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**Neutronics Code Vale for
Two-Dimensional Triagonal
(Hexagonal) and
Three-Dimensional Geometries**

D. R. Vondy
T. B. Fowler

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**NEUTRONICS CODE VALE FOR TWO-DIMENSIONAL TRIAGONAL (HEXAGONAL)
AND THREE-DIMENSIONAL GEOMETRIES**

D. R. Vondy
T. B. Fowler

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ABSTRACT

This report documents the computer code VALE designed to solve multigroup neutronics problems with the diffusion theory approximation to neutron transport for a triangular arrangement of mesh points on planes in two- and three-dimensional geometry. This code parallels the VENTURE neutronics code in the local computation system, making exposure and fuel management capabilities available. It uses and generates interface data files adopted in the cooperative effort sponsored by Reactor Physics RRT Division of the U.S. DOE. The programming in Fortran is straightforward, although data is transferred in blocks between auxiliary storage devices and main core, and direct access schemes are used. The size of problems which can be handled is essentially limited only by cost of calculation since the arrays are variably dimensioned. The memory requirement is held down while data transfer during iteration is increased only as necessary with problem size.

There is provision for the more common boundary conditions including the repeating boundary, 180° rotational symmetry, and the rotational symmetry conditions for the 30° , 60° , and 120° triangular grids on planes.

A variety of types of problems may be solved: the usual neutron flux eigenvalue problem, or a direct criticality search on the buckling, on a reciprocal velocity absorber (prompt mode), or on nuclide concentrations. The adjoint problem and fixed source problem may be solved, as well as the dominating higher harmonic, or the importance problem for an arbitrary fixed source.

COMPUTER CODE ABSTRACT

1. Program Identification: VALE, a code block for solving multigroup neutronics problems applying a discretized diffusion theory approximation to neutron transport.^a
2. Function: This code solves usual neutronics eigenvalue problems, and adjoint, higher harmonic fixed source, importance, and criticality search problems, treating up to three geometric dimensions. The code is used as a module of a local computation system.^{b,c}
3. Method of Solution: An inner, outer iteration procedure is used with several different data handling schemes programmed in parallel. Restrained line overrelaxation is used, and succeeding iterate flux sets may be accelerated by the Chebyshev process, and asymptotic extrapolation done when distinct error modes establish. Normally the eigenvalue of a problem is estimated each outer iteration from an overall neutron balance; however, source ratios are used in some situations. The reference formulation is mesh edge on planes of equally spaced mesh points, triangular geometry, on mesh centered planes. Macroscopic nuclear properties are calculated from nuclide concentrations and microscopic cross sections that may have a dependence on the local temperature.
4. Related Material: Standard interface data file specifications adopted in the U.S. DOE RRTD Reactor Physics code coordination effort are used with modest extensions.^d Input data must be read by a separate processor.
5. Restrictions: This code is quite thoroughly variably dimensioned. Generally the larger the problem, the more Input/Output required for iteration. Three-dimensional problems have been solved that contained more than 10^6 space, energy points.
6. Computer: This code has been run on IBM computers including the 3033, 360/91, and 360/195.

7. **Running Time:** Running time is directly related to problem size and inversely proportional to some measure of central processor and data transfer speeds. The basic rate of solution of eigenvalue problems is about 125 space energy points per second of central processor time on an IBM 3033. Thermal reactor lattice and cell problems normally require more time by perhaps a factor of two. Problems involving significant upscatter (multithermal-group treatment) require additional computer time, typically a factor of two or more.
8. **Programming Languages:** The programming is basically in the ASA 1966 FORTRAN language excepting certain extensions, especially those required for unindexed, mixed type block data transfers and direct access of data by record from disc. Known limitations of manufacturer's current compilers are not exceeded: for example, arrays are limited to three dimensions, dummy arguments in sub-routines to sixty. Special routines are used for certain functions including memory allocation, support of the data transfer procedures and to make available elapsed computer time for executing certain user options; these would require replacement for compatibility with a different operating system. The source deck consists of about 35,000 statements.
9. **Operating System:** The basic IBM MVT and MVS operating systems have been used with a FORTRAN IV, H level compiler version 21.8. Access capability of programs in the modular sense is essential to use the system of codes.
10. **Machine Requirements:** A 100,000 word core is needed, and preferably one much larger; auxiliary storage of the disc or drum type is essential, preferably several on different data channels. Typically the code uses 27 logical units.
11. **Authors:** D. R. Vondy
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Oak Ridge, Tennessee 37830

12. References:
- a. D. R. Vondy and T. B. Fowler, "Neutronics Code VALE for Two-Dimensional Triagonal (hexagonal) and Three-Dimensional Geometries," ORNL-5792
 - b. D. R. Vondy, T. B. Fowler, and G. W. Cunningham, III, "The BOLD VENTURE Computation System for Nuclear Reactor Core Analysis, Version III," ORNL-5711 (1981).
 - c. D. R. Vondy, T. B. Fowler, G. W. Cunningham, III, and L. M. Petrie, "A Computation System for Nuclear Reactor Core Analysis," ERDA Report, ORNL-5158 (1977).
 - d. G. E. Bosler, R. D. O'Dell, and W. M. Resnik, "LA SI2-III, A Generalized Processor for Standard Interface Files," ERDA Report, LA-6280 MS (April 1976).
13. Material Available: The package submitted to the National Energy Software Center at ANL, DOE sponsored, includes Fortran card image source decks for the VALE neutronics code, assembly language routines for use on a compatible computer, and an input data deck for sample problems plus the edit from the computer run for these. Other released members of the computation system are available.

I. INTRODUCTION

The VENTURE¹ code was the latest in a series of diffusion theory neutronics codes implemented at ORNL. It applied the mesh centered neutron balance finite-difference formulation. We yet find that this formulation is often cost effective, especially in comparison with other difference formulations, including so-called higher order schemes like the linear finite-element, or the simpler schemes like the nodal approach when account must be taken of a large number of geometric differences. Still, in triangular geometry (used primarily to treat the plane through hexagonal assemblies), the use of only three nearest neighbors of a point for the neutron transport approximation is poor, sometimes seriously inaccurate. Locating the mesh points at the material junctures, mesh edge, places one point at each corner of a hexagonal fuel assembly and one in the center in the coarsest modeling, effectively 3 points per hex. Each point thus has six neighbors, and an improvement over the leakage approximation of the mesh centered formulation is expected. Indeed with the mesh centered formulation, the flux level at other points that lie nearby is not accounted for in the leakage approximation. With the mesh-edge location, typically 3 points/hex are used compared with 6 points/hex for the mesh centered formulation, and the extra computation cost of tighter coupling is offset by the fewer points required. Furthermore, it is often possible to model many situations with a 30° pie-shaped repeating section, thereby reducing the cost of calculations by a factor of two over that to treat a 60° section, especially important for three-dimension problems. Further gain comes about by discarding the requirement to treat a parallelogram thereby eliminating a large number of inactive points. Maximum advantage is taken of a uniform mesh point arrangement on planes (triangular), and with these located between interfaces axially (mesh centered planes), the calculational burden is minimized.

Some gain in accuracy is often possible with a parametric formulation that allows part of the absorption term to lie off the matrix diagonal (linear flux and linear finite element equation formulation methods), an

option implemented with a parametrized fractional off-diagonal term. Paying the cost penalty of a consistent source calculation is deemed necessary, but parallel procedures are used so that the base calculation is not penalized.

A secondary objective of this effort was to develop a code that could serve as the starting point to treat the non-uniform arrangement of mesh points at the apexes of triangles of uniform properties. This capability is much needed in analysis to treat several different classes of problems, especially those involving mixed geometries: a round rod in a hexagonal fuel assembly, a cylindrical pressure vessel around a core of hexagonal fuel assemblies, a bowed core, etc. The mesh centered formulation should not be used because distortion of the mesh causes nearest neighbors to change with the obvious consequence that the representation can have a very low accuracy. Effort toward this future goal indeed was the primary impetus for this work.

It is not unusual to find that in some applications many axial planes of points are required to reduce the associated error of discretization to an acceptable level. Thus an integral part of this work was to identify and implement a preferred coarse mesh formulation for the axial coordinate as an alternative to the finite-difference formulation. This effort is yet in progress at the time of preparation of this document.

We assume that certain reports are readily available and rely on them for much documentation, such as the user's guide to the system codes² and the VENTURE code report.¹ Here only specific aspects are covered, differences from VENTURE, and exceptions.

The VALE code is in routine production use locally and remotely via terminal in the local system of codes for computation.³ The input processor⁴ is used for primary user problem description input, although special processors also prove very useful.² Certain modifications to the interface data files were necessary, as to block the data for a plane of mesh points into a simple record (*m* points instead of rectangular *ixj*), and a new geometry file is defined, TRIGOM.²

In this computation system the codes are executed in an order prescribed by the user with instructions to a control module. Not every sequence of execution would be useful or even viable, but no restraints are imposed that would limit flexibility. Loops over the successive use of a series of codes is usual, and problems are solved that require such a continuing sequence of calculations to produce a converged solution. In this sense the VENTURE and the VALE neutronics codes serve the same role. Only one would be used in a specific application. VALE provides parallel capability to VENTURE, excluding the perturbation capability of the latter. It has the capability to perform criticality searches, solve regular and adjoint problems, the fundamental and the dominate higher harmonic, and importance problems given an arbitrary fixed source that may have negative components, treat equilibrium xenon and to apply a temperature correlation on microscopic cross sections. The other codes in this system are compatible except for the perturbation code that remains to be upgraded.

In the following the application information, problem definition, and programming information are discussed. A sample problem is described in the Appendix with the input data and computer printout displayed.

Approximately three man years went into implementing the VALE code.

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II. APPLICATION INFORMATION

This section presents information about the code that is of special interest to the user.

A. Program Description

This code solves neutronics problems by applying the diffusion theory approximation to neutron transport.

It is a member of the local modular nuclear reactor computation system and does not read data from the user input stream. Information is supplied via standard interface data files, and results are printed and written on interface data files. A user's flow diagram is presented as Fig. 1 indicating the major tasks and the calculational path.

B. Program Considerations

Figure 2 lists the contents of the record DTNINS of the interface data file CONTRL showing the instructions to VALE and lists the programmed options. This record of the file CONTRL may be created with the input processor,⁴ or alternatively with the special processor DUTLIN.²

Figure 3 documents the contents of the special geometry file TRIGOM.

We found it necessary for the most efficient use of computer memory to avoid the requirement of a parallelepiped arrangement of mesh points. Instead of specifying I columns and J rows of mesh points on planes, giving IJ points, the number of points on a plane is specified and simple descriptions are given that identify the arrangements and relate neighbors on a 60° grid, equilateral arrangement of points. The special file TRIGOM is used to describe the geometry. Planes of mesh points are located between material interfaces, mesh centered.

Fig. 1. User flow chart, VALE neutronics code.

C
 CR NEUTRONICS INSTRUCTIONS
 C
 CL DTNINS, (IX(I),I=1,100), (IX(I),I=1,100)
 C
 CW 101*MULT + 100
 C
 CD DTNINS NEUTRONICS CONTROL IDENTIFIER, A(6)
 CD IX(1) REFERENCE REAL TIME, DAYS
 CD IX(2) MACHINE TIME ALLOWED FOR SOLUTION, MIN
 CD (ITERATION TERMINATED IF TIME EXCEEDED)
 CD IX(3) CYCLE TIME IN MINUTES TO WRITE RESTART DATA
 CD NOT DONE IF 0, ALWAYS DONE AT END IF NON-ZERO
 CD THIS OPTION IS IMPLEMENTED IN FEATURE ONLY.
 CD AN EFFECTIVE RESTART PROCEDURE FOR VALE
 CD (OR VENTURE) IS TO FLAG IX(9)=2 AND ALSO
 CD IX(16).GT.0 IF CHANGES IN THE PROBLEM
 CD ARE MINOR
 CD IX(4) POWER LEVEL OF REACTOR, WATTS THERMAL
 CD IF 0, NORMALIZATION IS TO ONE SOURCE NEUTRON
 CD (WATT-SEC/FISS DEFAULTED TO 3.2E-11 IF ZERO)
 CD IX(5) ENERGY CONVERSION FACTOR, FISSION TO THERMAL
 CD IX(6) FRACTION OF REACTOR TREATED
 CD IX(7) SPECIFIED MULTIPLICATION FACTOR FOR SEARCH IF
 CD NON-ZERO
 CD IX(8) SPECIFIED OVERRELAXATION COEFFICIENT IF NON-ZERO
 CD IX(9) ESTIMATE OF THE EIGENVALUE FOR CHEBYCHEV
 CD ACCELERATION ON OUTER ITERATIONS
 CD IX(10) ESTIMATE OF THE LOWER LIMIT OF THE SPECTRUM OF
 CD EIGENVALUES FOR CHEBYCHEV ACCELERATION
 CD IX(11) CONVERGENCE CRITERIA ON INTEGRAL QUANTITIES
 CD MAXIMUM RELATIVE CHANGE ON OUTER ITERATION
 CD IX(12) CONVERGENCE CRITERIA ON LOCAL OR POINT VARIABLES
 CD MAXIMUM RELATIVE POINT FLUX CHANGE ON OUTER
 CD ITERATION (.00005)
 CD IX(13) CONSTANT BUCKLING VALUE WHICH OVERRIDES THE DATA
 CD IN GEODST FILE IF NON-ZERO
 CD IX(14) RESERVED
 CD IX(15) RESERVED
 CD IX(16) RESERVED
 CD IX(17) RESERVED
 CD IX(18) RESERVED
 CD IX(19) LIMITING VALUE OF ANY DIFFUSION COEFFICIENT
 CD IF NOT ZERO - DEFAULT 100.0
 CD IX(20) PARAMETER FOR HIGHER ORDER VALE SOLUTION^a
 CD 1/6 = 0.1666666 - TAYLOR SERIES
 CD 7/36 = 0.194444 - LINEAR FLUX
 CD 1/4 = 0.25 - LINEAR FINITE ELEMENT
 CD IF MADE NEGATIVE, THE HIGHER ORDER APPROXIMATION
 CD IS NOT APPLIED TO THE SOURCE
 CD IX(21) THE ZONE AND GROUP DIFFUSION COEFFICIENTS
 CD THROUGH ZONE IX(43) (SEE BELOW) WILL BE
 CD MULTIPLIED BY THIS NUMBER IF NOT ZERO
 CD IX(22) THIS NUMBER WILL BE ADDED TO THE ZONE AND
 CD GROUP DIFFUSION COEFFICIENTS THROUGH ZONE
 CD IX(43) AFTER IX(21) IS APPLIED IF NOT ZERO
 CD IX(23) XENON+IODINE YIELD FRACTION FOR EQUILIBRIUM
 CD XENON - IF IX(69) GT 0
 CD IX(24) 'Q' FACTOR FOR POWER WEIGHTED REGULAR TIMES
 CD ADJOINT FLUX

^aValue constrained at each group to ensure positive flux solution.

Fig. 2. Specifications for DTNINS Record in Interface File CONTRL.

CD XX(25) REFERENCE TEMPERATURE (DEGREES C) OF THE
 CD NEXT-TO-LATEST VERSION 'GRUPIS' CROSS SECTION
 CD INTERFACE FILE
 CD XX(26) REFERENCE TEMPERATURE (DEGREES C) OF THE
 CD LATEST VERSION 'GRUPIS' CROSS SECTION INTERFACE
 CD FILE
 CD XX(27) CORRELATION PARAMETER FOR THE ARCTANGENT
 CD DEPENDENCE OF CROSS SECTIONS ON ZONE
 CD TEMPERATURES (LINEAR CORRELATION IF 0.0)
 CD XX(28) FACTOR APPLIED TO SPACE INTERPOLATION SLOPE
 CD FOR SPACE-ENERGY REBALANCE. IF ZERO, NO
 CD SPACE INTERPOLATION IS DONE, FOR VENTURE ONLY
 CD XX(29) FACTOR APPLIED TO THE FINAL REBALANCE FACTORS
 CD FOR SPACE-ENERGY REBALANCE - DEFAULT 1.0
 CD FOR VALE, THIS IS A FACTOR APPLIED TO THE AXIAL
 CD DIFFUSION COEFFICIENTS FOR 3-D PROBLEMS IF
 CD NOT ZERO
 CD XX(30) XENON DECAY CONSTANT FOR EQUILIBRIUM XENON -
 CD IF IX(69) GT 0
 CD XX(31) - XX(100) RESERVED
 C
 CD IX(1) INDICATOR THAT THE CODE BLOCK HAS INPUT DATA
 CD NOT CONTAINED IN THE STANDARD INTERFACE FILES
 CD OTHER THAN THIS BLOCK OF DATA IF .GT.0
 CD IX(2) RESTART OPTIONS- RESTART USING DATA FROM AN
 CD OLD CASE IF .GT. 0, REQUIRES SPECIAL RESTART
 CD DATA FILE
 CD FOR VALE SEE IX(3)
 CD IX(3) REFERENCE COUNT ON PROBLEMS (CYCLE NUMBER)
 CD IX(4) FORMULATION OPTIONS
 C
 CD VENTURE, MESH CENTRED FINITE-DIFFERENCE
 CD 1 - DIFFUSION THEORY (FUNDAMENTAL)
 CD 2 - SIMPLE P1 APPROXIMATELY (FUNDAMENTAL)
 CD -1 - DIFFUSION THEORY SOLUTION FOR THE DOMINANT
 CD ALLOWED FIRST HARMONIC REQUIRING THE
 CD FUNDAMENTAL REGULAR AND ADJOINT FLUX FILES
 CD 'RTFLUX' AND 'ATFLUX'. THE FIRST ITERATE
 CD SOURCE DISTRIBUTION WILL BE SKEWED TO
 CD EXCITE ALL SPACIAL FLUX HARMONICS SO
 CD THAT THE DOMINANT WILL SURFACE.
 CD -2 - SAME AS -1 BUT THE FIRST ITERATE SOURCE
 CD WILL NOT BE SKEWED. USUALLY FOR THIS
 CD OPTION THE 'RTFLUX' FILE MUST EITHER BE A
 CD UNIFORM FLUX DISTRIBUTION (IN WHICH CASE
 CD THE SOLUTION MAY OR MAY NOT BE FOR THE
 CD DOMINANT HARMONIC) OR AN INITIAL ESTIMATE
 CD OF THE DOMINANT HARMONIC FLUX DISTRIBUTION
 CD (FOR EXAMPLE, A COSINE FROM -1 TO +1
 CD ALONG A COORDINATE WHILE PERHAPS UNIFORM
 CD IN OTHER DIRECTIONS) THAT WILL CAUSE THE
 CD DESIRED HARMONIC TO SURFACE. THIS MAY
 CD ESPECIALLY BE USEFUL TO ACCELERATE
 CD CONVERGENCE WHEN TWO OF THE SPACIAL
 CD HARMONIC EIGENVALUES ARE NEARLY EQUAL.
 CD -10 - SPECIAL DOMINANT HARMONIC SOLUTION (RZ)
 CD ADJUSTING THE TOTAL LOSS TERM TO ACCOUNT
 CD FOR THE AZIMUTHAL HARMONIC
 C
 CD VALE, MESH EDGE TRIANGULAR

Fig. 2. (CONTINUED)

