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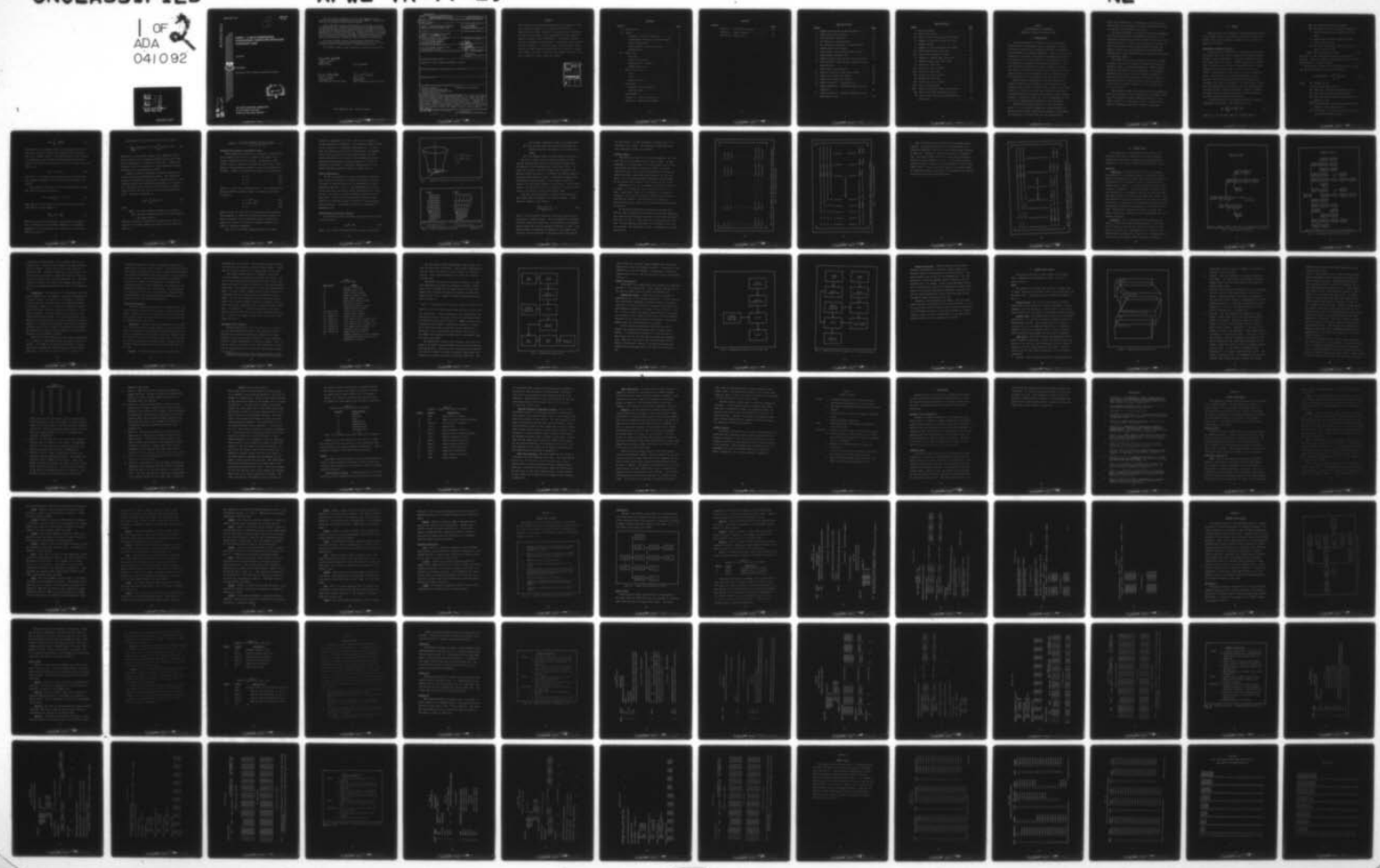

