESH ELEMENTS	132		MESH POINTS	252
	MESH GROUP-POINTS	504		SOLUTION POINTS	150
	NON-SOLUTION POINTS	102		SOLUTION GROUP-POINTS	300
BOUNDARY CONDITIONS	COLUMN 0	ZERO FLUX		COLUMN 6	ZERO FLUX
	ROW 0	ZERO CURRENT		ROW 2	ZERO CURRENT
	PLANE 0	ZERO FLUX		PLANE 11	ZERO FLUX
ITERATION PARAMETERS	INPUT EIGENVALUE	118093+01		CONVERGENCE PARAMETER	900000-03
	CHI(GROUP 1)	100000+01		CHI(GROUP 2)	000000+00
DATA STORAGE ALLOCATIONS	CENTRAL MEMORY	31199 WORDS		EXTENDED MEMORY	131072 WORDS
INPUT FILES	POINTWISE FLUX	(P=IEAF,I=SAMPLE PROBLEM FLUX ,T=220,V=002,S=POINTFLUX)			
	GEOMETRY	(P=IEAF,I=SAMPLE SECTION ONE ,T=250,V=002,S=SECTION1 ,SECTION=251)			
COMPOSITION DATA	CORRESPONDENCES	FILE INPUT			
BLOCKING COUNTS	TOTAL GROSS BLOCKS	44		TOTAL FINE BLOCKS	132
	GROSS BLOCKS / PLANE	4		FINE BLOCKS / PLANE	12
	GROSS BLOCK PLANES	11		FINE BLOCK PLANES	11

S P A T I A L - I T E R A T I O N R E S U L T S

GROUP 1	PASS 1	RHO = 9942695+00	OMEGA(8) = 1859255+01	SIGMA = 9000000+00	DELTA(40) = 1000000+00
GROUP 1	PASS 2	RHO = 9943048+00	OMEGA(16) = 1859658+01	SIGMA = 9954886+00	DELTA(40) = 1000000+00

```
GROUP 1    PASS 3    RHO = 9949038+00    OMEGA( 24) = 1866738+01    SIGMA = 9955068+00    DELTA( 43) = 1000000+00

GROUP 2    PASS 1    RHO = 9427354+00    OMEGA(  8) = 1613814+01    SIGMA = 9000000+00    DELTA( 10) = 1000000+00
GROUP 2    PASS 2    RHO = 9560804+00    OMEGA( 16) = 1653480+01    SIGMA = 9995000+00    DELTA( 12) = 1000000+00
GROUP 2    PASS 3    RHO = 9665903+00    OMEGA( 24) = 1690927+01    SIGMA = 9803717+00    DELTA( 14) = 1000000+00

GROUP 1   IT. = 43   R(1) = 2019333-03   DELTA = 1284980-01
GROUP 2   IT. = 14   R(1) = 1052193-03   DELTA = 7024315-01

SIG/I = 0000000+00   MAX. = 1289140+01   GAMMA = 1000020+01   RATIO( 0) = 1000000+01
SIG/O = 0000000+00   MIN. = 1136589+01   PT/AV = 3375498+02   EPS.(  1) = 9167697-01        LAMBDA = 118088023+01

GROUP 1   IT. = 43   R(1) = 9533508-04   DELTA = 1466378-01
GROUP 2   IT. = 14   R(1) = 2021984-04   DELTA = 7279247-01

SIG/I = 4279970+00   MAX. = 1205786+01   GAMMA = 1000053+01   RATIO( 0) = 1000000+01
SIG/O = 5206642+00   MIN. = 1171470+01   PT/AV = 1487700+02   EPS.(  2) = 2103682-01        LAMBDA = 118094317+01

GROUP 1   IT. = 43   R(1) = 3221661-04   DELTA = 1559710-01
GROUP 2   IT. = 14   R(1) = 6114299-05   DELTA = 8039722-01

SIG/I = 3364778+00   MAX. = 1188674+01   GAMMA = 9999954+00   RATIO( 0) = 1000000+01
SIG/O = 3777585+00   MIN. = 1175966+01   PT/AV = 1226465+02   EPS.(  3) = 6551240-02        LAMBDA = 118093775+01

GROUP 1   IT. = 43   R(1) = 1342869-04   DELTA = 1789346-01
GROUP 2   IT. = 14   R(1) = 2573593-05   DELTA = 7918475-01

SIG/I = 4169679+00   MAX. = 1183656+01   GAMMA = 1000001+01   RATIO( 1) = 1000000+01
SIG/O = 4777668+00   MIN. = 1178175+01   PT/AV = 9168756+01   EPS.(  4) = 2339891-02        LAMBDA = 118093851+01

GROUP 1   IT. = 43   R(1) = 5544632-05   DELTA = 2349045-01
GROUP 2   IT. = 14   R(1) = 1138510-05   DELTA = 6544315-01

SIG/I = 5068505+00   MAX. = 1181624+01   GAMMA = 9999998+00   RATIO( 2) = 7471799+00
SIG/O = 5631625+00   MIN. = 1179492+01   PT/AV = 9977669+01   EPS.(  5) = 1224509-02        LAMBDA = 118093831+01

GROUP 1   IT. = 43   R(1) = 2465465-05   DELTA = 3360653-01
GROUP 2   IT. = 14   R(1) = 5781950-06   DELTA = 5739172-01

SIG/I = 5564466+00   MAX. = 1181026+01   GAMMA = 9999998+00   RATIO( 1) = 4406815+00
SIG/O = 6050117+00   MIN. = 1180184+01   PT/AV = 1016708+02   EPS.(  6) = 6382631-03        LAMBDA = 118093807+01

ITERATIONS  6 ...EIGENVALUE = 118093807+01 ..REACTIVITY(PERCENTAGE) = 153215542+02 ......DOMINANCE = 507162837+00
LEVELS ..FLUX NORMALIZATION = 352588989+02 .....POWER NORMALIZATION = 352588989+02 ...POWER VOLUME = 660000000+04
```