CD		1 - DIFFUSION THEORY (FUNDAMENTAL)
CD		-1 - DIFFUSION THEORY (DOMINANT HARMONIC)
CD		-2 - SAME AS -1 BUT THE FIRST ITERATE SOURCE
CD		WILL NOT BE SKEWED
CD		3 - HIGHER ORDER (FUNDAMENTAL) - SEE IX(20)
CD		-3 - HIGHER ORDER (DOMINANT HARMONIC)
CD		-4 - SAME AS -3 BUT THE FIRST ITERATE SOURCE
CD		WILL NOT BE SKEWED
C		
CD		VANNER, MESH EDGE (2- AND 3-D SLAB INFO SHOWN)
CD		1 - FINITE DIFFERENCE
CD		2 - LINEAR FINITE DIFFERENCE (8, 10 NEIGHBORS)
CD		3 - EXTENDED TAYLOR SERIES (8, 10 NEIGHBORS)
CD		4 - LINEAR FINITE ELEMENT (8, 10 NEIGHBORS)
CD		5 - SINGLE TAYLOR SERIES (8, 10 NEIGHBORS)
CD		6 - USUAL FINITE DIFFERENCE (4, 6 NEIGHBORS)
CD		7 - COMPROMISE (8, 10 NEIGHBORS)
CD		8 - COMPROMISE (4, 6 NEIGHBORS)
CD		9 - COMPENSATED DIFFERENCE (4, 6 NEIGHBORS)
C		
CD	IX(5)	TYPE OF PROBLEM
CD		0- DETERMINE SOURCE MULTIPLICATION FACTOR
CD		1- SEARCH PROBLEM (FILE OF SEARCH DATA IS
CD		REQUIRED, SEE OPTION IX(10))
CD		2- FIXED SOURCE PROBLEM
CD		3- ADJOINT PROBLEM ONLY
CD		4- BUCKLING SEARCH
CD		5- PROMPT MODE ALPHA CALCULATION, 1/V SEARCH
CD	IX(6)	ADJOINT PROBLEM OPTIONS
CD		0 - NO ADJOINT PROBLEM TO BE DONE
CD		1 - EIGENVALUE TYPE PROBLEM
CD		(NORMALLY FOLLOWING A FORWARD PROBLEM)
CD		2 - FIXED SOURCE TYPE PROBLEM
CD	IX(7)	RESERVED
CD	IX(8)	OPTION TO FORCE DATA HANDLING MODE (FOR TESTING)
CD		-1 OPTION TO TERMINATE IF MEMORY ALLOCATION
CD		IS TOO SMALL FOR EFFICIENT EXECUTION (THE
CD		SPACE PROBLEM CANNOT BE STORED IN TWO-
CD		DIMENSIONS OR ENOUGH PLANES OF DATA CAN
CD		NOT BE STORED TO AVOID EXCESS TRANSFER
CD		IN THREE-DIMENSIONS)
CD		0- AUTOMATED TO MINIMIZE INPUT/OUTPUT
CD		1- BASE PROBLEM CORE CONTAINED
CD		2- SPACE PROBLEM AT EACH ENERGY CONTAINED
CD		3- ONE ROW CONTAINED IN CORE
CD		4- ONE OR MORE SPACE PLANES CONTAINED IN CORE
CD		5- MULTIPLE ROWS STORED FOR TWO DIMENSIONAL
CD		6- MULTI-LEVEL DATA TRANSFER
CD		FOR VAL, OPTIONS -1, 0, 2, AND 4 APPLY
CD	IX(9)	OPTIONS ON FLUX INITIALIZATION
CD		-1 SET ALL FLUX VALUES EQUAL
CD		0 AUTOMATED PROCEDURE
CD		1 POINT ENERGY MODEL, COSINE IN SPACE
CD		2 USE LATEST VERSION OF AVAILABLE SCALAR
CD		FLUX FILE
CD		3 USE NEXT-TO-LATEST VERSION OF AVAILABLE
CD		SCALAR FLUX FILE
CD	IX(10)	IDENTIFIES SEARCH DATA IN SEARCH FILE, IX(5) = 1
CD	IX(11)	IDENTIFIES SECONDARY SEARCH DATA IN SEARCH FILE
CD		TO BE USED IF CONSTRAINTS FOR FIRST SET ARE

Fig. 2. (CONTINUED)

CD		NOT SATISFIED, AND SECOND SEARCH IS TO BE DONE
CD	IX(12)	SPECIFIES THAT A 2-D (OR 1-D) PROBLEM IS TO BE
CD		SOLVED FOR THIS PLANE (OR ROW) OF A 3-D
CD		(OR 2-D) DESCRIPTION IF NON-ZERO
CD	IX(13)	ORDER IN THE CROSS SECTION FILE OF THE DIRECTION
CD		DEPENDENT TRANSPORT CROSS SECTION TO BE USED
CD		FOR THE FIRST COORDINATE DIRECTION (USUALLY 0)
CD	IX(14)	DITTO, SECOND COORDINATE DIRECTION
CD	IX(15)	DITTO, THIRD COORDINATE DIRECTION
CD	IX(16)	INSTRUCTION NORMALLY EXERCISED BY CONTROL MODULE
CD		TO INFORM THE NEUTRONICS MODULE TO RECOVER
CD		DATA FOR INITIALIZATION FROM FILES RZFLUX AND
CD		RTFLUX
CD	IX(17)	FORCE KEFF. CALC. BY SOURCE RATIO IF GT 0
CD	IX(18)	FISSION SOURCE DISTRIBUTION FUNCTION OPTION
CD		0- SET VALUES TO BE USED (SAME IN EACH ZONE)
CD		1- REGION DEPENDENT VALUES TO BE USED
CD	IX(19)	FISSION SOURCE DISTRIBUTION NORMALIZATION OPTION
CD		0- LEAVE UNNORMALIZED
CD		1- NORMALIZE EACH SET TO SUM TO UNITY
CD	IX(20)	CONSTRAINT ON OUTER ITERATIONS(MAX ALLOWED)
CD		(SET BY THE CODE IF NOT SPECIFIED)
CD		IF SET = 969 INITIAL DATA PROCESSING IS DONE
CD		FOR CHECKING INTERFACE DATA FILES, MEMORY
CD		REQUIREMENTS, ETC. AND NO CALCULATIONS
CD		ARE DONE - EXCEPT IF IX(9) IS GREATER
CD		THAN 1, THE RESIDUES PASS IS MADE TO
CD		CALCULATE KEFFECTIVE ONLY
CD	IX(21)	INNER ITERATION OPTION
CD		0- USE AUTOMATED PROCEDURE (RECOMMENDED)
CD		N- REFERENCE NUMBER OF INNERS = N
CD		SET BY THE CODE IF NOT SPECIFIED
CD		(IF 1 .LE. N .LE. 4, CHEBYSHEV ACCELERATION
CD		WILL NOT BE DONE ON OUTER ITERATIONS
CD		AS THE AUTOMATED PROCEDURE)
CD		FOR VALE, THIS IS ALSO THE NUMBER OF PLANES
CD		STORED FOR THE PLANE STORED MODE, IX(8)=4,
CD		(DEFAULT 4)
CD	IX(22)	OPTION TO REESTIMATE OVERRELAXATION FACTORS BY
CD		L1 NORM FOR ZERO SOURCE PROBLEM, SPECIAL INNER
CD		ITERATIONS ARE DONE (MAKE LARGE TO OVERRIDE
CD		THE AUTOMATED PROCEDURE WHICH EMPLOYS THIS)
CD	IX(23)	INITIALIZATION OPTIONS FOR PROCEDURES, CHOICE OF
CD		OVERRELAXATION COEFFICIENTS AND ITERATIONS
CD		-2 DONT DO ONE-DIMENSIONAL CALCULATION
CD		FOR INITIALIZATION
CD		-1 DONT USE 1-D OVERRELAXATION COEFFICIENTS
CD		0- USE AUTOMATED PROCEDURE, SOLVES 1-D PROBLEM
CD		CHEBYSHEV COEFFICIENTS ON OUTER ITERATIONS
CD		IF THE NUMBER OF INNERS IS .LT. 5
CD		EXCEPT WHEN CHEBYSHEV FLUX ON OUTERS
CD		1- SAME AS 0 BUT DO NOT CHEBYSHEV
CD		OVERRELAXATION COEFFICIENTS
CD		2- FIX THE NUMBER OF INNER ITERATIONS
CD		3- FIX NUMBER OF INNERS, NO CHEBYSHEV
CD		4- FIXED INNERS AND INITIAL COEFFICIENTS
CD		5- FIXED INNERS AND COEFFICIENTS, NO CHEBYSHEV
CD		6- SAME AS 4 BUT DONT USE 1-D COEFFICIENTS
CD		7- SAME AS 5 BUT DONT USE 1-D COEFFICIENTS
CD		FOR VALE THE AUTOMATED OPTION 0 IS THE SAME
CD		AS VENTURE OPTION -2, AND THE ONLY OTHER
CD		OPTIONS ARE 2, 3, 4, AND 5
CD	IX(24)	INNER ITERATION SWEEP ORDER

Fig. 2. (CONTINUED)

CD -1 NORMAL ORDERED
 CD 0 AUTOMATED (SIGMA-1 IF AVAILABLE, USUALLY)
 CD 1 SIGMA-1 ORDERED IF AVAILABLE
 CD IX(25) OUTER ITERATION CHEBYCHEV ACCELERATION OPTIONS
 CD .LT. 0 START AT THIS ITERATION
 CD 0- USE AUTOMATED PROCEDURE
 CD 1- APPLY ONLY AFTER THE FIRST EXTRAPOLATION
 CD 2- APPLY CONTINUOUSLY FROM THE START
 CD 3- DONT APPLY THE PROCESS
 CD .GT. 100- THE PROCESS IS STARTED AT ITERATION
 CD IX(25)-100 USING AN 1.1 NORM EIGENVALUE
 CD FOR THE AUTOMATED OPTION IN VENTURE, THE
 CD INITIALIZATION PROCEDURE DETERMINES WHETHER
 CD CHEBYCHEV ACCELERATION IS TO BE DONE
 CD FOR VALE, THE AUTOMATED OPTION IS NOT TO APPLY
 CD THE CHEBYCHEV ACCELERATION, THEREFORE FOR
 CD PROBLEMS IN WHICH THIS ACCELERATION IS
 CD DEEMED TO BE EFFECTIVE A NON ZERO VALUE
 CD MUST BE SPECIFIED
 CD IX(26) ASYMPTOTIC OUTERITERITION EXTRAPOLATION OPTIONS
 CD -1 SINGLE ERROR MODE ONLY
 CD 0- USE AUTOMATED PROCEDURE
 CD 1- SINGLE ERROR MODE USING DATA FOR ALTERNATE
 CD ITERATIONS
 CD 2- NOT ALLOWED
 CD 3- WE ARE TRYING TO FIGURE OUT WHAT THIS DOES
 CD IX(27) FORCED DELAY IN ASYMPTOTIC EXTRAPOLATION
 CD N- NOT ALLOWED FOR THIS MANY OUTER ITERATIONS
 CD (IF NEGATIVE, A FORCED PROCEDURE MAY BE
 CD EXECUTED EARLIER)
 C
 CN EDITS GENERALLY ARE NOT DONE WHEN FLAG IS ZERO
 C
 CD IX(28) OPTION FOR CONDENSED EDIT (TERMINAL) IF .GT. 1
 CD IX(29) OPTION TO EDIT THE PRINCIPAL MACROSCOPIC
 CD CROSS SECTIONS BY ZONE
 CD IX(30) OPTION TO EDIT THE MACROSCOPIC SCATTERING
 CD CROSS SECTIONS BY ZONE
 CD IX(31) OPTIONS ON ITERATION DATA EDITS
 CD -1- NO EDITS DURING ITERATION
 CD 0, OR 1- PRIMARY OUTER ITERATION DATA ONLY
 CD 2- GETS DETAILS EDITED FOR TESTING
 CD 3- REQUESTS EXTENDED EDIT FOR DEBUGGING
 CD IX(32) OPTION TO EDIT OVERALL NEUTRON BALANCE BY GROUP
 CD IX(33) OPTION TO EDIT NEUTRON BALANCE BY ZONE
 CD IX(34) RESERVED
 CD IX(35) OPTION TO EDIT SCALAR NEUTRON FLUX BY POINT
 CD IX(36) RESERVED
 CD IX(37) OPTION TO EDIT ZONE-AVERAGE FLUX BY GROUP
 CD IF .GT. 1, ALSO EDIT THE ZONE, GROUP ADJOINT FLUX
 CD IX(38) OPTION TO EDIT POWER DENSITY MAP BY INTERVAL
 CD IX(39) OPTION TO EDIT POWER DENSITY TRAVERSES THRU PEAK
 CD THIS OPTION APPLIES ONLY TO VENTURE - NOT VALE
 CD IX(40) OPTION TO EDIT NEUTRON DENSITY MAP (1/V FLUX
 CD WEIGHTING)
 CD IX(41) OPTION TO EDIT NEUTRON DEYSITY TRAVERSES
 CD THIS OPTION APPLIES ONLY TO VENTURE - NOT VALE
 CD IX(42) OPTION TO EDIT SCALAR ADJOINT FLUX
 CD IX(43) MAXIMUM ZONE NUMBER FOR WHICH IX(21) AND IX(22)

Fig. 2. (CONTINUED)

CD ARE TO BE APPLIED TO THE ZONE AND GROUP
 CD DIFFUSION COEFFICIENTS IF NOT ZERO
 CD IX(44) OPTION TO EDIT ATOMIC DENSITIES WHEN SEARCHING
 CD 0- NO EDIT
 CD 1- MINIMUM EDIT AT END
 CD 2- MAXIMUM EDIT DURING CALCULATION
 C
 CM OPTIONS IX(45) THROUGH IX(50): ONLY ONLY
 CM TO VENTURE - NOT VALE
 C
 CD IX(45) PERTURBATION OPTIONS - IF NEGATIVE, FILES RTFLUX
 CD AND ATFLUX ARE SUPPLIED AND NO NEUTRONICS
 CD CALCULATION IS DONE - OTHERWISE THE REGULAR
 CD AND/OR ADJOINT SOLUTION IS OBTAINED AS
 CD SPECIFIED ABOVE AND EITHER FLUX FILE NOT
 CD GENERATED MUST BE SUPPLIED
 CD 0- NO PERTURBATION CALCULATION
 CD 1- CALCULATE AND EDIT BASIC REGULAR*ADJOINT
 CD FLUX INTEGRALS EXCEPT TRANSPORT
 CD 2- ALSO CALCULATE AND EDIT TRANSPORT INTEGRALS
 CD (REQUIRED FOR COMPLETE PERTURBATION EFFECT)
 CD 3- ALSO EDIT MACROSCOPIC ABSORPTION CROSS
 CD SECTION SPACE POINT IMPORTANCE MAP
 CD 4- ALSO EDIT MACROSCOPIC PRODUCTION CROSS
 CD SECTION SPACE POINT IMPORTANCE MAP
 CD PLUS ABS-PROD MAP
 CD 5- ALSO EDIT 1/V SPACE POINT IMPORTANCE MAP
 CD IX(46) EDIT RESULTS FOR A 100 PERCENT CHANGE IN MACRO
 CD CROSS SECTIONS, ONLY IF IX(45).NE.0
 CD IX(47) OPTION TO WRITE POINT FLUX VALUES FOR EXPOSURE
 CD (EXERCISED ONLY IF IX(53) .GT. 0)
 CD .GT. 0 WRITE DATA FOR POINTS IN THIS ZONE
 CD -1 WRITE ONLY THE SPECTRUM FOR THE POINT WHERE
 CD THE POWER DENSITY IS A MAXIMUM INITIALLY
 CD -2 WRITE DATA FOR THE POINTS IN THE ZONE WHERE
 CD THE POWER DENSITY IS A MAXIMUM INITIALLY
 CD -3 WRITE ONLY THE SPECTRUM FOR THE POINT WHERE
 CD THE FIRST GROUP FLUX IS A MAXIMUM INITIALLY
 CD -4 WRITE DATA FOR THE POINTS IN THE ZONE WHERE
 CD THE FIRST GROUP FLUX IS A MAXIMUM INITIALLY
 CD .LT.-4 WRITE SPECTRUM FOR THIS MESH POINT
 CD IX(48) ANOTHER ZONE NUMBER FOR WHICH THE POINT FLUX
 CD VALUES ARE TO BE WRITTEN FOR EXPOSURE IF .GT. 0
 CD IX(49) OPTION TO EDIT THE DIRECT CONTRIBUTION TO CHANGE
 CD IN CONVERSION RATIO FROM UNIT CHANGE IN FERTILE
 CD CAPTURE AND FISSILE ABSORPTION (MACROSCOPIC)
 CD IX(50) OPTION TO WRITE SCALAR ADJOINT FLUX FILE AS
 CD THE PRODUCT OF THE REGULAR AND ADJOINT FLUX
 CD 0- NO
 CD 1- REWRITE THE LATEST VERSION OF AN OLD FILE
 CD (IF THERE IS NONE, WRITE A NEW ONE)
 CD 2- WRITE NEW FILE
 C
 CM OPTIONS ABOVE ARE TYPICAL FOR EACH FILE COVERED BELOW
 C
 CD IX(51) OPTION TO WRITE THE POINT SCALAR FLUX FILE
 CD IX(52) OPTION TO WRITE THE POINT FISSION SOURCE FILE
 CD IX(53) OPTION TO WRITE ZONE-AVERAGE SCALAR FLUX FILE
 CD IX(54) OPTION TO WRITE POINT POWER DENSITY FILE

Fig. 2. (CONTINUED)

CD	IX(55)	WRITE THE CONVERSION RATIO ADJOINT IMPORTANCE
CD		FIXED SOURCE FILE (ALWAYS ADDS A FILE OR TWO)
CD		.GT.0- WRITE COMBINED FILE (HAS NEGATIVE DATA)
CD		.LT.0- WRITE TWO FILES, ALL POSITIVE
CD	IX(56)	OPTION TO WRITE THE ZONE POWER DENSITY FILE
CD	IX(57)	OPTION TO WRITE THE ADJOINT ZONE AVERAGE FLUX
CD		FILE AZFLUX
CD	IX(58)	OPTION TO WRITE SCALAR ADJOINT FLUX FILE
CD		APPLICABLE ONLY IF AN ADJOINT PROBLEM WAS DONE
C		
CN		OPTIONS IX(59) THROUGH IX(63) APPLY ONLY
CN		TO VENTURE - NOT VALE
C		
CD	IX(59)	OPTION TO WRITE PERTURBATION INTEGRALS ON FILE
CD		PERTUB. IX(45) MUST BE NON-ZERO. TRANSPORT
CD		INTEGRALS ARE INCLUDED IF ABS(IX(45)) GT 2.
CD	IX(60)	OPTION TO WRITE SPECIAL FORMATTED DATA FILE
CD		(LOGICAL 4) AT THE END OF A CASE - SEE SECTION 204
CD		OF THE VENTURE REPORT
CD	IX(61)	A PLANE NUMBER AT WHICH ZONE AND GROUP BUCKLINGS
CD		ARE TO BE CALCULATED
CD	IX(62)	A SECOND PLANE NUMBER FOR THE BUCKLING CALCULATION
CD	IX(63)	OPTION TO WRITE A POINTWISE FIXED SOURCE FILE
CD		AS (DB**2) TIMES FLUX
CD	IX(64)	WRITE A POINT POWER DENSITY ADJOINT IMPORTANCE
CD		FIXED SOURCE FILE (ALWAYS ADDS A FILE)
CD		1 POINT WHERE POWER DENSITY IS MAX
CD		-1 POINT IN ZONE ABS(N) WHERE POWER DENSITY
CD		IS MAX
CD		2 POINT GIVEN BY IX(65-67) BELOW
CD	IX(65)	COLUMN NUMBER FOR IX(64)=2
CD	IX(66)	ROW NUMBER FOR IX(64)=2
CD	IX(67)	PLANE NUMBER FOR IX(64)=2
CD	IX(68)	RESERVED
CD	IX(69)	IF GT 0 EQUILIBRIUM XENON WILL BE ACCOUNTED FOR
CD		AND THIS IS THE ORDER NUMBER OF XENON IN THE
CD		NUCLIDE LIST (SET 1) IN SECTION 013 DVENTR
CD	IX(70)	FORCE DATA TRANSFER IN INITIALIZATION (TO TEST
CD		PROCEDURES)
CD	IX(71)	RESERVED
CD	IX(72)	RESERVED
CD	IX(73)	OVERRIDE DEFAULT OF FILES TO MEMORY (TO TEST
CD		PROCEDURES)
C		
CN		OPTIONS IX(74) THROUGH IX(77) APPLY ONLY
CN		TO VENTURE - NOT VALE
C		
CD	IX(74)	SPACE-ENERGY REBALANCE WILL BE DONE OCCASIONALLY
CD		IF GT 0
CD	IX(75)	THE NUMBER OF BOLCKS ALONG ROWS (LEFT-RIGHT)
CD		FOR REBALANCE - IX(74) .GT. 0
CD	IX(76)	THE NUMBER OF BOLCKS ALONG COLS (TOP-BOTTOM)
CD		FOR REBALANCE - IX(74) .GT. 0
CD	IX(77)	THE NUMBER OF BOLCKS ALONG PLANES (PORE-APT)
CD		FOR REBALANCE - IX(74) .GT. 0
CD	IX(78) - IX(79)	RESERVED
CD	IX(80)	OPTION TO ACCOUNT FOR THE DEPENDENCE OF THE
CD		CROSS SECTIONS ON THE LOCAL TEMPERATURE, REQUIRES
CD		TWO 'GRUPTS' FILES, A 'ZNTMP' FILE, AND REFERENCE
CD		TEMPERATURES (SEE IX(25), IX(26), AND IX(27))
CD		0- NO
CD		1- YES
CD	IX(81) - IX(100)	RESERVED
C		