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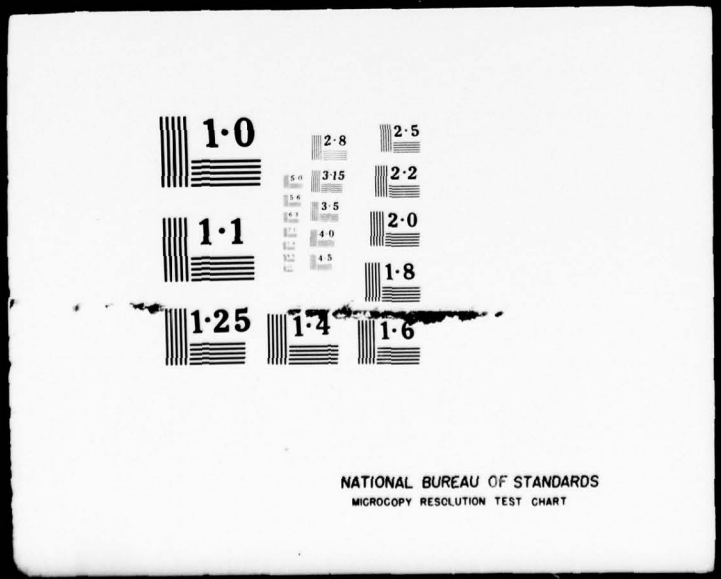

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AIRDIF: A TWO-DIMENSIONAL ATMOSPHERIC RADIATION DIFFUSION COMPUTER CODE

June 1977

Final Report

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Air Force Systems Command
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This report contains a user's guide for the AIRDIF code. AIRDIF is a computer code which employs a special form of diffusion theory to compute free field radiation environments from atmospheric nuclear detonations. The code may be run in either homogeneous air or 2-D variable density air. In addition to environments, AIRDIF is also capable of computing K-Factors, defined to be the ratio of the 2-D $4\pi r^2$ variable density air dose to the 1-D mass integral scaled dose, for a particular source, dose response function, and at a number of mass ranges.

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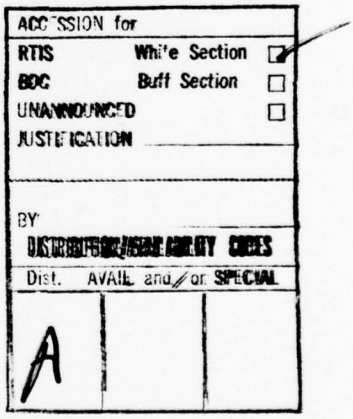
Preface

This document was originally submitted by Capt Edward L. Wolf as his master's thesis to the faculty of the School of Engineering, Air Force Institute of Technology, Air University in partial fulfillment of the requirements for the degree of Master of Science (AFIT GNE/PH/76D-8). The AIRDIF computer code was developed by Capt Raymond A. Shulstad at the Air Force Weapons Laboratory. A previous report, AFWL-TR-76-221, documented the AIRDIF theory and presented the results of a study where AIRDIF was used to evaluate mass integral scaling. This report presents a user's guide for AIRDIF.



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AIRDIF:
A TWO-DIMENSIONAL ATMOSPHERIC RADIATION DIFFUSION COMPUTER CODE

I. Introduction

The existing threat of nuclear war and our national defense policy of deterrence make it necessary to be able to evaluate the ability of aerospace vehicles to operate in the environment of a nuclear explosion. These evaluations are referred to as nuclear survivability/vulnerability studies. An integral part of these studies is the determination of the radiation environments from nuclear detonations. This must be done as a function of spatial location throughout the region of interest and involves the transport of nuclear weapon radiation in the atmosphere and the determination of the interaction of this radiation with aerospace vehicles.

These transport calculations have been carried out either by Monte Carlo simulation or by the method of mass integral scaling (MIS). Shulstad (Ref 1) gives a list of the Monte Carlo results which have been published in the open literature, and he also describes the method of mass integral scaling. As Shulstad points out, MIS is essentially a "fix-up" of a one dimensional (homogeneous) air calculation.

AIRDIF, the code described here, is an "in between" method. It is a true two dimensional calculation but one which involves several simplifying assumptions which permit its execution in a fraction of the time required for a

Monte Carlo calculation. Nevertheless, as Shulstad demonstrates (Ref 1), the agreement between AIRDIF and Monte Carlo is excellent for altitudes up to 25 km.