//

O U T P U T F I L I N G

```
POINTWISE FLUX.....OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM FLUX ,T=220,V=003,S=POINTFLUX ) -      511  WORDS

PARTITION POWER.....OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM PPWR ,T=222,V=003,S=PARTPOWER ) -     1036  WORDS
```

```
 FINE BLOCK POWER.............OUTPUT FILE - (P=IEAF,I=SAMPLE PROBLEM POWR ,T=255,V=003,S=FINEPOWER ) -       75  WORDS

   EDIT INTEGRAL..................SECTION - (SECTION IDENTIFICATION = 224 ,  SIZE =      572  WORDS)
   GEOMETRY.......................SECTION - (SECTION IDENTIFICATION = 251 ,  SIZE =      172  WORDS)
 S E C T I O N E D.............OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION ONE  ,T=250,V=003,S=SECTION1  ) -      744  WORDS

   GROSS BLOCK POWER..............SECTION - (SECTION IDENTIFICATION = 254 ,  SIZE =       28  WORDS)

   INTEGRATED FLUX................SECTION - (SECTION IDENTIFICATION = 253 ,  SIZE =      276  WORDS)
 S E C T I O N E D.............OUTPUT FILE - (P=IEAF,I=SAMPLE SECTION TWO  ,T=250,V=003,S=SECTION2  ) -      304  WORDS
                                                                                                        --------
                                                                TOTAL AMOUNT OF DATA IN THESE OUTPUT FILES -     2670  WORDS
```

```
* * * * * * * * * * * * * * *
*                           *
*  E N D  O F  O U T P U T  *
*                           *
* * * * * * * * * * * * * * *
```

ACKNOWLEDGMENTS

The PDQ-8 program is the latest in a series of PDQ programs. This program grew directly out of the PDQ-7 program (Reference 2) so that many people have indirectly contributed to portions of the present program. Much of that report is included in this manual virtually unchanged as is the report on the HARMONY cross section and depletion system (Reference 3). The dual block depletion system, motivated by a desire to calculate detailed power distributions efficiently in very large three - dimensional synthesis problems, materialized from discussions with R. J. Breen, D. L. Crum, C. A. Flanagan, M. J. Galper, W. D. Kimball, A. S. Rathbun, B. H. Ruth, and J. F. Walter. The new difference equations for quadrilateral geometry (Reference 8) resulted from analysis by I. K. Abu-Shumays and L. A. Hageman.

REFERENCES

(1) W. R. Cadwell, Editor, "Reference Manual - Bettis Programming Environment", WAPD-TM-1181 (1974).

(2) W. R. Cadwell, "PDQ-7 Reference Manual", WAPD-TM-678 (1967).

(3) R. J. Breen, O. J. Marlowe, C. J. Pfeifer, "HARMONY: System for Nuclear Reactor Depletion Computation", WAPD-TM-478 (1965).

(4) L. A. Hageman, C. J. Pfeifer, "The Utilization of the Neutron Diffusion Program PDQ-5", WAPD-TM-395 (1965).

(5) L. A. Hageman, "Numerical Methods and Techniques Used in the Two-Dimensional Neutron-Diffusion Program PDQ-5", WAPD-TM-364 (1963).

(6) L. A. Hageman, "The Chebyshev Polynomial Method of Iteration", WAPD-TM-537 (1967).

(7) L. A. Hageman, "The Estimation of Acceleration Parameters for Chebyshev Polynomials and Successive Overrelaxation Iteration Methods", WAPD-TM-1038 (1972).

(8) I. K. Abu-Shumays, L. A. Hageman, "Development and Comparison of Practical Discretization Methods for the Neutron Diffusion Equation over General Quadrilateral Partitions", ANS Proceedings of the Conference on Computational Methods in Nuclear Engineering, CONF-750413, Vol. I, pp. I117-I165 (1975).

(9) R. B. Kellogg, "Difference Equations for the Neutron Diffusion Equations in Hexagonal Geometry", WAPD-TM-645 (1966).

(10) R. S. Varga, "Matrix Iterative Analysis", Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1962).

(11) J. B. Yasinsky, "Combined Space-Time Synthesis with Axially Discontinuous Trial Functions", WAPD-TM-736 (1967).

(12) R. J. Breen, "The Representation of the Few-Group Cross Sections in Multiregion Diffusion-Depletion Calculations", WAPD-T-1721 (1965).

(13) A. J. Buslik, "The Description of the Thermal Neutron Spatially Dependent Spectrum by Means of Variational Principles", Bettis Technical Review, Reactor Technology, WAPD-BT-25, pp. 1-24 (1962).

(14) J. N. Sorenson, "Thermal Feedback Calculations in the PDQ-5 Few-Group Neutron Diffusion-Depletion Computer Program", WAPD-TM-639 (1967).

(15) L. L. Lynn, "A Digital Computer Program for Nuclear Reactor Design Water Properties", WAPD-TM-680 (1967).

(16) T. R. England, "CINDER - A One-Point Depletion and Fission Product Program", WAPD-TM-334 (1962).

*U.S. GOVERNMENT PRINTING OFFICE 1978-703-115/753