Fig. 2. (CONTINUED)

```

*****
C               REVISED 04/01/80
C
C
CP      TRIGON
C
CE      TRIANGULAR GEOMETRY DESCRIPTION
C
*****

```

```

-----
C
CR      FILE IDENTIFICATION (NV)
C
CL      HNAME, (HUSE(I), I=1,2), IVERS
C
CW      1+3*MULT
C
CD      HNAME      HOLLERITH FILE NAME - TRIGON - (A6)
CD      HUSE       HOLLERITH USER IDENTIFICATION (A6)
CD      IVERS      FILE VERSION NUMBER
C
CW      MULT       1 FOR LONG WORD, 2 FOR SHORT WORD MACHINES
C
-----

```

```

-----
C
CR      FILE REFERENCE INFORMATION (1D RECORD)
C
CL      IGOM, NZONE, NREG, WZCL, NCINTI, NCINTJ, NCINTK, NINTI, NINTJ, NINTK, INB1,
CL      INB2, JNB1, JNB2, KNB1, KNB2, NBS, WBCS, NIBCS, WZWB, NTRIAG, NRASS,
CL      (NGOP(I), I=1,5)
C
CW      27
C
CD      IGOM      GEOMETRY 5- SPECIAL TRIAGONAL, TWO-DIMENSIONAL
CD                  19- SPECIAL TRIAGONAL-2, THREE-DIMENSIONAL
CD      NZONE     NUMBER OF ZONES (EACH HOMOGENEOUS IN NEUTRONICS
CD                  PROBLEM)
CD      NREG      NOT DEFINED
CD      WZCL      NUMBER OF ZONE CLASSIFICATIONS (EDIT PURPOSES)
CD      NCINTI    NOT DEFINED
CD      NCINTJ    NOT DEFINED
CD      NCINTK    NUMBER OF THIRD DIMENSION COARSE MESH INTERVALS
CD                  NCINTK.EQ.1 FOR ONE AND TWO
CD                  DIMENSIONAL CASES.
CD                  A COARSE MESH INTERVAL IS DEFINED AS ONE
CD                  CONTAINING ONE OR MORE FINE MESH INTERVALS, EACH
CD                  OF WHICH CONTAINS THE SAME MATERIAL ZONE.
CD      NINTI     THE NUMBER OF POINTS ON A PLANE. POINTS ARE AT
CD                  THE INTERSECTIONS OF MESH LINES.
CD      NINTJ     NOT DEFINED
CD      NINTK     NUMBER OF THIRD DIMENSION FINE MESH INTERVALS
CD                  NINTK.EQ.1 FOR ONE AND TWO DIMENSIONAL
CD                  CASES.

```

Fig. 3. Contents of Geometry Description File TRIGOM.

CD	INB1	FIRST BOUNDARY ON FIRST DIMENSION	-
CD		0- ZERO FLUX (DIFFUSION)	-
CD		1- REFLECTED	-
CD		2- EXTRAPOLATED (DIFFUSION - DEL PHI	-
CD		/PHI = -C/D WHERE C IS GIVEN AS BNDC	-
CD		BELOW AND D IS THE GROUP DIFFUSION	-
CD		CONSTANT, TRANSPORT - NO RETURN)	-
CD		3- NOT DEFINED	-
CD		4- REPEATING (PERIODIC) WITH NEXT	-
CD		ADJACENT FACE 60 OR 120 DEGREE	-
CD		ROTATION).	-
CD		THE LEFT AND TOP BOUNDARIES ARE	-
CD		REPEATING.	-
CD		5- NOT DEFINED	-
CD		6- NOT DEFINED	-
C			-
CN		NOTE THAT FOR REPEATING BOUNDARIES, THE FIRST BOUNDARY IN	-
CN		ORDER WHICH IS INVOLVED CARRIES THE DESIGNATOR DEFINING	-
CN		THE REPEATING CONDITION.	-
C			-
CD	INB2	LAST BOUNDARY ON FIRST DIMENSION	-
CD	JNB1	FIRST BOUNDARY ON SECOND DIMENSION	-
CD		5- REPEATING ALONG THIS BOUNDARY - 180	-
CD		DEGREES. IF NPP EQUALS THE NUMBER OF	-
CD		POINTS ON THIS BOUNDARY, THEN THE FLUXES	-
CD		AT POINTS NPP/2 THROUGH NPP ARE EQUAL	-
CD		TO THE FLUXES AT POINTS 1 THROUGH NPP/2	-
CD		FOR THIS OPTION, INB1=INB2 AND	-
CD		NTRIAG=1.	-
CD	JNB2	LAST BOUNDARY ON SECOND DIMENSION	-
CD	KNB1	FIRST BOUNDARY ON THIRD DIMENSION	-
CD	KNB2	LAST BOUNDARY ON THIRD DIMENSION	-
CD	NBS	NUMBER OF BUCKLING SPECIFICATIONS	-
CD		1- SINGLE VALUE APPLIES EVERYWHERE	-
CD		.EQ.NZONE, ZONE-DEPENDENT	-
CD		N*WZONE, DATA IS GIVEN OVER ALL ZONES FOR	-
CD		THE FIRST ENERGY GROUP, THEN FOR THE NEXT	-
CD		GROUP, TO END OF LIST - IF THERE ARE NONE	-
CD		GROUPS, LAST GROUP DATA GIVEN IS USED	-
CD	NBCS	NUMBER OF CONSTANTS FOR EXTERNAL BOUNDARIES	-
CD		1- SINGLE VALUE USED EVERYWHERE	-
CD		6- INDIVIDUAL VALUES FOR EACH POSSIBLE	-
CD		SURFACE (BOUNDARY SPECS GIVE ACTUAL USE)	-
CD		N*6- SIX VALUES ARE GIVEN FOR THE FIRST	-
CD		ENERGY GROUP, THEN SIX FOR THE NEXT, TO	-
CD		THE END OF THE LIST - THE LAST GROUP DATA	-
CD		GIVEN APPLIES TO ALL ADDITIONAL GROUPS	-
CD	NIBCS	NUMBER OF CONSTANTS FOR INTERNAL BOUNDARIES	-
CD		1- SINGLE VALUES USED EVERYWHERE	-
CD		.GT.1- VALUES ARE GIVEN BY ENERGY GROUP	-
CD		WITH NON-BLACK CONDITION INDICATED BY	-
CD		ZERO ENPPY - LAST VALUE APPLIES TO	-
CD		ADDITIONAL GROUPS	-

Fig. 3. (CONTINUED)


```

CD  NZWBB      BLACK ABSORBER ZONE INDICATOR.
CD              0- NO BLACK ZONE.
CD              1- ONE BLACK ABSORBER ZONE.
CD  NTRIAG     MESH ORIENTATION
CD              0- RHOMBUS WITH 120 DEGREES AT UPPER LEFT
CD                CORNER (NPL.EQ.NPF BELOW).
CD              1- TRAPEZOID (OR TRIANGLE) WITH 60 DEGREES AT
CD                UPPER LEFT AND UPPER RIGHT CORNERS
CD                (NPL.LT.NPF).
CD              2- TRIANGLE WITH 30 DEGREES AT UPPER LEFT
CD                CORNER AND 60 DEGREES AT UPPER RIGHT
CD                CORNER (NPL.LT.NPF). INB1 AND JNB2 MUST BE 1
CD                AND NPF .GE. 3.
CD  NRASS      ZONE ASSIGNMENTS.
CD              0- TO COARSE MESH
CD              1- TO FINE MESH
CD  NGOP       NOT DEFINED.
C
C-----

```

```

C-----
CR          GEOMETRY DATA (2D RECORD)
C
CL  (BSQ(N),N=1,NBS), (BWDC(N),N=1,NBCS), (BNCI(N),N=1,NIBCS),
CL  (NZHBB(N),N=1,NZHBB), (NZC(N),N=1,NZONE)
C
CW  NBS+NBCS+NIBCS+NZHBB+NZONE
C
CD  BSQ        BUCKLING (B**2) VALUES (CH**2)
CD  BWDC       BOUNDARY CONSTANTS (DEL PHI/PHI =-C/D)
CD  BNCI       INTERNAL BLACK BOUNDARY CONSTANTS
CD  NZHBB      ZONE NUMBER WITH BLACK ABSORBER CONDITIONS
CD  NZC        ZONE CLASSIFICATIONS
C
C-----

```

```

C-----
CR          REFERENCE MESHPOINT DATA (3D RECORD)
C
CL  HPO,NPF,NPL,NRP,MNP,NRS,NOS,N03,NZA,NB,NC, (KPINTS(L),L=1,NCINTK)
C
CW  NCINTK + 11
C
CD  HPO        MZSHPOINT LOCATION OPTION
CD              0- UNIFORM, EQUILATERAL MESH ARRANGEMENT
CD                (SIMPLE GEOMETRY DESCRIBED BY DATA IN THIS
CD                RECORD, MNP=6)
CD              1- PARALLEL ROWS OF MESH POINTS
CD              2- GENERAL ARRANGEMENT
CD  NPF        NUMBER OF POINTS ALONG FIRST (TOP) ROW
CD              -- USED IF HPO = 0

```

Fig. 3. (CONTINUED)

```

CD      NPL      NUMBER OF POINTS ALONG LAST (BOTTOM) ROW      -
CD      -- USED IF NPD = 0. NPL MUST BE .EQ. OR .LT. NPP.      -
CD      FOR NPL.EQ.NPP, 120 DEGREES IS IN UPPER LEFT        -
CD      CORNER. IF NPL.LT.NPP, THE UPPER LEFT CORNER        -
CD      IS 30 OR 60 DEGREES (SEE NTRIAG ABOVE).              -
CD      NRP      NUMBER OF ROWS OF POINTS                      -
CD      -- USED IF NPD .LT. 2                                  -
CD      HNP      REFERENCE OR MAXIMUM NUMBER OF NEIGHBOR POINTS ON A -
CD      PLANE                                                 -
CD      NRS      NUMBER OF ZONE ASSIGNMENTS ON EACH PLANE     -
CD      NOS      NOT DEFINED                                   -
CD      NO3      NOT DEFINED                                   -
CD      NZA      NOT DEFINED                                   -
CD      NB       NOT DEFINED                                   -
CD      NC       NOT DEFINED                                   -
CD      NPINTS   NUMBER OF FINE MESH INTERVALS PER COARSE MESH -
CD      INTERVAL, THIRD DIMENSION                             -
C
C      MESHPOINTS HERE MAY BE INTERPRETED AS TRIANGLE CORNERS -
C
C-----

```

```

C-----
C      REFERENCE DATA (4D RECORD)                             -
C
C      CL      PMESH,QMESH,X1,X2,X3,(ZMESH(K),K=1,NCBNDK),    -
C
C      CW      MULT*(NCINTK+6)                                   -
C
CD      PMESH      LENGTH OF TRIANGLE LEG (MESHPOINT SPACING) IF FIXED -
CD      -- USED IF NPD = 0                                       -
CD      QMESH      NOT DEFINED                                   -
CD      X1         NOT DEFINED                                   -
CD      X2         NOT DEFINED                                   -
CD      X3         NOT DEFINED                                   -
CD      ZMESH      COARSE MESH BOUNDARIES, THIRD DIMENSION     -
CD      NCBNDK     NCINTK+1, NUMBER OF THIRD DIMENSION COARSE MESH -
CD      BOUNDARIES                                             -
C
C      NOTE THAT FOR TWO-DIMENSIONAL PROBLEMS, NCINTK=1, NCBNDK=2, -
C      ALTHOUGH DATA FOR THE THIRD DIMENSION ARE NOT USED (IGON=5); -
C
C-----

```

```

C-----
C      MESHPOINT ARRANGEMENTS (5D RECORD)                       -
C
C      CC      PRESENT IF NPO.EQ.1                               -
C
C      CL      (XMESH(I),I=1,NINT1),(YROW(J),J=1,NRP),(NMPR(J),J=1,NRP) -
C
C      CW      MULT*(NINT1 + NRP) + NRP                          -

```

Fig. 3. (CONTINUED)

```

C
CD    XHESH      LOCATION OF EACH MESHPOINT ON A PLANE MEASURED FROM
CD              REFERENCE ALONG X COORDINATE, CH
CD    YROW       ROW LOCATION MEASURED FROM REFERENCE ALONG Y
CD              COORDINATE (NORMAL TO X), CH
CD    NMPR       NUMBER OF MESH POINTS ON THE ROW
C
C-----

```

```

C-----
CR              MESHPOINT ARRANGEMENTS (6D RECORD)
C
CC              PRESENT IF NPO.EQ.2
C
CL              ((XYHESH(I,J),I=1,2),J=1,NINTI)
C
CW              2*NULT*NINTI
C
CD    XYHESH(1,J) LOCATION OF MESHPOINT MEASURED ALONG X COORDINATE
CD              FROM REFERENCE (INCREASING ORDER FOR ANY Y), CH
CD    XYHESH(2,J) LOCATION OF MESHPOINT MEASURED ALONG Y COORDINATE
CD              FROM REFERENCE, Y NORMAL TO X, (INCREASING), CH
C
C-----

```

THERE ARE NCINTK RECORDS WHICH FOLLOW IF NRRSS IS 0
 NINTK RECORDS WHICH FOLLOW IF NRRSS IS 1
 BUT ONLY ONE SET IF IGON IS 5

```

C-----
CR              TRIANGLE ZONE ASSIGNMENTS (7D RECORD)
C
CC              ALWAYS PRESENT
C
CL              (NR(I),I=1,NRS)
C
CW              NRS
C
CD    NR          ZONE NUMBER ASSIGNMENT TO MESH INTERVAL
C
CW              CONSIDER THAT NEAR-NEIGHBOR POINTS HAVE A LINE OF COUPLING.
CW              COUPLING LINES FORM TRIANGLES, THE TRIANGLES LYING
CW              WHOLLY BELOW A LOCAL HORIZONTAL LINE ARE ASSIGNED ZONE
CW              NUMBERS THROUGH THE MESH STARTING WITH THE FIRST (TOP)
CW              HORIZONTAL ROW, INCREASING X GIVEN Y, THEN INCREASING Y
C
C-----

```

```

C*****
C
CEOF          TRIGON
C
C*****

```

Fig. 3. (CONTINUED)

Other files that contain data by spacial mesh point have the data blocked as a given number of points on a plane. The usual interpretation of "the number of points...in each of three dimensions," L, M, and N would be a three-dimensional figure containing LMN points and relative positions simply related. In those files created and used by VALE, L is the number of points on each plane, M is 1, and N is the number of planes, so LMN is still the number of points. Other data in file TRIGOM must be used to obtain the full description of the two-dimensional mesh point arrangement. This is true of the flux data file RTFLUX, the adjoint flux ATFLUX, the fixed source FIXSRC, and the power density PWDINT.

C. System Control Requirements

The job control instructions required to execute VALE are nearly the same as for the VENTURE code and will not be repeated here. The user-supplied job control instructions are discussed in the Appendix. Note that VALE is module number 8 in the set while VENTURE is number 7.

Figure 4 shows the space requirements for the scratch I/O logical units. Generally the space for these units is specified by supplying override parameters in the job control instructions (see cataloged procedure in Ref. 2). It is not simple to define space requirements for all possible options. Therefore, values for these parameters will have to be determined and supplied, or override I/O control cards used to specify space for individual units.

D. An Input Data Processing Difficulty

The Special Processor DVENTR² was implemented to allow ready input of VENTURE data in a form convenient to the user, albeit inconvenient fixed field formats. A special advantage of this input is the generation of data for the geometry file GEODST, the cross section-nuclide concentration association file NDXSRF, and the zone density file ZNATDN. Otherwise if the data for the interface data files is supplied directly to the

Define N = Number of points on a plane.
 P = Number of planes.
 G = Number of groups.
 Z = Number of zones.
 W = Maximum scattering band width.
 D = 1 for long word computers, 2 for short word computers.
 T = 0 for two-dimensional, 1 for three-dimensional problems.
 S = 1 if criticality search, 0 if no search.
 F = 1 if fixed source problem, 0 if no fixed source.
 H = 1 if harmonic problem, 0 if fundamental.
 NB = Number of blocks, symbolic parameter, see Job Control Instructions, ref. 2.
 BS = Block size symbolic parameter.
 SEQ = Sequential file.
 DA = Direct access file.

UNIT NUMBER	TYPE	NB	BS	NUMBER OF RECORDS	RECORD LENGTH
21	SEQ	N1	B1	G plus 1 plus 2	W*Z 2*G G*Z
22,47	SEQ	NS	B1	15 plus 2 plus 7 plus 5	G*Z D*P D*G G
24,25,27,28	DA	N2	B1	G*P	D*N
26	DA	N2	B1	G*P	D*N*(S+H)
40	DA	N5	B2	G*P	D*2*N +D*2*N*T +D*N*S
41	SEQ	N4	B1	G*P	D*N*F
44	SEQ	NS	B1	G	D*Z
45	SEQ	N9	B1	G	D*2*N*T +Z
46	SEQ	N10	B1	P	D*N
48	SEQ	N1	B1	F	D*N
49	SEQ	N11	B1	P	2*N
52,54	SEQ	NS	B1	P	D*N*H

Fig. 4. Space Requirements for Scratch I/O Units.

Input Processor to take advantage of the free form format input, additional effort is normally required to generate the needed information.

The geometry file TRIGOM required by VALE must be generated with the Input Processor. The free form format input along with the flexible processing capability is especially useful to generate this file. Typically, we also supply the data for the Special Processor DVENTR to simplify the generation of other data files, using an abbreviated geometry description (slab) to produce the GEODST file that is not used, but also produced are ZNATDN, NDXSRF files, SEARCH file if desired, and the neutronics control instructions for VALE (or VENTURE!), record DTNINS and also two other records conveying core size and a problem title in the file CONTRL.

22

III. PROBLEM DEFINITION

This section presents the neutron flux, eigenvalue balance and related equations oriented toward the routine user. Some detail has been omitted since it would seem to cause confusion rather than convey useful information.

A. Discussion

This code solves the nuclear reactor neutronics problem. If there is any fixed neutron source, the neutron flux solution is a direct consequence whether or not there is any source from fission. Lacking a fixed source, there is a set of solutions each of which satisfies the equations and has a distinct eigenvalue; we normally seek that solution called the fundamental that has the most positive eigenvalue of any of the set (that is, the multiplication factor, k_{eff}), a solution that normally has all components of the neutron flux ≥ 0 representative of real conditions. The adjoint solution may be of interest which is the importance function for contributions to the multiplication. Since reactors operate at the critical state on the average, there is primary interest in this condition, $k_{eff} = 1$, so criticality search procedures to establish such a state may be of interest. Then the capability to solve for the dominant higher harmonic or importance for an arbitrary fixed source may be of interest.