The basis of AIRDIF is a special form of the multigroup diffusion equation which is described in Section II. The simplifying assumptions are those inherent in the use of the diffusion equation: namely, that the region of interest is large with respect to the radiation mean free path, the spatial variation is slowly varying, and the directional distribution of the radiation flux is linear with the cosine of directional angle.

The AIRDIF code is user oriented in that it is simple to operate and does not require an extensive knowledge of diffusion theory or computer technology. AIRDIF produces radiation environments in one dimensional (1-D) infinite homogeneous air as well as in 2-D variable density air. Given the proper input, this code is capable of producing correction factors, called K-Factors, which are defined to be the $4\pi r^2$ 2-D variable density air dose divided by the $4\pi r^2$ 1-D MIS dose.

This report contains five sections and five appendices. Section II contains a brief description of the theory. Section III describes the code itself, and Section IV is a users's guide (ie, instructions on how to use this code). Section V discusses limitations inherent in the code.

II. Theory

This section is not intended to give detailed derivations of the theory behind the calculations within the AIRDIF code. Instead, this section presents a summary of the theory presented in reference 1.

Atmospheric Diffusion Equation

Given a nuclear detonation at a specified altitude and the proper input data, AIRDIF computes the multigroup energy fluences, doses, and K-Factors (if opted) throughout a spatial domain about the source. AIRDIF is based on a special form of diffusion theory which is summarized below. An analytical first collided source is used so that diffusion theory is only applied to the solution of the collided fluences. Solutions are thus obtained separately for the collided and uncollided fluences over each energy group throughout the region of interest. The total group fluences are then obtained by simple addition of the collided and uncollided particle fluences everywhere. Doses are computed by summing over all groups the product of the fluence and the dose response function in each group.

As mentioned above, the uncollided particle fluence is determined analytically. The equation used is

$$F_V^{g'} = \frac{S_0^{g'}}{4\pi r^2} \exp\left(-\frac{\Sigma_T^{g'}}{\rho_0} * \text{RHOR}\right) \qquad (1)$$

where ρ_0 is the sea level density (1.225E-3 gm/cm^3),

$F_V^{g'}$ = the uncollided fluence in group g'

$S_0^{g'}$ = the number of group g' particles emanating from an isotropic point source at r=0 and $Z=Z_S$

r = slant range between the source and mesh point in units of cm

$\Sigma_T^{g'}$ = the total macroscopic cross section at sea level in units of cm^{-1}

$$RHOR = \int_0^r \rho \, dr \text{ in units of } g/cm^2 \qquad (2)$$

and where ρ is the atmospheric density as a function of altitude. Note that "RHOR" is often referred to as the mass range (gm/cm^2) or optical density.

The collided fluences are found numerically by solving the diffusion equation which can be written as

$$\nabla\cdot\left(D^g \nabla F^g\right) - \Sigma_R^g F^g = -S^g - \sum_{g'=1}^{g-1} \Sigma_S^{g'\to g} F^{g'} \qquad (3)$$

where $\Sigma_R^g = \Sigma_T^g - \Sigma_S^{g\to g}$ in cm^{-1}

g = the energy group number

D^g = the group g diffusion coefficient in cm

F^g = the group g fluence in particles/cm^2

Σ_R^g = the macroscopic removal cross section for group g in cm^{-1}

$\Sigma_S^{g'\to g}$ = the macroscopic scatter cross section from group g' into group g in cm^{-1}.

S^g = the source of uncollided particles for group g in particles/cm^3 given by

$$S^g = \sum_{g'=1}^{g} \Sigma_S^{g' \to g} F_V^{g'} \qquad (4)$$

where $F_V^{g'}$ is the uncollided fluence in group g' given by Eq (1). All cross sections for AIRDIF are entered at sea level density ($\rho_0 = 1.225 \times 10^{-3} g/cm^3$). The cross section at any altitude Z is determined within AIRDIF by multiplying the sea level value by the ratio of the densities, f(z), at altitude z and sea level, i.e.,

$$f(z) = \rho(z)/\rho(0) \qquad (5)$$

where $\rho(z)$ is the density at altitude Z as given by the 1962 U.S. Standard Atmosphere (Ref 2) which was incorporated into AIRDIF.