The flux, eigenvalue problem is cast in matrix notation as

$$(A - \frac{1}{k} M) \phi = 0 \quad (1)$$

where A is the space coupling, energy scattering coupling, loss operator; M is the fission source, distribution operation; ϕ is the neutron flux; and k is the eigenvalue. We note the other problems solved: the adjoint problem,

$$(A^T - \frac{1}{k} M^T) \phi^* = 0, \quad (2)$$

the fixed source problem,

$$(A - M) \phi = S \quad (3)$$

and the importance problem

$$(A^T - M^T) \phi^* = S^* \quad (4)$$

Complicated solution techniques are used that are discussed elsewhere. Basically one applies an iteration procedure

$$\phi_m = B_m \phi_{m-1} \quad (5)$$

where B_m is the operator and m the outer iteration. The error may be expressed in matrix vector notation as

$$\epsilon_m = \phi_m - \phi_\infty \quad (6)$$

where ϕ_∞ is the true solution, unknown. Hopefully $\epsilon_m \rightarrow 0$ as m increases, and at termination ϵ_m is sufficiently small that the results are acceptable for the analysis task.

B. Solution Method

Problems are solved by iteration. At each energy new flux values are obtained at each space point in an inner iteration sweep. These new values are obtained from the neutron accounting equations for a discrete elemental volume given flux values at neighboring points. Acceleration techniques are applied that include the use of the latest values as they are obtained, simultaneous solution of a full row of points, overrelaxation that moves a value further in the calculated direction of change, and σ_1 ordering of the sweeps that accelerates propagation in comparison with normal ordering. Several inner iterations are done at each energy to reduce the discrepancy between the current flux estimates and the current distributed source of neutrons into this energy. Note that there is an optimum number of inner iterations in the sense of minimizing the cost of solution. With too few inner iterations, the outer iteration process

is more difficult to solve, while with too many there is waste of effort in moving the intermediate solutions toward the answer for the intermediate source.

An outer iteration consists of a full sweep over all energy (groups) involving inner iteration at each. Not only must the fission source be obtained at each location but also the inscattering source, and the multiplication factor estimated. The fission source each outer iteration is divided by the multiplication factor to force a pseudo steady state condition admitting solution. Alternatively other types of problems may be solved such as a buckling or nuclide concentration search to establish a steady state condition.

Acceleration schemes are applied to the outer iterations. For these to be generally effective, the same procedure must be used each outer iteration, such as the same number of inner iterations at one energy. This allows simple error vectors to establish that then can be eliminated by asymptotic extrapolation or be suppressed by the application of the Chebyshev polynomials on demand.

We rely on outer iteration convergence criteria to terminate the iteration process, specifically a bound on the maximum relative point flux change. At termination results are produced to test reliability of the solution and an estimate is made of the absolute error.

C. Geometry

The mesh points are arranged on an equilateral triangular grid repeated on all planes. A parallelogram need not be described. For the three-dimensional problem the planes of mesh points are located mesh centered between interfaces for the axial finite-difference formulation.

Special routines are used for each of the 120°, 60°, and 30° mesh point arrangements illustrated in Fig. 5. Of concern to the user is the requirement to describe the desired problem accurately with as few mesh

120° MESH POINT ARRANGEMENT

60° MESH POINT ARRANGEMENT

30° MESH POINT ARRANGEMENT

NOTES

1. MATERIAL REFERENCE ORDER NUMBER ASSIGNMENTS TO TRIANGLES ARE INDICATED; NOTE THE ALLOWANCE FOR TRUNCATION OF THE POINTS IN THE 60° ARRANGEMENT SO THAT AN EQUILATERAL FIGURE IS NOT NECESSARY.
2. ROTATIONAL SYMMETRY ALLOWED ABOUT MESH POINT 1 IN 120° AND 60° ARRANGEMENTS.
3. 180° ROTATIONAL SYMMETRY ABOUT THE TOP EDGE IS ALLOWED ONLY IN 60° MESH POINT ARRANGEMENT.

Fig. 5. Allowed Configurations-Mesh Points on Planes

points as necessary to obtain a reliable solution taking advantage of the available boundary conditions. Quite generally when there is 30° symmetry or repetition, it can be modeled directly as 30° at less than half the cost of representing it in a 60° section, and obviously far cheaper than as a full core. Of special utility is the repeating boundary condition. By 180° repeating boundary is meant that the two-dimensional figure may be rotated 180° and abutted to the original requiring special coupling along the top row of mesh points and materials:

By rotational symmetry about a point is meant that the given figure may be rotated clockwise and abutted to the original, or counterclockwise as well. There are few limitations in such application, but one is that there must be the same number of mesh points along the coupling lines.

D. Specific Equations

We display the finite-difference form of the equations in what follows. The two-dimensional equations are a simple subset of the three-dimensional equations with a unit axial length. These equations result from usual application of the diffusion theory approximation to neutron transport,

$$-\nabla \cdot D_g \nabla \phi_g + \Sigma_g \phi_g = S_g, \quad (7)$$

at any spacial location, where D is the diffusion coefficient and Σ is the macroscopic cross section for removal of neutrons. S is the local source,

$$S_g = \frac{1}{k} \chi_g \sum_{g^1} V \Sigma_{f,g^1} \phi_{g^1} + \sum_{g^1} \Sigma_{g^1 \rightarrow g} \phi_{g^1}, \quad (8)$$

the first term being the fission source and the last term the scattering source. With a fixed source, Eq. (8) would have such an added term and $k = 1$.

Referring to Fig. 6, a parameterized neutron balance equation can be written for a volume element on an arbitrary reference plane as

$$(IS)_g + (FS)_g + (SS)_g = [R_g + Q_g] \phi_{0,g} \quad (9)$$

with the following definitions.

$$(IS)_g = \text{IN-LEAKAGE SOURCE} = \frac{H}{T} [(\phi_{1,g} - \phi_{0,g})(E_{1,g} + E_{2,g}) + (\phi_{2,g} - \phi_{0,g})(E_{2,g} + E_{3,g}) \\ + (\phi_{3,g} - \phi_{0,g})(E_{3,g} + E_{4,g}) + (\phi_{4,g} - \phi_{0,g})(E_{4,g} + E_{5,g}) \\ + (\phi_{5,g} - \phi_{0,g})(E_{5,g} + E_{6,g}) + (\phi_{6,g} - \phi_{0,g})(E_{6,g} + E_{1,g})]$$

$$(FS)_g = \text{FISSION SOURCE} = \frac{x_g A \Delta}{k} \left(\sum_l \left\{ [(1-2\alpha)\phi_{0,l} \sum_{M=1}^6 \nu \Sigma_{f,M,l}] \right. \right. \\ \left. \left. + \alpha \left[\nu \Sigma_{f,1,l}(\phi_{6,l} + \phi_{1,l}) + \nu \Sigma_{f,2,l}(\phi_{1,l} + \phi_{2,l}) + \nu \Sigma_{f,3,l}(\phi_{2,l} + \phi_{3,l}) \right. \right. \right. \\ \left. \left. \left. + \nu \Sigma_{f,4,l}(\phi_{3,l} + \phi_{4,l}) + \nu \Sigma_{f,5,l}(\phi_{4,l} + \phi_{5,l}) + \nu \Sigma_{f,6,l}(\phi_{5,l} + \phi_{6,l}) \right] \right\} \right)$$

$$(SS)_g = \text{SCATTERING SOURCE} = A \Delta \left(\sum_l \left\{ [(1-2\alpha)\phi_{0,l} \sum_{M=1}^6 \Sigma_{S,M,l}] \right. \right. \\ \left. \left. + \alpha \left[\Sigma_{S,1,l}(\phi_{6,l} + \phi_{1,l}) + \Sigma_{S,2,l}(\phi_{1,l} + \phi_{2,l}) + \Sigma_{S,3,l}(\phi_{2,l} + \phi_{3,l}) \right. \right. \right. \\ \left. \left. \left. + \Sigma_{S,4,l}(\phi_{3,l} + \phi_{4,l}) + \Sigma_{S,5,l}(\phi_{4,l} + \phi_{5,l}) + \Sigma_{S,6,l}(\phi_{5,l} + \phi_{6,l}) \right] \right\} \right)$$

$$R_g = \text{REMOVAL LOSS} = A \Delta \sum_{M=1}^6 \Sigma_{R,M,g}$$

$$Q_g = \text{BOUNDARY LOSS} = \sum_B B_{B,g} \Delta T \phi_{B,g} + \sum_R \phi_{R,g} B_{R,g} + \sum_N \phi_{N,g} B_{N,g}$$

Fig. 6. Finite Difference Volume Element

$$L_{F,g} = \sum_{M=1}^6 \frac{A D_{M,F,g} D_{M,C,g}}{(\Delta FF) D_{M,C,g} + (\Delta F) D_{M,F,g}}, \text{ Fore Leakage Constant}$$

$$L_{A,g} = \sum_{M=1}^6 \frac{A D_{M,A,g} D_{M,C,g}}{(\Delta AA) D_{M,C,g} + (\Delta A) D_{M,A,g}}, \text{ Aft Leakage Constant}$$

$$B_{N,g} = \sum_{M=1}^6 \frac{C_{NA} D_{M,F,g}}{D_{M,F,g} + (\Delta F)(BC)}, \text{ Fore Boundary Leakage Constant}$$

$$B_{R,g} = \sum_{M=1}^6 \frac{C_{RA} D_{M,A,g}}{D_{M,A,g} + (\Delta A)(BC)}, \text{ Aft Boundary Leakage Constant}$$

$$E_{M,g} = D_{M,g} - 2\alpha A \Sigma_{R,M,g}$$

where α is the off-diagonal loss term parameter:^a

- 0 - Normal finite difference
- 1/6 - Taylor series formulation
- 7/36 - Linear flux formulation
- 1/4 - Linear finite element formulation

and the interpretation is:

- C = Boundary condition constant
- k = Multiplication factor
- χ = Fission spectrum
- ϕ = Flux
- D = Diffusion coefficient
- Σ_R = Removal cross section (absorption + out-scatter + buckling loss)
- Σ_S = Scattering cross section
- $\nu \Sigma_f$ = Neutron production, neutrons per fission times fission cross section.
- $\Delta A, \Delta AA, \Delta F, \Delta FF$: Axial mesh spacing (see Fig. 6).

^aBut at each group the value of α is limited such that $E_{M,g} > 0$ for all M, a rather severe constraint that ensures no negative flux values will be calculated.

Subscripts:

- A = Aft material (to the rear)
 B = Boundary flux for left, right, top, bottom boundaries
 R = Boundary for aft boundary
 N = Boundary for fore boundary
 C = Center material
 F = Fore material (to the front)

g or ℓ = Energy group

i=1,6 = Mesh point reference to near neighbors on the plane

M = Material

Solving Eq. (9) for $\phi_{0,g}$ gives the form used to calculate the new local flux estimate based on available iterate data for the other points:

$$\begin{aligned}
 \phi_{0,g} = & \left[\phi_{1,g}(E_{1,g} + E_{2,g}) + \phi_{2,g}(E_{2,g} + E_{3,g}) + \phi_{3,g}(E_{3,g} + E_{4,g}) \right. \\
 & + \phi_{4,g}(E_{4,g} + E_{5,g}) + \phi_{5,g}(E_{5,g} + E_{6,g}) + \phi_{6,g}(E_{6,g} + E_{1,g}) \\
 & \left. + \phi_{F,g}L_{F,g} + \phi_{A,g}L_{A,g} + (FS)_g + (SS)_g \right] / \left[R_g + Q_g + 2 \sum_{M=1}^6 E_{M,g} \right] \quad (10)
 \end{aligned}$$

E. Validation

When a new computer code applies unique equations, the developers face a major task in proving that the coding is free of major discrepancies. We claim to have done a reasonable amount of proof testing to assure a relatively high reliability of reported solutions. The solution procedures are not one-to-one with those in the VENTURE code, but enough so to allow the assumption of no gross procedural discrepancies. Fortunately the formulation for two dimensional triangular geometry allows a direct comparison of results with those generated in Germany^{5,6} and the US.⁷ The apparent error-free results obtained by extrapolating results for

two mesh point arrangements have been found to agree well with similar results produced by other codes including VENTURE. Elaborate testing has been done of the 30°, 60°, and 120° mesh point arrangements and optional boundary conditions by solving the same problem many different ways.

The analyst must of course carry responsibility for the reliability of application. He may well find that the considerable effort invested in validation and in producing reliability information to be quite valuable.

We present results for two documented benchmark problems in Tables 1 and 2 and Fig. 7 (Ref. 5 and 7). Note that the formulation of the VALE code is adequate compared to other finite-difference codes, the procedures are cost effective, and the results are reliable.

Additional results are reported here for the KFK problem. Shown below are results obtained for the formulations involving off-diagonal loss and source terms on planes with the coarsest modeling, three points per hex:

Mesh Edge Formulation	α	k_{eff}
Usual Finite Difference	0	1.012487
	1/8	1.012585
Taylor Series	1/6	1.012625
Linear Flux	7/36	1.012626
Linear Finite Element	1/4	1.012644

Although the value of k_{eff} moves away from the apparent solution without a difference error, 1.0117, as α increases, it appears that this is due to a loss in the compensation of the error and that more accurate planar solutions are obtained. This is indicated by the peak power density results shown below:

Formulation	Points per Hex	α	Relative Peak Power Density
Mesh Centered (VENTURE)	6	--	0.9953
	24	--	1.0038
	54	--	1.0051
	(∞)		1.006
Mesh Edge (VALE)	3	0	1.0113
	3	1/6	1.0089
	3	7/36	1.0086
	3	1/4	1.0079
	12	0	1.0079
	48	0	1.0073
	(∞)		1.007

A cost benefit analysis would be required to justify the extra cost of using the off-diagonal formulation in a specific application. A relatively large error with the coarse mesh representation would certainly bear special consideration. In some applications it may prove more attractive to use more mesh points (increase the mesh points per hex from 3 to 12). The contribution from the off-diagonal term goes to zero as the mesh spacing is reduced. The evidence that we have accumulated indicates that the linear finite element formulation is usually but not always superior to the others that apply a smaller value of α . The constraint that is applied to the "higher order" formulation selects the largest value of α up to the specified value that leaves a positive diagonal term (after subtracting $2\alpha\Sigma\Delta^2$) at each group by testing over the macroscopic properties of all the zones. Such a constraint is deemed to be essential, even though rather severe.

Table 1. KFK Three-Dimensional Fast Breeder Reactor Benchmark Problem Results (Four Groups)

Code	Code Source	Sector in Degrees	Mesh Points Per Hex	Mesh	Spacial Mesh Points	Outer Iterations	Inner Iterations Per Outer	Memory Used (bytes ^a)	Computer	Processor Time (min)	k_{eff}
D3E	KFK, FRG	30	3	90x19	1,710			300K	IBM 370/168	1.2	1.007256
			12	324x37	11,988			1200K	"	10.0	1.010481
			27	702x55	38,610			1100K	"	29.7	1.011139
			(Extrapolate)								1.01166
DIF3D	ANL	60	6	34x17x18	10,409	15	10	1200K	IBM 360/195	1.0	1.016630
			24	68x34x36	83,232	18	18	1900K	"	12.0	1.013038
			54	102x51x54	280,908	18	26	1900K	"	58.0	1.012317
			(Extrapolate)								1.01174
VENTURE	ORNL	60	6	34x17x18	10,404	18	4	458K	IBM 360/195	2.0	1.016660
			24	68x34x36	83,232	24	4	962K	"	14.0	1.013068
			54	102x51x54	280,908	29	5	1678K	"	62.0	1.012347
			(Extrapolate)								1.01177
VALE	ORNL	30	3	90x18	1,620	19	4	290K	IBM-3033	0.8	1.012488
			12	324x36	11,664	21	4	420K	"	4.75	1.011884
			48	1225x72	88,200	34	5,7,4,5	1450K	"	47.8	1.011766
			(Extrapolate)								1.01173
VALE ^b	$\alpha = 1/4$ $\alpha = 7/36$	30	3	90x18	1,620	20	4	290K	"	0.9	1.012644
		30	3	90x18	1,620	20	4	290K	"	0.9	1.012626

^a 4 bytes per short word, data for the VALE runs estimated (virtual memory).^b Off-diagonal loss term on planes instead of usual finite difference, with consistent source, $\alpha = 1/4$ for linear finite element, $\alpha = 7/36$ linear flux approximation.

Table 2. GA High Temperature Gas Cooled Reactor Benchmark Problem Results (Four Groups)

Code	Mesh (planar x axial)	Space Points	Outer Iterations	Processor Time (min)	Peak Power Density	k_{eff}
VENTURE ^a	38x19x8	5,776	30	1.9	1.6249	1.090687
	38x19x16	11,552	34	3.9	1.6102	1.090632
	38x19x24	17,328	34	6.1	1.5975	1.091075
	38x19x ∞				1.587	1.09143
VALE ^b	300x8	2,400	40	1.8	1.5837	1.088212
	300x16	4,800	38	3.5	1.5767	1.088012
	300x24	7,200	39	5.5	1.5668	1.088400
	300x32	9,600	43	8.0	1.5628	1.088676
	1128x32	36,096	45	23.8	1.6216	1.089370
	300x ∞				1.558	1.08903
	∞				1.636	1.0898
VALE ^c	$\alpha=1/4$ 300x16	4,800	33	3.3	1.6233	1.087444
	$\alpha=7/36$ 300x16	4,800	34	3.4	1.6129	1.087545
GATT ^d	1201x31	37,231	79	115.2		1.088504

^a IBM-3033, 60° Sector (1/6 of core).

^b IBM-3033, 60° Sector.

^c Off-diagonal loss term instead of usual finite difference, with consistent source, $\alpha = 1/4$ finite element, $\alpha = 7/36$ linear flux approximation, initialized with a cosine axial flux distribution.

^d Univac 1110, full core model, General Atomic.

Fig. 7. Plot of k_{eff} vs Mesh for Three Differencing Methods

IV. PROGRAMMING INFORMATION

This section presents information of primary use to the individual implementing this code about the subroutines, program overlay, and local adaptation.

A. Source Program

Most of the programming in this code is FORTRAN language. However, some service routines are in machine dependent IBM ASSEMBLER language. Figure 8 lists the names of some of the special subroutines and their use. The source program consists of 214 routines totaling nearly 35,000 cards.

B. Program Implementation

This code is not a stand-alone code and must be implemented in a modular environment under compatible rules.

The data used in this code is variably dimensioned and therefore the core storage requirements are a function of the problem to be solved. On the IBM-360 model computers, the program plus system routines require approximately 100,000 words of core storage when the code is loaded with the recommended overlay structure shown in Fig. 9. The core storage for data is supplied by the user at run time. Depending upon the amount of storage available for data, the user chooses one of two modes of data storage. Information about disk storage requirements is included in the printout of each run.

C. Conversion to Other Computers

On an IBM machine, much of the calculation is done in double precision and certain data carried as long words. On long-word machines, this data should be carried as regular length and the associated double precision operations changed to single precision. This change is essential

DOPC INITIALIZES, OPENS, AND CLOSES DATA FILES
 ENTRY ROXY COMMUNICATES DATA ARRAYS
 CALLS SEEK, RITE, DEFILE, CLOSDA

RITE DATA TRANSFER MANAGER AND WRITES DATA (FORTRAN WRITE) -
 CALLED BY HOST ROUTINES
 ENTRY REED READS DATA (FORTRAN READ) - CALLED BY HOST
 ROUTINES
 ENTRY ROXX COMMUNICATES DATA ARRAYS
 CALLS CRIT, CRED

SEEK INTERFACE DATA FILES MANAGER
 CALLS RITE, REED

CRIT ASSEMBLY LANGUAGE ROUTINE FOR CORE TO CORE DATA TRANSFER
 ENTRY CRED CORE TO CORE DATA TRANSFER

GETCOR ASSEMBLY LANGUAGE ROUTINE TO ALLOCATE CORE DYNAMICALLY FOR
 THE VARIABLY DIMENSIONED ARRAYS AT RUN TIME

PRECOR ASSEMBLY LANGUAGE ROUTINE TO FREE CORE ALLOCATED BY GETCOR

DEFILE ASSEMBLY LANGUAGE ROUTINE TO EXECUTE THE FORTRAN DEFINE FILE
 STATEMENT USING PROBLEM DEPENDENT VARIABLES (OPENS DIRECT
 ACCESS FILES) - ACCESSES SYSTEM ROUTINE INCEDIOS

CLOSDA ASSEMBLY LANGUAGE ROUTINE TO CLOSE DIRECT ACCESS FILES

Fig. 8. The Role of Special Subroutines.