The diffusion coefficient in Eq (3) incorporates a transport correction and is defined by

$$D^g \equiv 1/\{3\Sigma_{TR_0}^g f(z)\} = D_0^g/f(z) \qquad (6)$$

where $\Sigma_{TR_0}^g$ is the macroscopic transport cross section at sea level and is further defined by

$$\Sigma_{TR_0}^g \equiv \Sigma_T^g - \Sigma_{S1}^{g \to g} \qquad (7)$$

where Σ_T^g is the total macroscopic cross section and $\Sigma_{S1}^{g \to g}$ is the P_1 cofficient in the Legendre expansion of the angular dependence of the scattering cross section for the in-group scatter of group g.

Incorporation of Eq (5) and (6) into Eq (3) yields

$$\nabla\cdot\left[\frac{D_0^g}{f(z)}\nabla F\right]-\Sigma_{R_0}^g f(z)\,F^g = -S^g-\sum_{g'=1}^{g-1}\Sigma_S^{g'\to g}f(z)\,F^{g'} \qquad (8)$$

Inspection of the spatial leakage term $\nabla\cdot\left[\{D_0^g/f(z)\}\nabla F^g\right]$ in Eq (8) reveals that the density gradient $(\partial/\partial z(\rho_0/\rho_z))$ must also be determined as a function of altitude. A model was developed under the assumption of local exponential density variation and incorporated into AIRDIF.

Diffusion theory as employed in AIRDIF, separates collided and uncollided multigroup fluences. The uncollided fluence is determined by analytically evaluating Eq (1). The collided fluences are determined numerically by solving Eq (8). The total group fluences are then found by a simple group by group addition of the collided and uncollided fluences. Doses are determined by

$$\text{Dose} = \sum_{g=1}^{G} F_T^g(r)\,D_R^g \qquad (9)$$

where

$F_T^g(r)$ = the total fluence for group g at location r

D_R^g = the dose response function to a given material for energy group g.

Finally, K-Factors (if opted) are computed as the ratio of the 2-D $4\pi r^2$ variable density air dose to the 1-D $4\pi r^2$ MIS dose, i.e.,

$$\text{K-Factor} \equiv \frac{\text{2-D } 4\pi r^2 \text{ variable density air dose}}{\text{1-D } 4\pi r^2 \text{ MIS dose}} \tag{10}$$

Nonorthogonal Expanding Coordinate System

Since atmospheric density, $\rho(z)$, decreases exponentially with increasing altitude (z), radiation mean free path increases exponentially with altitude. To maintain a mesh interval which is constant in a mean free path sense, AIRDIF employs a nonorthogonal coordinate system which expands with altitude. AIRDIF's coordinates are defined by the equations

$$x_1 = r \tag{11}$$

$$x_2 = \phi \tag{12}$$

$$x_3 = z \tag{13}$$

where r, ϕ, and z are as shown in Fig. 1. The transformation from the AIRDIF coordinate system to cartesian coordinates is given by

$$x = r\, e^{Z/H} \cos \phi \tag{14}$$

$$y = r\, e^{Z/H} \sin \phi \tag{15}$$

$$z = z \tag{16}$$

where H in Eq (14) and (15) is the mesh expansion parameter. This parameter is varied with source altitude to control the rate of expansion of the coordinate system to coincide as closely as possible to the rate of density decrease of the 1962 U.S. Standard Atmosphere.

Note that, if the mesh expansion parameter is made

infinite in magnitude, Eq. (14), (15), and (16) reduce to normal cylindrical coordinates. This property enables AIRDIF to also operate in 1-D infinite homogeneous air. In this mode, the density function f(z) is set equal to the density ratio $\rho(z_s)/\rho_0$ where z_s is the source altitude, and the density gradient is set to zero. These operations are all performed automatically by the code when the 1-D mode of operation is selected. A pictorial representation of the AIRDIF expanding coordinate system is shown in Fig. 1.

Finite Differencing

Eq (8) is represented in terms of continuous functions and is finite differenced in AIRDIF for numerical solution. The region of problem definition is represented by a grid network as depicted in Fig. 2. By approximating the derivatives with first and second central differences (Ref 4:184), Eq (8) is replaced by a finite difference equation at each mesh point. These are nine point finite difference equations in 2-D variable density air because of the nonorthogonal coordinates. They reduce to five point equations in homogeneous air.

Matrix Equation Iterative Solution

The resulting finite difference equations can be written in matrix form as

$$\underline{A}\ \underline{F}^g = \underline{S}^g \qquad (17)$$

where $\underline{A}$ = a block tridiagonal matrix, which is a function

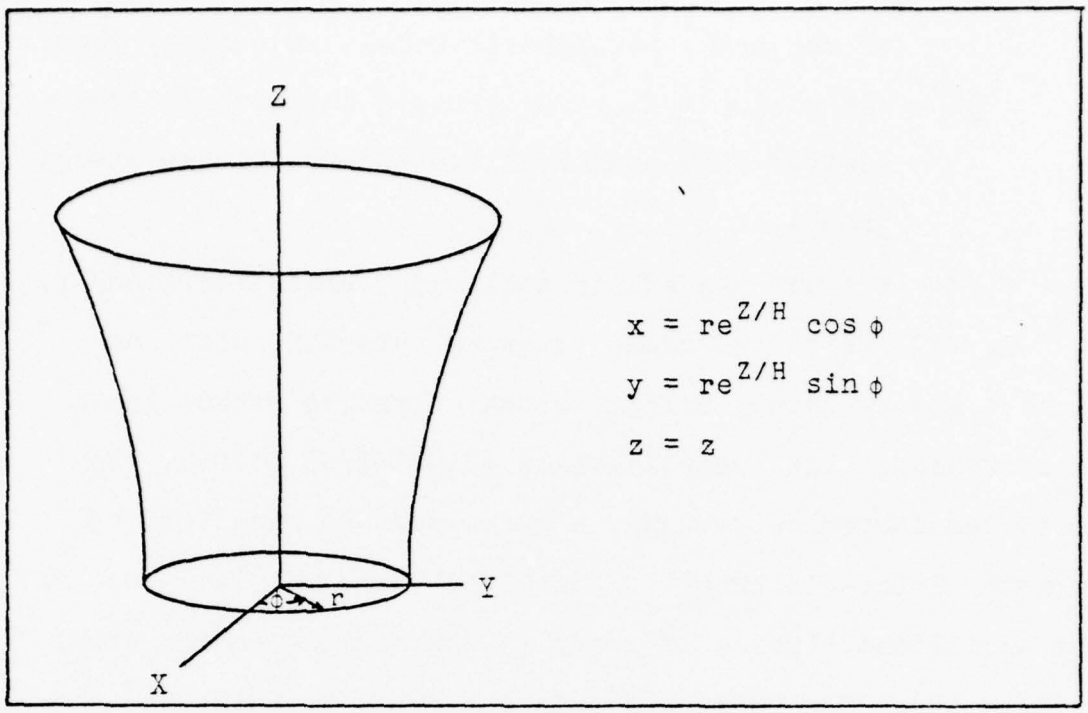

Fig. 1. AIRDIF Nonorthogonal Coordinate System (From Ref 1)