THE FOLLOWING LISTS THE SUBROUTINES IN THE RECOMMENDED FOUR LEVELS OF OVERLAY, A, B, C, AND D. IN ADDITION THE FOLLOWING ROUTINES ARE IN THE ROOT SEGMENT.

MAIN, IONO, VENT, DRIV, DIFF, APLY, A122, PFGG, MROD, TIME, FERR, SKER, KEEP, RITE, SEEK, DOPC, CRIT, STOR, PRTH, PRTI, PRTR, PRIT, SERH, CHPH, CHPI, PRC2, PRC3, PRC4, PRC5, PRC6, PRC7, THER, GETCOR, PRECOR, DEFILE, CLODA

OVERLAY LEVELA

INSERT SGX0,SGX1,SGX2,SGX3,SCAL

OVERLAY LEVELA

INSERT CORE,CORI,CORP,CORD,CORB,DASU,DDSP

OVERLAY LEVELA

INSERT HAC1,VZT2,HACA,HACB,HAC2,HAC3,HAC5,CHDM,HAC4,HAC6

INSERT ADM1,ADM2,ADM3,DCID

OVERLAY LEVELA

INSERT CON1,NEW1,NEW2,CON2,CON3,MSH3,CKCT,NEW3

OVERLAY LEVELA

INSERT LIZE,LIZ1,LUCK,LIZ2,RCOV

OVERLAY LEVELA

INSERT INUX,INU1,INU2

OVERLAY LEVELA

INSERT COMC,PROS,ZIO3,RDSC,REV1,RSIG,RWR4,RWR8,RGFF,BSQV,FXSR,FSBP

INSERT CMST,PRC1,SP2X,PEPS,COER,IFTD,TWOS,HST2

OVERLAY LEVELB

INSERT T121,T122,T123,T601,T602,T603,T001,T302,T303

OVERLAY LEVELB

INSERT B121,B122,B123,B601,B602,B603,B301,B302,B303,DCON,DELZ,CYMC

INSERT ZRDC,ZRNC,ZQDC,DWHP

OVERLAY LEVELA

INSERT OUTR,CHBF,XTRP,JUSB,ATED,BHAV,NEWS,CHEV,OELK,RDUE,RELI,ZINS

INSERT PSOR,SSOR,FLUX,PS2D,SS2D,AJPS,AJSS,AJFP,FBAE,RLBL,HOPS,SGDA

INSERT D2SF,SPJA,FPJA,D2SS,SSJA

OVERLAY LEVELB

INSERT DOIN,MUEX,ETR1,ETR2

OVERLAY LEVELB

INSERT K121,K122,K123,H121,H122,H123

OVERLAY LEVELB

Fig. 9. Recommended Overlay Structure.


```
INSERT KTR1,KTR2,KTR3,HTR1,HTR2,HTR3
OVERLAY LEVELB
INSERT J121,J122,J123
OVERLAY LEVELB
INSERT JTR1,JTR2,JTR3
OVERLAY LEVELB
INSERT CRPS,SPRC
OVERLAY LEVELB
INSERT S121,S122,S123
OVERLAY LEVELB
INSERT STR1,STR2,STR3
OVERLAY LEVELB
INSERT HS21,HS22,HS23
OVERLAY LEVELB
INSERT HSR1,HSR2,HSR3
OVERLAY LEVELC
INSERT INSP,INPL,ADSR,ADPA
OVERLAY LEVELD
INSERT I121,I122,I123
OVERLAY LEVELD
INSERT I601,I602,I603
OVERLAY LEVELD
INSERT I301,I302,I303
OVERLAY LEVELA
INSERT EDIT,PBAR
OVERLAY LEVELB
INSERT MBAL,PFCR,SOBL,WZPD
OVERLAY LEVELB
INSERT RZFL,POUT,AOJT
OVERLAY LEVELB
INSERT PDPA,PDP1,PDP2,PDP3,PDP4,PDP5,PDP6,PDEM,WRC1,WRC2,WRC3,WRC4
INSERT WRC5,WRC6,WRC7
```

Fig. 9. (CONTINUED)

to minimize storage requirements. Alphanumeric characters are carried in the guise of real numbers (Hollerith) as A(6) requiring long-word storage on an IBM machine.

As a convenience for conversion to a long word computer, a multiplier is carried through the routines, MULT or NDP or LX(39), which must be 2 for an IBM machine and 1 for long-word machines. This multiplier adjusts the lengths of words for short-word storage and manipulations avoiding extensive reprogramming upon conversion.

The following changes are required for use on a long-word machine and should be done with a FORTRAN source deck processor:

1. Delete all REAL*8 statements.
2. Change library function references from double to single precision, e.g., SQRT and EXP instead of DSQRT and DEXP.
3. Change all references to "Double Precision," as in function definition statements.
4. Change the apostrophes which delimit alphanumeric strings in FORMAT and DATA statements.

Further requirements include:

1. Change LX(39) to 1 from 2.
2. Replace the subroutine TIMER to provide information from the local system,
 - ICLOCK -- gives cpu time
 - ITIME -- gives clock time
 - MODEL -- gives computer model
 - IDAY -- gives alphanumeric: Month-Day-Year
 - JSTIME -- gives cpu time remaining
 - JOBNUM -- gives alphanumeric: Job number
 - IOLEFT -- gives the number of I/O's remaining
 - TIME -- gives alphanumeric: time of day

3. Satisfy the data access, transfer requirements including the dynamic opening of the files with parameters which are problem dependent and selective default of files to be resident by replacing the data handling service routines.
4. Provide local capability to allocate memory at run time, or fix the allocations for container arrays and communication.
5. Provide an equivalent program overlay structure.

Local system routines would be needed to satisfy items 2, 3, and 4 immediately above unless those supplied are compatible.

Note that the assembly language routines can only be used on compatible IBM machines (otherwise use the Fortran source decks). You must correct any discrepancies missed by the IBM compiler, and please report this information back to us.

The code is used locally as a module of a computation system. Effecting stand alone capability should not be hard using those modules needed including input data processing capability. It should be most attractive to implement an equivalent modular system, either one-to-one with that in use at ORNL, or adapt the modules into another system.

In converting this code, consideration should be given to data storage and transfer requirements. If large problems are to be solved, even a large extended core cannot contain a set of the flux values, so they must be carried on disc.

D. Limitations

Certain features of the standard interface data file specifications imply capability which is not available. Only the geometry options described herein are available. Quite generally, it has been assumed that the data is simply blocked in the files. No provision has been made to account for partially filled records, for example. At this time the other modules in this system can not process the geometry file TRIGOM and capability that would require this (perturbation, local exposure) is not available.

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This work was done for the Physics Section of the Reactor Research and Technology Division of USDOE in the Simulation and Evaluation of Energy Systems Section of the Engineering Physics Division of ORNL under C. R. Weisbin. We note that lengthy discussions were held about methods with a number of individuals at several installations having varied experience and various viewpoints in an open atmosphere that directly influenced this product.

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APPENDIX: SAMPLE PROBLEM

The simple four group, three-dimensional problem used as a sample⁵ here was selected from the set we have treated primarily from convenience considerations. In what follows is a brief description of the problem. The input stream with job control information is shown in Fig. A1 and the computer printout showing results is presented as Fig. A2.

The problem is a three-dimensional model of a liquified metal cooled fast breeder reactor core. It treats only a 30° sector. The instructions to the control module cause the use of the Input Processor and the Special Processors for converting input data to interface files and the nuclide ordered cross sections of ISOTXS to the group ordered from GRUPXS. The printout from the computer follows the data processing and computational flow documenting the use of solution procedures and presenting results.

The first printout file is a condensed edit. Information is printed by the control module, first about the instructions it has received, then the module accesses, and finally a wrap-up showing the status of the interface data files. As each code is executed, it prints a limited amount of information in this file. Thus the file is a condensed history of the calculation. Note that the VALE code printed information about the iterative neutronics problem, the peak power density and the multiplication factor. Such auxiliary information as the primitive conversion ratio that would normally be printed is not available because macroscopic cross sections were used for benchmarking (pseudo microscopic).

We note that this three-dimensional problem requires less than two minutes IBM 3033 computer processor time to compute the regular and adjoint fluxes.

The problem is solved in the mode where all of the data for one group over space is stored in memory. The automated capability for defaulting scratch data files to memory when space allows is used for the first two files, the ones of most importance regarding the amount of use.

Point flux values are initially set equal over space and energy. Four inner iterations are used each outer iteration and preferred over-relaxation coefficients are calculated after a delay to propagate boundary conditions. Chebyshev acceleration is not used on outer iteration, but the dominant error vector is removed by asymptotic extrapolation accelerating convergence. The acceptable convergence level for termination is 5×10^{-5} maximum relative flux change on outer iteration. The dominant outer iteration error vector for the regular flux problem appears to play no significant role in the iterative solution, the error vector removed by extrapolation having an eigenvalue of only 0.61. After termination, an additional sweep of the equations produces the reliability data about the solution showing seven digit agreement between two independent estimates of the multiplication factor. Computer time is displayed with a breakdown into major computational tasks.

The neutron balance is printed on option. Special auxiliary calculations are always done to produce zone average and peak zone power densities, and maps are produced on option. Finally the adjoint problem in the reactivity sense is solved and related information printed.

```
//USERID JOB (CHARG),'USER ADDRESS',MSGLEVEL=(1,1)
//STEP EXEC BOLDVENT,
// NB1=1,NB2=1,B1=3520,B2=32000,N1=50,N5=50,N1=100,
// N2=20,N3=10,N4=10,N5=10,N6=10,N7=10,N8=10,N9=10,N10=10,N11=10,
// N12=20,N13=10,N14=10,N15=10,N16=20,
// GOSIZE=500K
//GO.SYSIN DD *
```

```
=CONTROL1
      VALE RUN OF KFK LHPBR BENCHMARK PROBLEM.
41000                                0
1 2 6 2 8 0
END
```

INPUT PROCESSOR DATA FOLLOWS.

```
0V TRIGON
1D
$ IGON $ 19
$ NZONE $ 6
$ NREG,NZCL,NCINTI,NCINTJ $ 0 0 0 0
$ NCINTK $ 4
$ POINTS $ 90
$ NINTJ,NINTK $ 0 18
$ LRTBFB $ 1 2 1 1 2 2
$ NBS $ 0
$ NBCS $ 1
$ NIBCS $ 1
$ NZWBB $ 0
$ WTRIAG $ 2
$ NRASS,NGOP $ 1 0 0 0 0 0
2D
$ BSQ(NBS) $
$ BWDC(NBCS) $ 0.4692
$ BWCI(NIBCS) $ 0.4692
$ NZHBB $
$ NZC(NZONE) $ 0 6R
3D
$ NPO $ 0
$ NPP $ 18
$ NPL $ 2
$ NRP $ 9
$ NWP $ 6
$ NRS $ 153
$ NOS,N03,NZA,NB,NC $ 0 0 0 0 0
$ KPINTS $ 4 5 5 4
4D
$ PMESH $ 6.4665
$ QMESH,X1,X2,X3 $ 0.0 4R
$ ZMESH $ 0.0 40.0 87.5 135.0 175.0
7D $ NR(NRS) $
4 16R 4 9R 3 8R
4 13R 5 3R 4 6R 3 7R
4 1R 5 3R 4 6R 5 3R 4 6R 3 6R
5 1R 4 6R 4 6R 3 8R
4 1R 4 9R 3 7R
```

Fig. A1. Input Data for Sample Problem.


```

      4 7R 3 6R
      4 1R 3 8R
      3 5R
      3 1R
7D 153S
7D 153S
7D 153S
7D
      1 16R 2 9R 3 8R
      1 13R 5 3R 2 6R 3 7R
      1 1R 6 3R 1 6R 5 3R 2 6R 3 6R
      6 1R 1 6R 2 6R 3 8R
      1 1R 2 9R 3 7R
      2 7R 3 6R
      2 1R 3 8R
      3 5R
      3 1R
7D 153S
7D 153S
7D 153S
7D 153S
7D
      1 16R 2 9R 3 8R
      1 13R 6 3R 2 6R 3 7R
      1 1R 6 3R 1 6R 6 3R 2 6R 3 6R
      6 1R 1 6R 2 6R 3 8R
      1 1R 2 9R 3 7R
      2 7R 3 6R
      2 1R 3 8R
      3 5R
      3 1R
7D 153S
7D 153S
7D 153S
7D 153S
7D
      4 16R 4 9R 3 8R
      4 13R 6 3R 4 6R 3 7R
      4 1R 6 3R 4 6R 6 3R 4 6R 3 6R
      6 1R 4 6R 4 6R 3 8R
      4 1R 4 9R 3 7R
      4 7R 3 6R
      4 1R 3 8R
      3 5R
      3 1R
7D 153S
7D 153S
7D 153S
0V ISOTXS
1D
$NGROUPS 4
$NISO 6
$NAXUP 0
$NAXDW 3
$NAXORDS 0
$NICHISTS 1
$NSCHAXS 1
$NSBLOKS 1

```

Fig. A1. (CONTINUED)

```

2D
$HSETIDS
* KFK LAYER BENCHMARK CROSS SECTIONS
$HISONH$ *H1 * *H2 * *H3 * *H4 * *H5 * *H6
$CHI $ 0.768 0.232 0.0 0.0
$VEL $ 1.7234E+9 4.0246E+8 7.9700E+7 3.1594E+7
$EMAX $ 1.05E+7 8.0E+5 1.0E+4 1.0E+3
$EMIN $ 1.0E-4
$LOCA $ 0 3 6 9 12 15

4D
$HABSID, HIDENT, HNATS *H1 * *KFKINR* *INCORE*
$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
$KBR, ICHI, IALP, INP, IN2N, IND, INT$ 1 0 1 0 5R
$LTOT, LTRN, ISTRPD, IDSCT, LORDS 1 1 0 0 1
$JBAND, IJJ$ 1 2 3 4 1 4R

5D
$STRPL-H1$ 0.11587 0.21220 0.46137 0.34571
$STOTPL-H1$ 0.0 0.0 0.0 0.0
$SNGAN-H1$ 0.690577E-3 0.1830758E-2 0.92948E-2 0.173045E-1
$SPIS-H1$ 0.39123E-2 0.18286E-2 0.36334E-2 0.92415E-2
$SNUTOT-H1$ 3.03607 2.91217 2.88187 2.87951

7D
$SCAT-H1 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4$
0.0
0.0 0.23597E-1
0.0 0.16153E-2 0.40791E-5
0.0 0.46838E-2 0.42309E-7 0.44493E-7

4D
$HABSID, HIDENT, HNATS *H2 * *KFKINR* *OTCORE*
$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
$KBR, ICHI, IALP, INP, IN2N, IND, INT$ 1 0 1 0 5R
$LTOT, LTRN, ISTRPD, IDSCT, LORDS 1 1 0 0 1
$JBAND, IJJ$ 1 2 3 4 1 4R

5D
$STRPL-H2$ 0.11588 0.21213 0.46770 0.35349
$STOTPL-H2$ 0.0 0.0 0.0 0.0
$SNGAN-H2$ 0.662205E-3 0.1839559E-2 0.100354E-1 0.20476E-1
$SPIS-H2$ 0.48531E-2 0.26377E-2 0.51332E-2 0.13238E-1
$SNUTOT-H2$ 3.07906 2.91492 2.88494 2.88253

7D
$SCAT-H2 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4$
0.0
0.0 0.23262E-1
0.0 0.15718E-2 0.46451E-5
0.0 0.43414E-2 0.40724E-7 0.49968E-7

4D
$HABSID, HIDENT, HNATS *H3 * *KFKINR* *RADBLK*
$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
$KBR, ICHI, IALP, INP, IN2N, IND, INT$ 2 0 1 0 5R
$LTOT, LTRN, ISTRPD, IDSCT, LORDS 1 0 0 1
$JBAND, IJJ$ 1 2 3 4 1 4R

5D
$STRPL-H3$ 0.14584 0.28443 0.52703 0.40732
$STOTPL-H3$ 0.0 0.0 0.0 0.0
$SNGAN-H3$ 0.1115267E-2 0.3063463E-2 0.1002116E-1 0.1299948E-1
$SPIS-H3$ 0.27688E-2 0.44347E-4 0.12274E-3 0.34952E-3
$SNUTOT-H3$ 2.79641 2.44098 2.42317 2.42295

```

Fig. A1. (CONTINUED)

7D

\$SCAT-H3 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4\$
 0.0
 0.0 0.32071E-1
 0.0 0.27776E-2 0.38880E-5
 0.0 0.58971E-2 0.90018E-7 0.45039E-7

4D

\$HABSID, HIDENT, HNATS *H4 * *KPKINR* *AXIBLK*
 \$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
 \$KBR, ICHI, IALP, INP, IN2W, IND, INT\$ 2 0 1 0 5R
 \$LTOT, LTRW, ISTRPD, IDSCT, LORD\$ 1 1 0 0 1
 \$JBAND, IJJS 1 2 3 4 1 4R

5D

\$STRPL-H4\$ 0.12270 0.23133 0.46274 0.33749
 \$STOTPL-H4\$ 0.0 0.0 0.0 0.0
 \$SNGAN-H4\$ 0.82277E-3 0.2170873E-2 0.7640834E-2 0.971851E-2
 \$SFIS-H4\$ 0.19453E-2 0.31065E-4 0.87566E-4 0.23769E-3
 \$SNUTOT-H4\$ 2.79026 2.44188 2.42309 2.42299

7D

\$SCAT-H4 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4\$
 0.0
 0.0 0.26322E-1
 0.0 0.22889E-2 0.28907E-5
 0.0 0.53536E-2 0.62133E-7 0.33248E-7

4D

\$HABSID, HIDENT, HNATS *H5 * *KPKINR* *ABSREG*
 \$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
 \$KBR, ICHI, IALP, INP, IN2W, IND, INT\$ 7 0 1 0 5R
 \$LTOT, LTRW, ISTRPD, IDSCT, LORD\$ 1 1 0 0 1
 \$JBAND, IJJS 1 2 3 4 1 4R

5D

\$STRPL-H5\$ 0.13317 0.25355 0.58044 0.54168
 \$STOTPL-H5\$ 0.0 0.0 0.0 0.0
 \$SNGAN-H5\$ 0.1866958E-2 0.126433E-1 0.634405E-1 0.16868
 \$SFIS-H5\$ 0.0 0.0 0.0 0.0
 \$SNUTOT-H5\$ 0.0 0.0 0.0 0.0

7D

\$SCAT-H5 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4\$
 0.0
 0.0 0.22946E-1
 0.0 0.37687E-2 0.10320E-5
 0.0 0.86815E-2 0.70361E-11 0.10489E-7

4D

\$HABSID, HIDENT, HNATS *H6 * *KPKINR* *POLREG*
 \$HASS, EPISS, ECAPT, TEMP, SIGPOI, ADENSS 0.0 6R
 \$KBR, ICHI, IALP, INP, IN2W, IND, INT\$ 7 0 1 0 5R
 \$LTOT, LTRW, ISTRPD, IDSCT, LORD\$ 1 1 0 0 1
 \$JBAND, IJJS 1 2 3 4 1 4R