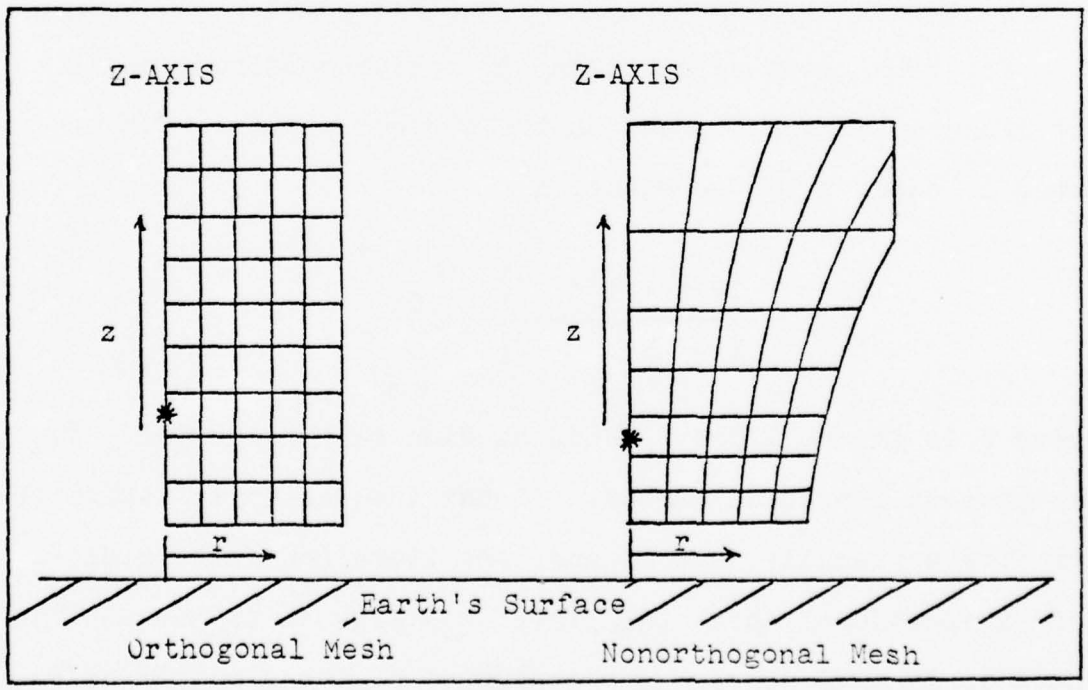

Fig. 2. AIRDIF Atmospheric Meshing (From Ref 3)

of the mesh, atmospheric model, and energy group,

$\underline{S}^g$ = the source vector for group g and includes the scatter from both collided and uncollided energy groups,

$\underline{F}^g$ = the unknown scalar collided fluence for group g.

Eq (17) is solved group by group, starting with the highest energy group, using a block iterative method known as successive line overrelaxation (SLOR) (Ref 5:199). To start the iterative process, a guess must be made for the unknown fluence in group g. In AIRDIF, the initial guess for the uncollided fluence in group 1 (the highest energy group containing source particles), is set equal to twice the value of the uncollided fluence in this group. For all other groups, the iterative process is initiated by using the solution to the previous group as the initial guess.

For each group calculation, iteration continues until the fluence value converges to the correct answer. Convergence is checked by the equation

$$\left| \frac{F^{(p)} - F^{(p-1)}}{F^{(p)}} \right| \leq .01 \qquad (18)$$

where F is the collided fluence at each mesh point and p is the present iteration number. If the inequality is satisfied for five consecutive iterations, the iteration is terminated and an additional check for proper convergence is made. This check is made by comparing the product of the $\underline{A}$ matrix and the group fluence vector $\underline{F}^g$ to the group source vector $\underline{S}^g$ at

all mesh points. If the difference is greater than 0.10, iterations are resumed. This process is continued until both convergence checks are satisfied.

Storage Method

The matrix $\underline{A}$ in Eq (17) is block tridiagonal. As a result, most of the elements have a value of zero. To take advantage of the sparseness of the tridiagonal matrix, special storage procedures are used in AIRDIF to conserve computer memory. Also, special multiplication schemes are used to eliminate unnecessary multiplication by zero elements. The following discussion summarizes the structure of the $\underline{A}$ matrix and storage of its elements within AIRDIF.

Referring to Fig. 3, the number of entries on each row is equal to the number of nonzero fluence points in the mesh. This number (NPTS) is the product of the number of horizontal mesh points on each row (NHOR) and the number of altitude rows (NROW). Although each row of matrix $\underline{A}$ contains NPTS points, there are at most nine nonzero elements on each row.

If the finite difference equations are written from left to right starting with the bottom row and each successive row, then the matrix $\underline{A}$ can be written in the block tridiagonal form shown in Fig. 4. Note there are 3 nonzero matrices per row. The zero matrices indicated in this figure do not have to be stored. The subscripts in Fig. 4 correspond to a given altitude row.

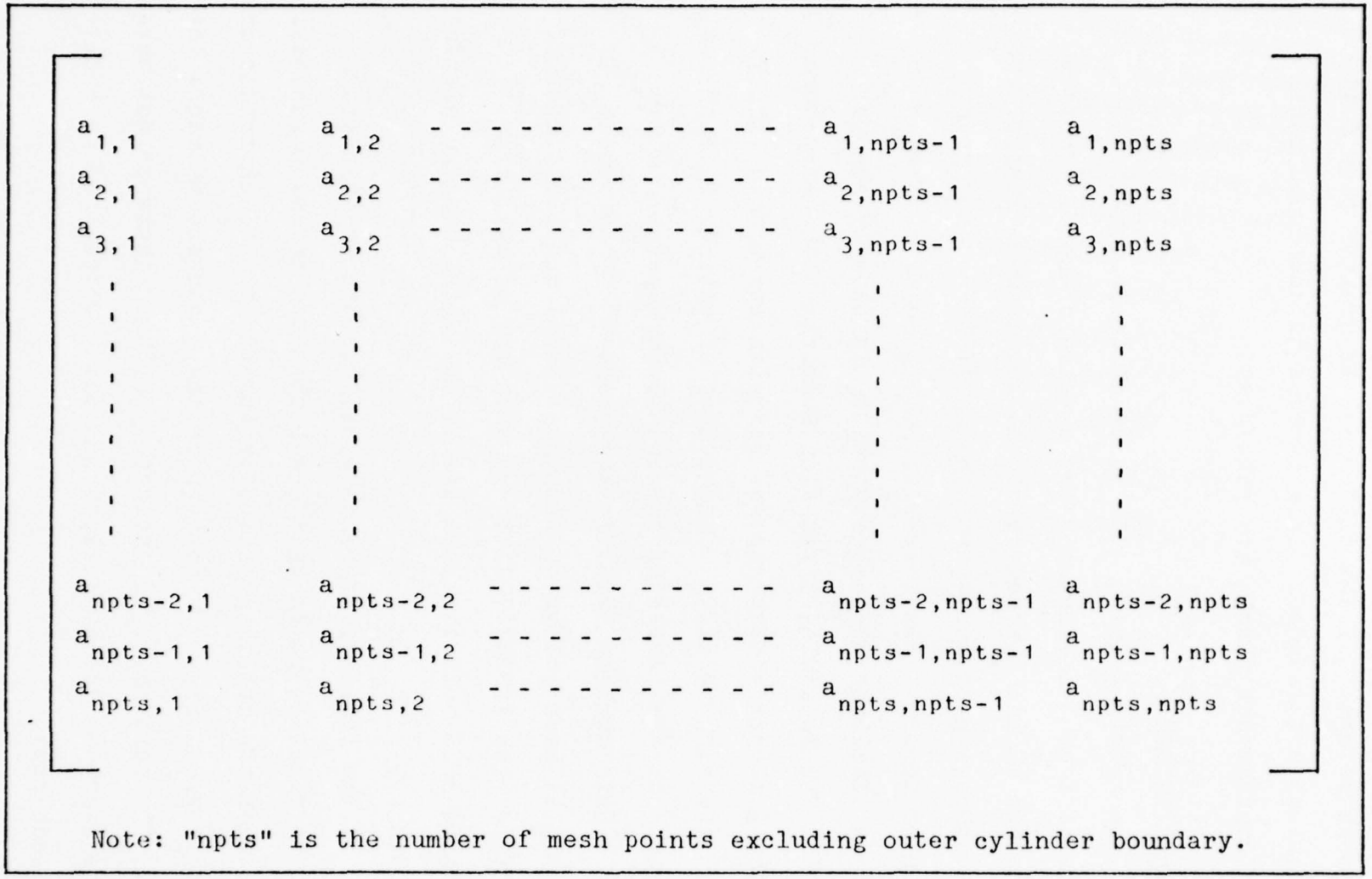

Fig. 3. The Coefficient Matrix A.