5D

\$STRPL-H6\$ 0.72206E-1 0.11487 0.32642 0.19272
 \$STOTPL-H6\$ 0.0 0.0 0.0 0.0
 \$SNGAN-H6\$ 0.216305E-3 0.168800E-3 0.11468E-2 0.78660E-3
 \$SFIS-H6\$ 0.0 0.0 0.0 0.0
 \$SNUTOT-H6\$ 0.0 0.0 0.0 0.0

```

7D
$SCAT-H6 1-1, 2-2 1-2, 3-3 2-3 1-3, 4-4 3-4 2-4 1-4$
0.0
0.0 0.12942E-1
0.0 0.12871E-2 0.68780E-6
0.0 0.34533E-2 0.43633E-11 0.69903E-8
STOP
END

DCRSPR
1
END

DVENTR
001
0.0
0.0
0.0
:
1 1 0 1 0 0 0 0 0 0 2 1 0 0 1 1 0 0 0 0 0 0 0
002
0
0
0
0.0 0.25
0.0
003
1 1 1
004
1 67945.36 1 72245.70 1 171108.2 1 118055.6 1 11678.82 1 16839.22
0
005
1 2 3 4 5 6
012
0
1 6 1 0 0.0

013
6
6
H1 H2 H3 H4 H5 H6
020
1 1
H1 1.0
2 2
H2 1.0
3 3
H3 1.0
4 4
H4 1.0
5 5
H5 1.0
6 6
H6 1.0
0
END
/*
//

```

Fig. A1. (CONTINUED)

SOLD VENTURE VMS-4 MSB OF THE IIR-762/000. CONTROL 900-CONTROL 1, DATE-05-13-01, TIME-11.14.26, JOBNAME-TSTFALL .
INITIALIZATION, REFERENCE - TERMINAL I/O= 9.99, CPU MIN= 3.10

```

RUN TITLE AND CONTROL MODULE DATA
FILE RUN OF SPE INPUT SEARCHING PROBLEM.
4000      0      0      0      0      0      0      0      0      0      0
   1 2 6 2 8

```

INITIAL I/O FILE MANAGEMENT TABULAR						
FILE BASE SUPPLIED BY						
FILE NUMBER	SEARCH	USER-EXIST	USER-STRCH	VERSION	WRITTEN	USER IDENTIFICATION
10	CONTROL			1	1	TOPFALE 05-13-01

TOUWLYS TO BE ACCESSED IN ORDER
1 2 6 2 4

READ DATA AND ACCESS NUMBER 1	- PENDING I/O	9.97, CPU #10	3.18
READ DATA FOR A SPECIAL PROCESSOR	- PENDING I/O	9.91, CPU #10	3.16
ACCESS PROC 'SSOR 'DCDSR'	- PENDING I/O	9.90, CPU #10	3.16
READ INPUT DATA ONLY (LOOK-AHEAD)	- PENDING I/O	9.88, CPU #10	3.15
ACCESS MODULES 6 0 0 0 0	- PENDING I/O	9.87, CPU #10	3.15
ACCESS PROCESSOR 'DVENT'	- PENDING I/O	9.81, CPU #10	3.10

```

ACCESS MODULES 0 0 0 0 3 - BEHAVIOR: I/O= 9.30, CPU MIN= 3.11
ITERATIONS, CONVERGENCE, SPACE, PEAK PORT DENSITY, K = 14 -0.649400-05 0.0 1.32199E-16 1.0124075
PRIMITIVE CONVERSION PATT, ALSO FOR CRITICAL SYSTEM, PHEL COMPRESSION (ATONS/WATT-SBC) - 0.26149 0.20163 0.0
ADJOINT - ITERATIONS, CONVERGENCE, K = 18 -0.666050-05 1.0124074

```

PIML I/O FILE MANAGEMENT TABLES						
FILE NAME SUPPLIED BY						
FILE NUMBER	SERK	USER-EXIST	USER-STACK	VERSION	UNIT/TYPE	USER
						IDENTIFICATION
10	CONTROL			1	1	TEMPFILE 05-13-01
11	TRIGON			1	1	TEMPFILE 05-13-01
12	ISOTRY			1	1	TEMPFILE 05-13-01
13	GROUP15			1	1	GROUP 15 ADE
14	GROUP57			1	1	TEMPFILE 05-13-01
15	HUXSRP			1	1	TEMPFILE 05-13-01
16	ZKATDO			1	1	TEMPFILE 05-13-01
17	DTPLDY			1	1	TEMPFILE 05-13-01
18	ATTLOI			1	1	TEMPFILE 05-13-01

WRAP-UP NOT COMPLETE. -- DRIVEN TO SETK NEW CASE - REMAINING I/O= 7.54, CPU HIR= 1.33 - TIME=16.06.40

DVENTP - SPECIAL INPUT MODULE - JANUARY 17, 1979 - QUALITY ASSURANCE LEVEL 0

CASE TITLE - VALB RUN OF EYE L97BN BENCHMARK PROBLEM.

[illegible]

INPUT SECTION 1

INSTR SWITCH 2																	
YXX	0.0			0.0					0.0				0.0				
YYX	0.0			0.0					0.0				0.0				
XYY	0.0			0.0					0.0				0.0				
IXC	1	0	0	1	0	0	0	0	0	0	25	0	0	0	0	0	0
IYC	1	1	0	1	0	0	0	0	0	2	1	0	0	1	1	0	0
ICY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XYX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IXY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PXXX	0.0			2.500000E-01					0.0				0.0				
XXXX	0.0			0.0					0.0				0.0				

DTNINS RECORD ADDED TO FILE CONTAL

Fig. A2. Selected Output from Sample Problem.

INPUT SECTION 3

```

1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0
SECRETRY NO. 1 1-D SLAB
BSQ 0.0
IYDZ 1
BDC 0.0 0.0 9.999999E 29 9.999999E 29 9.999999E 29 9.999999E 29
BDEI 0.692000E-01

```

INPUT SECTION 4

```

MEMOY REQUIRED 990
YSLJ/YSLJ 1 1.000000E 00 1 1.000000E 00 1 1.000000E 00 1 1.000000E 00 1 1.000000E 00 1 1.000000E 00
YSLJ/YSLJ 1 1.000000E 00
YSLJ/YSLJ 1 1.000000E 00
YSLJ/YSLJ 1 1.000000E 00
YSLJ 0.0 1.000000E 00 2.000000E 00 3.000000E 00 4.000000E 00 5.000000E 00 6.000000E 00
YSLJ 0.0 1.000000E 00
YSLJ 0.0 1.000000E 00

SECRETRY NO. 1
J/IX 1 0.0 2 1.0000 3 2.0000 4 3.0000 5 4.0000 6 5.0000 7 6.0000
I/IX 1 0.0 2 1.0000
K/IX 1 0.0 2 1.0000
I/I 1 0.5000 2 1.5000 3 2.5000 4 3.5000 5 4.5000 6 5.5000
I/I 1 0.5000

KB/I 1 0.5000
MEMOY REQUIRED 990

```

INPUT SECTION 5

ZONE INPUT BY REGION

```

LAYER NUMBER 1
1 2 3 4 5 6

```

INPUT SECTION 12

```

YSL 0
1 6 1 0 0.0
0 1 0 0 0.0

REGION VOL SUR 6.000000E 00 TOMB VOL SUR 6.000000E 00
MEMOY REQUIRED 1052
INTERFAC FILE GEODST HAS BEEN WRITTEN ON UNIT 14

```

INPUT SECTION 13

```

YSL 6
MEMOY REQUIRED 1212
TITLE FROM CROSS SECTION FILE / KTK INPDR BENCHMARK CROSS SECTIONS
NEX(1) 6 FOR SET 1
Y1 Y2 Y3 Y4 Y5 Y6

```

INPUT SECTION 20

```

VCPD 0 NCVS 0 TIMES 0.0

1 1
Y1 1.000000E 00 0.0 0.0 0.0
2 2
Y2 1.000000E 00 0.0 0.0 0.0
3 3
Y3 1.000000E 00 0.0 0.0 0.0
4 4
Y4 1.000000E 00 0.0 0.0 0.0
5 5
Y5 1.000000E 00 0.0 0.0 0.0
6 6
Y6 1.000000E 00 0.0 0.0 0.0
0 0

```

INTERFAC FILE MDISRT HAS BEEN WRITTEN ON UNIT 15

Fig. A2. (CONTINUED)

VALR - NEUTRONICS MODEL - VERSION 1 - JANUARY 1, 1979 - QUALITY ASSURANCE LEVEL 0

Q08 TITLE - VALR Q08 OF SPE L9P99 BENCHMARK PROBLEM.

STORAGE REQUIRED FOR CROSS SECTION CHECK 120 WORDS

TITLE OF THE LATEST VERSION CROSS SECTION FILE
SPE L9P99 BENCHMARK CROSS SECTIONS

CROSS SECTION CHECK COMPLETED NORMALLY

REFERENCE REAL TIME FROM I9AT99 INTERFACE FILE = 0.0 DAYS

SOLUTION BY FINITE-DIFFERENCE DIFFUSION THEORY
TICETVALUE PROBLEM
A REGULAR ADJOINT WILL FOLLOW FORWARD PROBLEM
TECHNIQUE NUMBER 19 SPECIAL TRIANGULAR-2, THREE-DIMENSIONAL
TRIANGULAR OPTION 2 30 DEGREES
NUMBER OF ENERGY GROUPS 8
NUMBER OF UPSCATTER GROUPS (HAY) 0
NUMBER OF DOWNSCATTER GROUPS (HAY) 3
NUMBER OF POINTS ON EACH PLANE 90
NUMBER OF ROWS OF POINTS ON EACH PLANE 9
NUMBER OF POINTS ON FIRST (TOP) ROW 18
NUMBER OF POINTS ON LAST (BOTTOM) ROW 2
NUMBER OF INTERVALS IN DIMENSION 3 (PLANES) 18
NUMBER OF ZONES 6
NUMBER OF BLACK ANSWERED ZONES 0
BOUNDARY INDICATORS- LEFT 1 RIGHT 2
TOP 1 BOTTOM 1
FRONT 2 REAR 2

MEMORY REQUIREMENTS FOR DATA STORAGE

	WORDS
STORAGE AVAILABLE	41000
MACRO CALCULATION	282
EQUATION CONSTANTS CALCULATION	714
INITIAL FLUX	384
ITERATIVE PROCESS SPACE STORED MODE	24512
ITERATIVE PROCESS PLANE STORED MODE	7232

DATA WILL BE STORED FOR 1 GROUP AND 18 PLANES FOR THE SPACE STORED MODE (24512)

MEMORY LOCATIONS RESERVED FOR DATA STORAGE---	41000
MAX MEMORY LOCATIONS REQUIRED FOR THIS PROB---	24512
MEMORY LOCATIONS NOT USED-----	16488

THE ARRAY SIZES FOR STORING SCRATCH I/O DATA FILES IN MEMORY ARE AS FOLLOWS

UNIT	DATA STORED	WORDS
49	POINT COMPOSITION NUMBERS-----	27051
25	WUSIG BY POINT-----	40815
24	FLUX-----	53777
27	FLUX-----	66738
28	FLUX-----	79699
40	TOT. LOSS, COMPLYING, SRECH. LOSS-	131540

SPECIAL SCRATCH DATASET REQUIREMENTS MAXIMUM PHYSICAL RECORD IS 7200 WORDS

FILE	CONTAINER	ARRAYS	CONTROL	88 DATA	16390									
FILE 49	DEFAULTS TO CORE - NO. RECS,	REC. LETH,	TOT. LETH,	START LOC,	CORE LEFT.	18	180	3240	1	13150				
FILE 25	DEFAULTS TO CORE - NO. RECS,	REC. LETH,	TOT. LETH,	START LOC,	CORE LEFT.	72	180	12960	3241	190				
DIRECT ACCESS FILE 24	REQUIRES	4 RECORDS	3240 WORDS IN LENGTH											
DIRECT ACCESS FILE 27	REQUIRES	4 RECORDS	3240 WORDS IN LENGTH											
DIRECT ACCESS FILE 28	REQUIRES	4 RECORDS	3240 WORDS IN LENGTH											
DIRECT ACCESS FILE 40	REQUIRES	4 RECORDS	12960 WORDS IN LENGTH											

DD PARAMETERS FOLLOW FOR B1 = 3520 AND B2 = 32000

Q2= 19 Q3= 19 Q4= 10 Q5= 4 Q6= 10 Q7= 3 Q8= 3 Q9= 1 Q10= 5 Q11= 2 Q12= 10 Q13= 10 Q14= 10 Q15= 10
Q16= 19

FOR THE ASSIGNED DATA STORAGE, THE REQUIRED REGION SIZE IS APPROXIMATELY 644K BYTES

***** (WATT.SEC/PISS) AND (WATT.TEC/CAPT) ARE ZERO ON GROUPS - DEFAULTING TO 3.2E-11

Fig. A2. (CONTINUED)

PRINCIPAL RADIOGRAPHIC CROSS SECTIONS

GROUP 1

ZONE	D	SIGA	SIGDP	SIGDP	SEARCH SIGA	SEARCH SIGDP
1	2.274787E-00	4.602872E-03	1.187800E-02	1.251925E-13	0.0	0.0
2	2.274539E-00	5.515300E-03	1.490297E-02	1.552991E-13	0.0	0.0
3	2.285409E-00	3.800465E-03	7.702696E-03	8.860150E-14	0.0	0.0
4	2.714653E-00	2.768076E-03	5.027806E-03	6.224952E-14	0.0	0.0
5	2.503067E-00	1.066957E-03	0.0	0.0	0.0	0.0
6	4.616424E-00	2.163049E-04	0.0	0.0	0.0	0.0

ZONE	FISSILE SIGA	FF FTLLE SIGMG	SIGMG	SIGP
1	4.602872E-03	0.0	6.905769E-04	3.912296E-03
2	5.515300E-03	0.0	6.622048E-04	4.853096E-03
3	0.0	1.115246E-03	1.115246E-03	2.768799E-03
4	0.0	8.227767E-04	8.227767E-04	1.945299E-03
5	0.0	0.0	1.066957E-03	0.0
6	0.0	0.0	2.163049E-04	0.0

GROUP 2

ZONE	D	SIGA	SIGDP	SIGDP	SEARCH SIGA	SEARCH SIGDP
1	1.570845E-00	3.659356E-03	5.325187E-03	5.81515E-14	0.0	0.0
2	1.571363E-00	4.477255E-03	7.680679E-03	8.440633E-14	0.0	0.0
3	1.171930E-00	3.107809E-03	1.002501E-04	1.419103E-15	0.0	0.0
4	1.440943E-00	2.201937E-03	7.585495E-05	9.940796E-16	0.0	0.0
5	1.314605E-00	1.264329E-02	0.0	0.0	0.0	0.0
6	2.901832E-00	1.688000E-04	0.0	0.0	0.0	0.0

ZONE	FISSILE SIGA	FF FTLLE SIGMG	SIGMG	SIGP
1	3.659356E-03	0.0	1.030757E-03	1.028599E-03
2	4.477255E-03	0.0	1.039550E-03	2.637699E-03
3	0.0	3.063462E-03	3.063462E-03	4.434690E-05
4	0.0	2.170872E-03	2.170872E-03	3.106499E-05
5	0.0	0.0	1.264329E-02	0.0
6	0.0	0.0	1.688000E-04	0.0

GROUP 3

ZONE	D	SIGA	SIGDP	SIGDP	SEARCH SIGA	SEARCH SIGDP
1	7.224061E-01	1.292820E-02	1.047090E-02	1.162688E-13	0.0	0.0
2	7.127080E-01	1.516859E-02	1.480896E-02	1.442623E-13	0.0	0.0
3	6.324750E-01	1.014389E-02	2.974195E-04	3.927678E-15	0.0	0.0
4	7.203470E-01	7.728394E-03	2.121802E-04	2.802111E-15	0.0	0.0
5	5.742770E-01	6.344044E-02	0.0	0.0	0.0	0.0
6	1.921179E-00	1.146800E-03	0.0	0.0	0.0	0.0

ZONE	FISSILE SIGA	FF FTLLE SIGMG	SIGMG	SIGP
1	1.292820E-02	0.0	9.294797E-03	3.633399E-03
2	1.516859E-02	0.0	1.003539E-02	5.133197E-03
3	0.0	1.002115E-02	1.002115E-02	1.227399E-04
4	0.0	7.640831E-03	7.640831E-03	8.756598E-05
5	0.0	0.0	6.344044E-02	0.0
6	0.0	0.0	1.146800E-03	0.0

GROUP 4

ZONE	D	SIGA	SIGDP	SIGDP	SEARCH SIGA	SEARCH SIGDP
1	9.641990E-01	2.654599E-02	2.661097E-02	2.957270E-13	0.0	0.0
2	9.429784E-01	3.371397E-02	3.815888E-02	4.236156E-13	0.0	0.0
3	4.183579E-01	1.334899E-02	8.460688E-04	1.118463E-14	0.0	0.0
4	9.476442E-01	9.956196E-03	5.759203E-04	7.604078E-15	0.0	0.0
5	6.153694E-01	1.686800E-01	0.0	0.0	0.0	0.0
6	1.729425E-00	7.865999E-04	0.0	0.0	0.0	0.0

ZONE	FISSILE SIGA	FF FTLLE SIGMG	SIGMG	SIGP
1	2.654599E-02	0.0	1.730449E-02	9.241095E-03
2	3.371397E-02	0.0	2.047599E-02	1.323799E-02
3	0.0	1.299947E-02	1.299947E-02	3.495194E-04
4	0.0	9.718504E-03	9.718504E-03	2.376900E-04
5	0.0	0.0	1.686800E-01	0.0
6	0.0	0.0	7.865999E-04	0.0

FISSION SPECTRUM CONSTANT FOR ALL ZONES

7.679999E-01 2.320000E-01 0.0 0.0

1/V CONSTANT FOR ALL ZONES

5.802495E-10 2.004720E-09 1.254705E-08 3.145160E-08

Fig. A2. (CONTINUED)

5 PLANE - EACH TRIANGLE - POINT NUMBERS ASSIGNMENTS

4 PLANE - EACH TRIANGLE - POINT NUMBERS ASSIGNMENTS

3 PLANE - EACH TRIANGLE - POINT NUMBERS ASSIGNMENTS

2 PLANE - EACH TRIANGLE - POINT NUMBERS ASSIGNMENTS

1 PLANE - EACH TRIANGLE - POINT NUMBERS ASSIGNMENTS

SCATTERLINE MACROSCOPIC CROSS SECTIONS	1	2	3	4	5
GROUP 1	0.0	0.0	0.0	0.0	0.0
GROUP 2	0.0	0.0	0.0	0.0	0.0
GROUP 3	0.0	0.0	0.0	0.0	0.0
GROUP 4	0.0	0.0	0.0	0.0	0.0
GROUP 5	0.0	0.0	0.0	0.0	0.0
GROUP 6	0.0	0.0	0.0	0.0	0.0
GROUP 7	0.0	0.0	0.0	0.0	0.0
GROUP 8	0.0	0.0	0.0	0.0	0.0
GROUP 9	0.0	0.0	0.0	0.0	0.0
GROUP 10	0.0	0.0	0.0	0.0	0.0
GROUP 11	0.0	0.0	0.0	0.0	0.0
GROUP 12	0.0	0.0	0.0	0.0	0.0
GROUP 13	0.0	0.0	0.0	0.0	0.0
GROUP 14	0.0	0.0	0.0	0.0	0.0
GROUP 15	0.0	0.0	0.0	0.0	0.0
GROUP 16	0.0	0.0	0.0	0.0	0.0
GROUP 17	0.0	0.0	0.0	0.0	0.0
GROUP 18	0.0	0.0	0.0	0.0	0.0
GROUP 19	0.0	0.0	0.0	0.0	0.0
GROUP 20	0.0	0.0	0.0	0.0	0.0
GROUP 21	0.0	0.0	0.0	0.0	0.0
GROUP 22	0.0	0.0	0.0	0.0	0.0
GROUP 23	0.0	0.0	0.0	0.0	0.0
GROUP 24	0.0	0.0	0.0	0.0	0.0
GROUP 25	0.0	0.0	0.0	0.0	0.0
GROUP 26	0.0	0.0	0.0	0.0	0.0
GROUP 27	0.0	0.0	0.0	0.0	0.0
GROUP 28	0.0	0.0	0.0	0.0	0.0
GROUP 29	0.0	0.0	0.0	0.0	0.0
GROUP 30	0.0	0.0	0.0	0.0	0.0
GROUP 31	0.0	0.0	0.0	0.0	0.0
GROUP 32	0.0	0.0	0.0	0.0	0.0
GROUP 33	0.0	0.0	0.0	0.0	0.0
GROUP 34	0.0	0.0	0.0	0.0	0.0
GROUP 35	0.0	0.0	0.0	0.0	0.0
GROUP 36	0.0	0.0	0.0	0.0	0.0
GROUP 37	0.0	0.0	0.0	0.0	0.0
GROUP 38	0.0	0.0	0.0	0.0	0.0
GROUP 39	0.0	0.0	0.0	0.0	0.0
GROUP 40	0.0	0.0	0.0	0.0	0.0
GROUP 41	0.0	0.0	0.0	0.0	0.0
GROUP 42	0.0	0.0	0.0	0.0	0.0
GROUP 43	0.0	0.0	0.0	0.0	0.0
GROUP 44	0.0	0.0	0.0	0.0	0.0
GROUP 45	0.0	0.0	0.0	0.0	0.0
GROUP 46	0.0	0.0	0.0	0.0	0.0
GROUP 47	0.0	0.0	0.0	0.0	0.0
GROUP 48	0.0	0.0	0.0	0.0	0.0
GROUP 49	0.0	0.0	0.0	0.0	0.0
GROUP 50	0.0	0.0	0.0	0.0	0.0
GROUP 51	0.0	0.0	0.0	0.0	0.0
GROUP 52	0.0	0.0	0.0	0.0	0.0
GROUP 53	0.0	0.0	0.0	0.0	0.0
GROUP 54	0.0	0.0	0.0	0.0	0.0
GROUP 55	0.0	0.0	0.0	0.0	0.0
GROUP 56	0.0	0.0	0.0	0.0	0.0
GROUP 57	0.0	0.0	0.0	0.0	0.0
GROUP 58	0.0	0.0	0.0	0.0	0.0
GROUP 59	0.0	0.0	0.0	0.0	0.0
GROUP 60	0.0	0.0	0.0	0.0	0.0
GROUP 61	0.0	0.0	0.0	0.0	0.0
GROUP 62	0.0	0.0	0.0	0.0	0.0
GROUP 63	0.0	0.0	0.0	0.0	0.0
GROUP 64	0.0	0.0	0.0	0.0	0.0
GROUP 65	0.0	0.0	0.0	0.0	0.0
GROUP 66	0.0	0.0	0.0	0.0	0.0
GROUP 67	0.0	0.0	0.0	0.0	0.0
GROUP 68	0.0	0.0	0.0	0.0	0.0
GROUP 69	0.0	0.0	0.0	0.0	0.0
GROUP 70	0.0	0.0	0.0	0.0	0.0
GROUP 71	0.0	0.0	0.0	0.0	0.0
GROUP 72	0.0	0.0	0.0	0.0	0.0
GROUP 73	0.0	0.0	0.0	0.0	0.0
GROUP 74	0.0	0.0	0.0	0.0	0.0
GROUP 75	0.0	0.0	0.0	0.0	0.0
GROUP 76	0.0	0.0	0.0	0.0	0.0
GROUP 77	0.0	0.0	0.0	0.0	0.0
GROUP 78	0.0	0.0	0.0	0.0	0.0
GROUP 79	0.0	0.0	0.0	0.0	0.0
GROUP 80	0.0	0.0	0.0	0.0	0.0
GROUP 81	0.0	0.0	0.0	0.0	0.0
GROUP 82	0.0	0.0	0.0	0.0	0.0
GROUP 83	0.0	0.0	0.0	0.0	0.0
GROUP 84	0.0	0.0	0.0	0.0	0.0
GROUP 85	0.0	0.0	0.0	0.0	0.0
GROUP 86	0.0	0.0	0.0	0.0	0.0
GROUP 87	0.0	0.0	0.0	0.0	0.0
GROUP 88	0.0	0.0	0.0	0.0	0.0
GROUP 89	0.0	0.0	0.0	0.0	0.0
GROUP 90	0.0	0.0	0.0	0.0	0.0
GROUP 91	0.0	0.0	0.0	0.0	0.0
GROUP 92	0.0	0.0	0.0	0.0	0.0
GROUP 93	0.0	0.0	0.0	0.0	0.0
GROUP 94	0.0	0.0	0.0	0.0	0.0
GROUP 95	0.0	0.0	0.0	0.0	0.0
GROUP 96	0.0	0.0	0.0	0.0	0.0
GROUP 97	0.0	0.0	0.0	0.0	0.0
GROUP 98	0.0	0.0	0.0	0.0	0.0
GROUP 99	0.0	0.0	0.0	0.0	0.0
GROUP 100	0.0	0.0	0.0	0.0	0.0

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 6

[illegible]

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 7

[illegible]

THE SUBBED ASSIGNMENTS FOR EACH TRIANGLE - PLANE 0

[illegible]

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 9

[illegible]

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 10

[illegible]

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 11

[illegible]

Fig. A2. (CONTINUED)

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 12

```

1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 3 3 3 3 3 3
1 1 1 1 1 1 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3
1 6 6 6 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3 3
6 1 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 3 3 3 3 3
1 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3
2 2 2 2 2 2 3 3 3 3 3 3
2 3 3 3 3 3 3 3
3 3 3 3
3

```

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 13

```

1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3
1 1 1 1 1 1 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3
1 6 6 6 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3
6 1 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 3 3 3 3
1 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3
2 2 2 2 2 2 3 3 3 3 3 3
2 3 3 3 3 3 3 3
3 3 3 3
3

```

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 14

```

1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 3 3 3 3 3 3
1 1 1 1 1 1 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3
1 6 6 6 1 1 1 1 1 1 1 6 6 6 2 2 2 2 2 2 3 3 3 3 3
6 1 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 3 3 3 3
1 2 2 2 2 2 2 2 2 3 3 3 3 3 3 3
2 2 2 2 2 2 3 3 3 3 3 3
2 3 3 3 3 3 3 3
3 3 3 3
3

```

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 15

```

4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
4 6 6 6 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
6 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 3 3 3 3 3 3
4 3 3 3 3 3 3 3
3 3 3 3
3

```

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 16

```

4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
4 6 6 6 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
6 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 3 3 3 3 3 3
4 3 3 3 3 3 3 3
3 3 3 3
3

```

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 17

```

4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
4 6 6 6 4 4 4 4 4 4 4 6 6 6 4 4 4 4 4 4 3 3 3 3 3
6 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3 3
4 4 4 4 4 4 3 3 3 3 3 3
4 3 3 3 3 3 3 3
3 3 3 3
3

```

Fig. A2. (CONTINUED)

ZONE NUMBER ASSIGNMENTS FOR EACH TRIANGLE - PLANE 10

ICSE VOLUMES - TOTAL = 8.578724691936D 05
6.794536102819D 04 7.224570032951D 04 1.711082376225D 05 1.190556306136D 05 1.167881621866D 04
1.683922318507D 04

*****NOTE - THE ZONE VOLUMES (VOL1(H)) HAVE BEEN PRE-WRITTEN ON THE INTERFACE FILE WDSHP*****

BUCKLING VALUE FOR ALL ZONES AND GROUPS IS 3.0

THERE ARE NO BLACK ABSORBED ZONES

BOUNDARY CONSTANTS								
GROUP	LEFT	RIGHT	TOP	EXTERNAL	BOTTOM	FRONT	REAR	INTERNAL
	1	2	1			2	2	
1	0.0	4.69200E-01	0.0		0.0	4.69200E-01	4.69200E-01	4.69200E-01
2	0.0	4.69200E-01	0.0		0.0	4.69200E-01	4.69200E-01	4.69200E-01
3	0.0	4.69200E-01	0.0		0.0	4.69200E-01	4.69200E-01	4.69200E-01
4	0.0	4.69200E-01	0.0		0.0	4.69200E-01	4.69200E-01	4.69200E-01

BY TAXINUM AND MINIMUM DIFFUSION COEFFICIENTS ARE 4.61642E 00 5.74277E-01

EQUILATERAL TRIANGLES ON PLANES - SIDE = 6.4665 TRIANGLE AREA = 1.810669100 01

PINE MESH DESCRIPTION - POINT IS LOCATED AT THE CENTROID OF THE VOLUME ELEMENT

DISTANCE TO POINT - DIMENSION 3 (FRONT TO REAR)

[illegible]

FIXED OVERRELAXATION COEFFICIENT BEFORE ADJUSTMENT

```

BITAC = 1.525229E 00 RBOC = 9.503188E-01
ABZAL = 9.600536E-01 ABZAG = 9.503188E-01
ARO 9.035851E-01 9.354420E-01 8.771367E-01 9.060164E-01
BITA 1.400154E 00 1.877672E 00 1.351131E 00 1.405241E 00
IEND      4      0      0      0

```

4 FLOT - HIGHVALUE PROBLEM FOLLOWS
4 INJERS WIN, 4 INJERS MAY - CHEBYCHEV BETA ON INJERS

SIGSA-1 CHDRING

PROCED=28-0, 1, 2, 3, a-NORMAL, CHECKSYES, SERES, DTYPE, SERED		ICVF=0, 1-YES, NO THERMS CONF.		OCVF=0, 1-YES, NO OUTDYS CONF.							
ITER	PROC	ICVF	OCVF	FLOX CHANGE	HU-BAD OTHERS-HU	SER-IDB	ACCELERATION	PARAMETERS	SOURCE	R-CALL	R-ESR3
1	0	0	0	1.150179 01	0.0 0.0	1.00000	0.3	0.0	1.14321E 16	0.2872272	1.0600000
2	0	0	0	1.128190 01	0.03638 0.0	1.00000	1.00000	0.0	7.35129E 16	0.8889516	1.0000000
3	0	0	0	1.555470 00	0.12425 0.0	1.00000	0.14188	0.0	7.11876E 15	3.3363900	1.0000000
4	0	0	0	-5.87576D 01	0.13557 0.0	1.00000	0.16193	-0.03063	6.56808E 15	0.9787095	1.0000000

3RD OVERALLIZATION COEFFICIENTS CALCULATED

1.42029 1.54880 1
*** THREE* CALCULATED

10-DEFS CALCULATED													
5	6	7	8	9	10	11	12	13	14	15	16	17	
5	0	0	0	-2.6754E-01	0.32650	0.0	1.00000	-1.97828	3.24960	6.90886E	15	0.9983139	1.0002000
6	0	0	0	-1.5173E-01	0.58897	0.0	1.00000	2.48632	-0.21142	6.90250E	15	1.0030008	1.0014582
7	0	0	0	-9.52972E-02	0.58386	0.0	1.00000	1.38715	0.00808	6.92319E	15	1.0073178	1.0073178
8	0	0	0	-5.8381E-02	0.61063	0.0	1.00000	-0.85499	1.10321	6.92865E	15	1.0093996	1.0093996
9	0	0	0	-3.8564E-02	0.62029	0.0	1.00000	1.13078	0.23860	6.93172E	15	1.0106858	1.0106858
10	0	0	0	-2.0609E-02	0.68854	0.0	1.00000	0.73970	0.48265	6.93328E	15	1.0114159	1.0114159
11	0	0	0	-1.2425E-02	0.61214	0.0	1.00000	2.00330	-0.79953	6.93614E	15	1.0118475	1.0118475
12	2	0	0	-1.2211E-02	0.61710	0.0	0.0	0.61176	0.0	6.93662E	15	1.0121033	1.0121033
13	0	0	0	3.93185E-03	0.0	0.0	1.00000	0.0	0.0	6.93538E	15	1.0125062	1.0125062
14	0	0	0	2.82951E-04	0.76475	0.0	1.00000	0.02958	0.04444	6.93531E	15	1.0124992	1.0124992
15	0	0	0	2.00590E-04	0.75651	0.0	1.00000	3.27629	0.00251	6.93527E	15	1.0124932	1.0124932
16	0	0	0	1.43896E-04	0.70856	0.0	1.00000	-2.45017	4.40793	6.93526E	15	1.0124907	1.0124907
17	3	0	0	9.76008E-05	0.68734	0.0	1.00000	2.88662	-0.50362	6.93525E	15	1.0124893	1.0124893
18	0	0	0	6.65981E-05	0.68884	0.0	1.00000	1.97725	0.16177	6.93524E	15	1.0124886	1.0124886
19	0	0	0	4.64948E-05	0.69381	0.0	0.0	-3.46805	4.16038	6.93524E	15	1.0124881	1.0124881

ESTIMATED ABSOLUTE POINT FLUX RELATIVE ERROR 1.051550-04

FINAL CALCULATED REFLECTIVE 1.0124874

MULTIPLICATION RELIABILITY ESTIMATORS

BY THE SUM OF THE SQUARES OF THE RESIDUES-----	1,0124881
COEFF. AND LOG10 CORRESP. ESTIMATE OF COV. B1, B2, COV22-----	1.0126122

TOPPER AND LOWER BOUNDS ESTIMATES BY MAX WFL PLOT CHANGE-----	1.0123309	1.0124480
TOPPER AND LOWER BOUNDS ESTIMATES OVER ALL SIGNIFICANT POINTS-----	1.0163000	1.0086000

UPPER AND LOWER BOUNDS ESTIMATES OVER ALL SIGNIFICANT POINTS:----- 1.0182885 1.0000094

POWER OF INNER ITERATIONS, OUTER ITERATION ERROR, EIGENVALUE, AND OVERRELAXATION COEFFICIENTS 4 4.93606D-01
1.42029 1.56080 1.32025 1.38239

CPU AND CLOCK HYPOTHESES REQUIRED FOR THIS SIGNATURE PROBLEM ARE 0.418 4.002

ITERATION TIMING STATISTICS

CALCULATION	TIMER UNITS	SECONDS
MISS-SOURCE	310	3.10
SCAT-SOURCE	242	2.42
IN-LEAKAGE	1608	16.08
P-E SWEEP	1211	12.11
CHIB ACCL.	0	0.0
OTHER	1536	15.36
OVERALL	4907	49.07

TOTAL I/O REQUESTS = 701

LEAKAGE 1.36905E-01 TOTAL LOSSES 9.87646E-01 TOTAL PRODUCTIONS 1.00000E 00 REACTOR POWER (WATTS) 0.0

PRIMITIVE FISSION CONVERSION RATIO IS 2.61494E-01, ESTIMATE FOR CRITICAL SYSTEM IS 2.81630E-01
FISSION DESTRUCTION PER UNIT ENERGY (ATOMS/WATT-SEC) IS 0.0

GROUP	LEFT	RIGHT	TOP	BOTTOM	FRONT	BACK
1	0.0	1.19478E-02	0.0	0.0	7.30065E-04	1.26860E-03
2	0.0	8.13733E-02	0.0	0.0	8.79006E-03	1.69685E-02
3	0.0	8.39509E-03	0.0	0.0	8.07092E-04	1.80574E-03
4	0.0	3.23636E-03	0.0	0.0	3.65435E-04	1.21739E-03
SUM	0.0	1.04952E-01	0.0	0.0	1.06327E-02	2.12602E-02

GROUP NEUTRON BALANCE FOR EACH ZONE

ZONE	GROUP	ABSORPTIONS	B*2	LOSSES	1/V LOSS	OUT-SCATTER	IN-SCATTER	SOURCE	POWER (WATTS)	AVERAGE FLUX
1	1	5.57548E-02	0.0	0.0	0.0	2.85882E-01	0.0	3.99378E-01	1.51648E-12	1.78276E-04
	2	1.07799E-01	0.0	0.0	0.0	9.17288E-02	2.85832E-01	1.20555E-01	3.32283E-12	8.35757E-04
	3	6.72470E-02	0.0	0.0	0.0	2.43632E-02	9.17754E-02	0.0	6.04782E-13	7.65554E-05
	4	2.53206E-02	0.0	0.0	0.0	0.0	2.43661E-02	0.0	2.82077E-13	1.40383E-05
SUM		3.56722E-01	0.0	0.0	0.0	4.01973E-01	4.01973E-01	5.19633E-01	5.72016E-12	
2	1	4.32258E-02	0.0	0.0	0.0	1.42351E-01	0.0	3.33691E-01	1.21715E-12	1.08483E-04
	2	1.51280E-01	0.0	0.0	0.0	5.31133E-02	1.82314E-01	1.00803E-01	2.85197E-12	4.67690E-04
	3	4.52405E-02	0.0	0.0	0.0	1.29626E-02	5.31453E-02	0.0	4.90454E-13	4.13285E-05
	4	1.66082E-02	0.0	0.0	0.0	0.0	1.49643E-02	0.0	2.04682E-13	6.81869E-06
SUM		2.56495E-01	0.0	0.0	0.0	2.48424E-01	2.48424E-01	4.34493E-01	4.74526E-12	
3	1	9.43891E-03	0.0	0.0	0.0	7.79472E-02	0.0	1.67189E-02	2.15314E-13	1.42023E-05
	2	5.05647E-02	0.0	0.0	0.0	4.87687E-02	7.79377E-02	5.05051E-03	2.49156E-14	1.02405E-04
	3	2.46195E-02	0.0	0.0	0.0	1.43740E-02	4.87765E-02	0.0	9.54031E-15	1.41957E-05
	4	9.49340E-03	0.0	0.0	0.0	0.0	1.43257E-02	0.0	7.95417E-15	4.15626E-06
SUM		9.81364E-02	0.0	0.0	0.0	1.41040E-01	1.41040E-01	2.17694E-02	2.57726E-13	
4	1	4.20691E-03	0.0	0.0	0.0	4.57146E-02	0.0	9.03964E-03	1.08100E-13	1.47096E-05
	2	3.86537E-02	0.0	0.0	0.0	4.01814E-02	4.57095E-02	2.73072E-03	1.74505E-14	1.48696E-04
	3	2.08968E-02	0.0	0.0	0.0	1.44756E-02	4.01853E-02	0.0	7.57664E-15	2.29036E-05
	4	1.01141E-02	0.0	0.0	0.0	0.0	1.44768E-02	0.0	7.74201E-15	4.62157E-06
SUM		7.44916E-02	0.0	0.0	0.0	1.00372E-01	1.00372E-01	1.17704E-02	1.40849E-13	
5	1	1.21164E-03	0.0	0.0	0.0	1.48924E-02	0.0	0.0	0.0	5.55701E-05
	2	4.02428E-02	0.0	0.0	0.0	1.19955E-02	1.48918E-02	3.3	0.0	2.72539E-04
	3	1.56891E-02	0.0	0.0	0.0	2.14697E-03	1.19962E-02	0.0	0.0	2.11754E-05
	4	5.18516E-03	0.0	0.0	0.0	0.0	2.14697E-03	0.0	0.0	2.65208E-06
SUM		6.22872E-02	0.0	0.0	0.0	2.93449E-02	2.70349E-02	0.0	0.0	
6	1	3.83914E-04	0.0	0.0	0.0	2.29714E-02	0.0	0.0	0.0	1.05402E-04
	2	1.54612E-03	0.0	0.0	0.0	1.17907E-02	2.29705E-02	0.0	0.0	5.44007E-04
	3	1.15364E-03	0.0	0.0	0.0	3.47389E-03	1.17919E-02	0.0	0.0	5.97392E-05
	4	1.93116E-04	0.0	0.0	0.0	0.0	3.47390E-03	0.0	0.0	1.45795E-05
SUM		3.27699E-03	0.0	0.0	0.0	3.82367E-02	3.82363E-02	0.0	0.0	

OVERALL NEUTRON BALANCE

GROUP	ABSORPTIONS	B*2	LOSSES	1/V LOSS	OUT-SCATTER	IN-SCATTER	SOURCE	POWER (WATTS)
1	1.14822E-01	0.0	0.0	0.0	6.29758E-01	0.0	7.58527E-01	3.05704E-12
2	4.94083E-01	0.0	0.0	0.0	2.57575E-01	6.29655E-01	2.29138E-01	6.21717E-12
3	1.72916E-01	0.0	0.0	0.0	7.17462E-02	2.57670E-01	0.0	1.11235E-12
4	6.45330E-02	0.0	0.0	0.0	0.0	7.17537E-02	0.0	5.06455E-13
SUM	8.50764E-01	0.0	0.0	0.0	9.59079E-01	9.59080E-01	9.87665E-01	1.38930E-11

ZONE VOLUMES FOLLOW: TOTAL VOLUME 4.57473E 05

6.79454E 04 7.22457E 04 1.71108E 05 1.18056E 05 1.16788E 04 1.68772E 04

THE TOTAL FLUX INTENSITY FILE PFLUX (VERSION 1) HAS BEEN WRITTEN ON UNIT NUMBER 17

Fig. A2. (CONTINUED)

THE AVERAGE POWER DENSITY FOR EACH TRIANGLE ON PLANE 1

2.80269E-19	2.76957E-19	2.73679E-19	2.46950E-19	2.60670E-19	2.50611E-19	2.42672E-19	2.31310E-19	2.23016E-19
2.13472E-19	2.06737E-19	1.96432E-19	1.88335E-19	1.76433E-19	1.64499E-19	1.49810E-19	1.37950E-19	1.26630E-19
1.16921E-19	1.07797E-19	1.01791E-19	9.31960E-20	8.49505E-20	7.58968E-20	6.53181E-20	5.35785E-20	4.33751E-20
4.98039E-20	3.85220E-20	2.82776E-20	2.03530E-20	1.28751E-20	7.70595E-21	2.63500E-21	2.52429E-21	2.45000E-21
2.29004E-19	2.22433E-19	2.06600E-19	2.05213E-19	1.94729E-19	1.93064E-19	1.82429E-19	1.74276E-19	1.58270E-19
1.46341E-19	0.0	0.0	0.0	1.04797E-19	9.73457E-20	9.17516E-20	8.21173E-20	7.37067E-20
6.26946E-20	7.54940E-20	5.97900E-20	4.78505E-20	3.53105E-20	2.67070E-20	1.69745E-20	1.10067E-20	2.18630E-20
0.0	0.0	0.0	1.06073E-19	1.00567E-19	1.70569E-19	1.60329E-19	1.57107E-19	1.42097E-19
0.0	0.0	3.0	1.01773E-19	4.54310E-20	8.75815E-20	7.96470E-20	6.83200E-20	5.96704E-20
6.00570E-20	5.63406E-20	4.13512E-20	3.22766E-20	2.05407E-20	1.38496E-20	0.0	1.77213E-19	1.76044E-19
1.71701E-19	1.65664E-19	1.55300E-19	1.43763E-19	1.32300E-19	1.20290E-19	1.11639E-19	1.02400E-19	9.37700E-20
8.50990E-20	1.04067E-19	9.14304E-20	7.33234E-20	6.22626E-20	4.60239E-20	3.68294E-20	2.34810E-20	1.62673E-20
1.67047E-19	1.58900E-19	1.52606E-19	1.41805E-19	1.32091E-19	1.21221E-19	1.12063E-19	1.00197E-19	9.11405E-20
7.82358E-20	9.80369E-20	7.05933E-20	6.45000E-20	4.97007E-20	4.02774E-20	2.50070E-20	1.02955E-20	1.36705E-20
1.26864E-19	1.17537E-19	1.08135E-19	9.59570E-20	8.14456E-20	7.29731E-20	6.33604E-20	7.10100E-20	5.27721E-20
4.31394E-20	2.76419E-20	1.97320E-20	9.76679E-20	1.17000E-19	1.06292E-19	8.46316E-20	7.40796E-20	5.46730E-20
0.53161E-20	2.89540E-20	2.09750E-20	7.41586E-20	5.52127E-20	0.62000E-20	2.96170E-20	2.16512E-20	2.10066E-20

THE AVERAGE POWER DENSITY FOR EACH TRIANGLE ON PLANE 18

3.77720E-19	3.77422E-19	3.77433E-19	3.77000E-19	3.76095E-19	3.77051E-19	3.75040E-19	3.74263E-19	3.67795E-19
3.62172E-19	3.50919E-19	3.41356E-19	3.29705E-19	3.20771E-19	3.11953E-19	3.06947E-19	2.97109E-19	2.80708E-19
2.68047E-19	2.47281E-19	2.18775E-19	1.93049E-19	1.79671E-19	1.63657E-19	1.23700E-19	1.40099E-19	1.26468E-19
8.60040E-20	6.63077E-20	4.81042E-20	3.42925E-20	2.14822E-20	1.27846E-20	3.77191E-19	3.79100E-19	3.76638E-19
3.87695E-20	3.84287E-20	3.98010E-20	3.72772E-20	3.64233E-20	3.40051E-20	3.32422E-20	3.20710E-20	3.10103E-20
3.78190E-20	0.0	0.0	0.0	2.51367E-20	2.20969E-20	1.91157E-20	1.63273E-20	1.40055E-20
1.15945E-19	1.37225E-19	1.06729E-19	8.30010E-20	6.06913E-20	4.58135E-20	2.85735E-20	1.83090E-20	3.95325E-20
0.0	0.0	0.0	3.78038E-20	3.51504E-20	3.31562E-20	3.16077E-20	3.10182E-20	3.00730E-20
0.0	0.0	9.0	2.57792E-20	2.14707E-20	1.78740E-20	1.57090E-20	1.20550E-20	1.09072E-20
1.21930E-19	9.94029E-20	7.15995E-20	5.51072E-20	3.47060E-20	3.22913E-20	0.0	3.63700E-20	3.46659E-20
3.19700E-19	3.09157E-19	2.90520E-19	2.47709E-19	2.60244E-19	2.65132E-19	2.35711E-19	2.21060E-19	1.86073E-19
1.68046E-19	1.34765E-19	1.69367E-19	1.31101E-19	1.10390E-19	7.97087E-20	6.34095E-20	3.94003E-20	2.70699E-20
3.10041E-19	2.88477E-19	2.74000E-19	2.58390E-19	2.49005E-19	2.25083E-19	2.10431E-19	1.05050E-20	1.71343E-19
1.01533E-19	1.77900E-19	1.38282E-19	1.16400E-19	8.53679E-20	6.90500E-20	3.35700E-20	3.06590E-20	2.46297E-20
2.22054E-19	2.10355E-19	1.84001E-19	1.70590E-19	1.82046E-19	1.27931E-19	1.43333E-19	1.23017E-19	8.92652E-20
7.30546E-20	0.61702E-20	3.70935E-20	1.70026E-20	2.02460E-20	1.02046E-20	1.43006E-20	1.25082E-20	9.10872E-20
7.55657E-20	4.77497E-20	1.45443E-20	1.24000E-20	4.14067E-20	7.63339E-20	0.80149E-20	1.53517E-20	3.55467E-20

THE MAXIMUM POWER DENSITY IS 1.3219946E-16 IN ZONE 1 ON PLANE 10 IN TRIANGLE 1

THE MAXIMUM POWER DENSITIES IN EACH ZONE ARE

1.32199E-16 1.25595E-16 1.11590E-17 0.0 0.0

D.A. NO RECCPD LENGTH FROM CORE AND PROCS 12969 12960

CORE STORAGE REQUIRED IS 24539 WORDS

ELAPSED CPU AND CLOCK MINUTES ARE 0.474 4.805

ADJUST PROBLEM FOLLOWS

4 INHERS HIS, 4 INHERS HAY - CHERYSHEV BETA ON INHERS

SIGNA-1 ORDERING

PROCINDEX=0,1,2,3,4-NORMAL,CHERYSHYEV,CHERYX,DEREX,SENEX, ICVP=0,1-YES,BC INHERS CONVR. OCVP=0,1-YES,BC CUTERS CONVR.

TYPE	PROC	ICVP	OCVP	PLX CHNG	HT-BAY	OTHER-HU	SEN-IND	ACCELERATION	PARAMETERS
1	0	0	0	0.430990 00	0.0	0.0	1.00000	0.3	0.0
2	0	1	0	2.305339 01	14.26100	0.0	1.00000	1.00000	0.0
3	0	0	0	-5.519990-01	0.15000	0.3	1.00000	0.10070	0.0
4	0	0	0	-2.477210-01	0.34555	0.0	1.00000	0.23248	0.03953

NEW OVERRELAXATION COEFFICIENTS CALCULATED

1.38202 1.32180 1.50926 1.42044

NEW INHERS CALCULATED

	4	3	2	1	0	0	0	0	0
5	0	0	0	0	-1.230190-31	0.47669	0.0	1.00030	1.15953
6	0	0	0	0	0.204620-02	0.47670	0.0	1.70000	176.12717
7	0	0	0	0	6.521470-02	0.72806	0.0	1.70030	3.31694
8	0	0	0	0	4.995170-02	0.71259	0.0	1.30000	1.90917
9	0	0	0	0	3.197270-02	0.70641	0.0	1.03030	3.71112
10	0	0	0	0	2.511270-02	0.69280	0.0	1.00000	-7.50331
11	0	0	0	0	1.711960-02	0.69064	0.0	1.72070	2.65701
12	0	0	0	0	4.430640-02	0.63957	0.0	0.0	3.81212
13	0	0	0	0	2.755910-04	0.0	0.0	1.03000	0.0
14	0	0	0	0	2.120930-04	0.77935	0.0	1.70000	0.01000
15	0	0	0	0	1.617850-04	0.83025	0.0	1.70000	4.01290
16	0	0	0	0	1.020400-04	0.64721	0.0	1.00000	-0.12297
17	0	0	0	0	4.730800-05	0.66683	0.0	1.03000	1.70768
18	0	0	0	0	-4.464050-05	0.64573	0.0	1.00000	1.80700

ESTIMATED ABSOLUTE POINT PLX RELATIVE ERROR 9.920440-05

MULTIPLICATION RELIABILITY ESTIMATORS

BY THE SQ OF THE SQUARES OF THE RESIDUES	1.0124878
UPPER AND LOWER BOUNDS ESTIMATES BY MAX REL PLX CHNG	1.0125311
UPPER AND LOWER BOUNDS ESTIMATES OVER ALL SIGNIFICANT POINTS	1.0124917

NUMBER OF ITERATION ITERATIONS, OUTER ITERATION EPOCH EIGENVALUE, AND OVERRELAXATION COEFFICIENTS 4 6.89571D-01

1.38202 1.32180 1.50926 1.42044

CPU AND CLOCK MINUTES REQUIRED FOR THIS EIGENVALUE PROBLEM ARE 0.794 4.564

ITERATION TIMING STATISTICS

CALCULATION	TIMER UNITS	SECONDS
FISS-SOURCE	33	0.33
SCAT-SOURCE	201	2.01
IS-LEAKAGE	1645	16.45
*-2 SWEEP	1161	11.61
CHRD. ACCL.	0	0.0
OTHER	1648	16.48
OVERALL	4728	47.28

TOTAL I/O REQUESTS = 657

***** THE ADJOINT NEUTRON BALANCE DOES NOT INCLUDE BOUNDARY LEAKAGES OR INTERNAL BLACK BOX LOSSES *****

PRIMITIVE FISSION CONVERSION RATIO IS 9.009530-02, ESTIMATE FOR CRITICAL SYSTEM IS 1.130330-01
FISSION DESTRUCTION PER UNIT ENERGY (ATONS/UNIT-SEC) IS 0.0

ADJOINT GROUP NEUTRON BALANCE FOR EACH ZONE

ZONE GROUP	ABSORPTIONS	LOSSES	1/V LOSS	OUT-SCATTERED	IN-SCATTERED	SOURCE	POWER (WATTS)	AVERAGE FLUX
1 4	1.69338E 14	0.0	0.0	2.98707E 13	0.0	0.0	1.88446E 04	9.38050E 10
1 3	6.94698E 13	0.0	0.0	8.70175E 12	2.98702E 13	0.0	6.20772E 02	7.90050E 10
1 2	2.27945E 13	0.0	0.0	1.04936E 14	6.48010E 12	7.90030E 13	3.64369E 02	9.16455E 10
1 1	3.33080E 13	0.0	0.0	0.0	1.46959E 14	2.61793E 14	9.05966E 02	1.06505E 11
SUM	7.94903E 14	0.0	0.0	1.05517E 14	1.05517E 14	3.40077E 14	3.70157E 03	
2 4	1.30133E 14	0.0	0.0	1.67577E 13	0.0	0.0	1.63511E 03	5.34274E 10
2 3	4.91020E 13	0.0	0.0	5.11140E 12	1.67570E 13	0.0	5.32405E 02	4.40003E 10
2 2	1.69540E 13	0.0	0.0	8.00908E 13	5.09657E 12	6.64504E 13	3.19630E 02	5.20165E 10
2 1	1.05394E 13	0.0	0.0	0.0	6.81360E 13	2.20442E 14	6.90977E 02	6.15041E 10
SUM	2.20010E 14	0.0	0.0	1.39960E 14	1.09460E 14	2.07120E 14	3.17033E 03	
3 4	1.55017E 13	0.0	0.0	6.00025E 12	0.0	0.0	1.29003E 01	6.78672E 09
3 3	9.73153E 12	0.0	0.0	2.66042E 12	6.40099E 12	0.0	3.76002E 00	5.60662E 09
3 2	5.29020E 12	0.0	0.0	5.46707E 13	2.66479E 12	4.41710E 12	2.41929E 00	9.96325E 09
3 1	0.90112E 12	0.0	0.0	0.0	5.06705E 13	1.46221E 13	2.31961E 02	1.34515E 10
SUM	1.90725E 13	0.0	0.0	6.41913E 13	6.41913E 13	1.40392E 13	2.21136E 02	
4 4	4.05067E 12	0.0	0.0	4.33119E 12	0.0	0.0	6.15300E 00	6.05202E 09
4 3	5.30964E 12	0.0	0.0	1.50639E 12	4.33112E 12	0.0	1.91960E 00	5.06335E 09
4 2	1.50917E 12	0.0	0.0	4.29070E 13	1.50040E 12	2.90766E 12	1.62005E 00	1.30075E 10
4 1	6.09575E 12	0.0	0.0	0.0	5.29090E 13	9.62516E 12	1.37003E 02	1.06516E 10
SUM	2.30490E 13	0.0	0.0	4.80250E 13	4.80250E 13	1.25130E 13	1.66797E 02	
5 4	2.19671E 13	0.0	0.0	1.13059E 12	0.0	0.0	0.0	1.11509E 10
5 3	9.11202E 12	0.0	0.0	5.01355E 11	1.13059E 12	0.0	0.0	1.22943E 10
5 2	4.20604E 12	0.0	0.0	7.63089E 12	5.01207E 11	0.0	0.0	2.00901E 10
5 1	0.31582E 13	0.0	0.0	0.0	7.63089E 12	0.0	0.0	3.01374E 10
SUM	1.41159E 13	0.0	0.0	9.30603E 12	9.30603E 12	0.0	0.0	
6 4	7.69591E 11	0.0	0.0	3.37063E 12	0.0	0.0	0.0	5.91011E 10
6 3	9.41937E 11	0.0	0.0	1.75990E 12	1.37063E 12	0.0	0.0	4.00002E 10
6 2	1.66619E 11	0.0	0.0	1.27500E 13	1.09907E 12	0.0	0.0	5.06101E 10
6 1	2.00013E 11	0.0	0.0	0.0	1.27712E 13	0.0	0.0	6.03607E 10
SUM	2.12916E 12	0.0	0.0	1.72130E 13	1.72130E 13	0.0	0.0	

ADJOINT OVERALL NEUTRON BALANCE

GROUP	ABSORPTIONS	LOSSES	1/V LOSS	OUT-SCATTERED	IN-SCATTERED	SOURCE	POWER (WATTS)
4	3.05763E 14	0.0	0.0	6.23250E 13	0.0	0.0	3.50072E 03
1	1.41700E 14	0.0	0.0	1.96493E 13	6.23239E 13	0.0	1.16100E 03
2	5.10020E 13	0.0	0.0	3.53010E 14	1.96265E 13	1.53064E 14	6.88067E 02
3	7.19656E 13	0.0	0.0	0.0	1.53063E 14	5.06703E 14	1.91799E 03
SUM	6.16519E 14	0.0	0.0	6.35013E 14	6.35013E 14	6.59769E 14	7.32903E 03

*CORE VOLTAGES FOLLOW. TOTAL VOLTAGE 4.57873E 05

6.79854E 04 7.22057E 04 1.71104E 05 1.10256E 05 1.16700E 04 1.60392E 04

THE TOTAL FLUX INTERFACE FILE APPLIES (VERSION 1) HAS BEEN WRITTEN ON UNIT NUMBER 10

THE ADJOINT AVERAGE POWER DENSITY FOR EACH TRIANGLE ON PLANE 10

6.20181E-04	6.27727E-04	6.26770E-04	6.23700E-04	6.20021E-04	6.17563E-04	5.11960E-04	6.06159E-04	5.95002E-04
5.81126E-04	5.64131E-04	5.48903E-04	5.29599E-04	5.11073E-04	4.93011E-04	4.77027E-04	4.50152E-04	4.40201E-04
4.12170E-04	1.81707E-04	1.40163E-04	1.00109E-04	2.73154E-04	2.30632E-04	2.05209E-04	2.45090E-04	2.01909E-04
1.51699E-04	1.25009E-04	9.80335E-05	6.91627E-05	4.57601E-05	2.93650E-05	6.22560E-05	6.20707E-05	6.10601E-05
6.20574E-04	6.11723E-04	6.11002E-04	5.92007E-04	5.76297E-04	5.50313E-04	5.29508E-04	5.09600E-04	4.91137E-04
4.76819E-04	0.0	0.0	0.0	3.05207E-04	1.40000E-04	3.05007E-04	2.66531E-04	2.34040E-04
1.99176E-04	2.39003E-04	1.91315E-04	1.50710E-04	1.16460E-04	0.93637E-05	5.95618E-05	4.00242E-05	6.20730E-04
0.0	0.0	0.0	5.02160E-04	5.53202E-04	5.26350E-04	5.00563E-04	4.54733E-04	4.60510E-04
0.0	0.0	0.0	3.49007E-04	1.34590E-04	2.00026E-04	2.50712E-04	2.17630E-04	1.09540E-04
2.16776E-04	1.00750E-04	1.30956E-04	1.06067E-04	7.13420E-05	5.07050E-05	0.0	5.67173E-04	5.06776E-04
5.07066E-04	4.90476E-04	4.40032E-04	4.49004E-04	4.19599E-04	4.09341E-04	3.69712E-04	3.40000E-04	3.01137E-04
2.70000E-04	3.20395E-04	2.90316E-04	2.32501E-04	1.90970E-04	1.49152E-04	1.21153E-04	8.97966E-05	5.09090E-05
4.93112E-04	4.60720E-04	4.45639E-04	4.13101E-04	3.97920E-04	3.62006E-04	3.40000E-04	3.93500E-04	2.01025E-04
2.92277E-04	1.00831E-04	2.40771E-04	2.10561E-04	1.59192E-04	1.11405E-04	0.76011E-05	6.53121E-05	1.95652E-04
3.60192E-04	3.81710E-04	3.03311E-04	2.81075E-04	2.41990E-04	2.19021E-04	2.53301E-04	2.20927E-04	1.66159E-04
1.30635E-04	9.20023E-05	6.99550E-05	2.81010E-04	1.60050E-04	1.13000E-04	2.53067E-04	2.20940E-04	1.60050E-04
1.03261E-04	9.59509E-05	7.10000E-05	2.20202E-04	1.70472E-04	1.00920E-04	9.73237E-05	7.47705E-05	7.52703E-05

THE ADJOINT MAXIMUM POWER DENSITY IS 0.977005E-02 IN ZONE 1 ON PLANE 10 IN TRIANGLE 1

THE ADJOINT MAXIMUM POWER DENSITIES IN EACH ZONE ARE

0.97719E-02 0.72700E-02 7.03000E-03 4.10550E-03 0.0 0.0

SDPC OFF OF CONTAINER APPAYS, CONTROL 16, MAX DATA 14200

TOTAL CPU TIME IS 1.645 MINUTES AND TOTAL CLOCK TIME IS 11.719 MINUTES