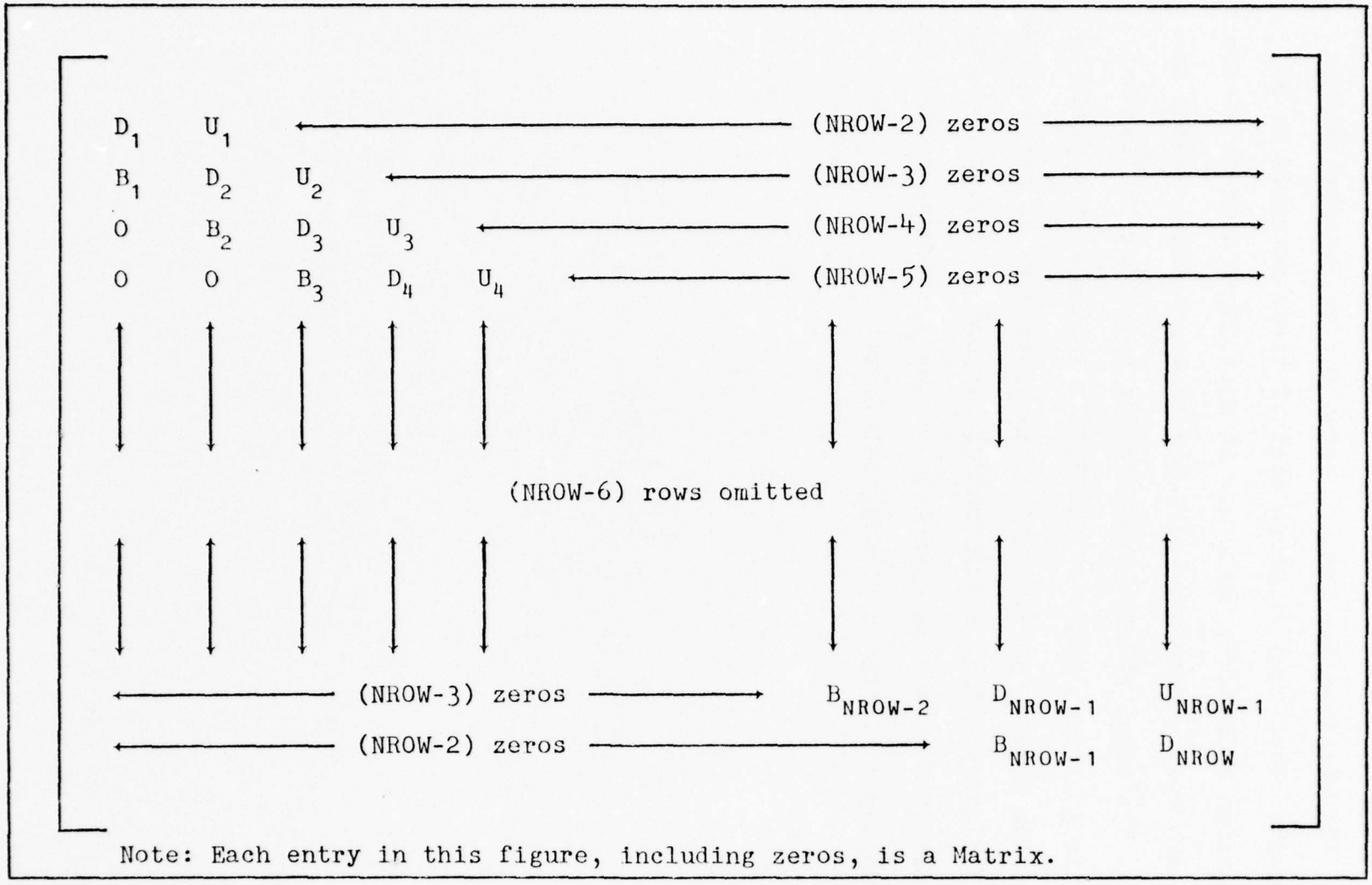

Fig. 4. The Matrix A in Block Notation.

Fig. 5 shows the storage setup for an internal matrix element. Note that although each of these matrices is of dimension NHOR*NHOR, there are at most three nonzero elements on each row. Therefore, they can be stored as a 3*NHOR array. The total storage required for the block tridiagonal matrix $\underline{A}$ is then (NROW)(3)(NHOR*3). If the entire $\underline{A}$ matrix had been stored, it would have been necessary to store $(NHOR*NROW)^2$ words. Thus a substantial savings in computer memory is realized by taking advantage of the sparseness and storing the $\underline{A}$ matrix in block tridiagonal form.

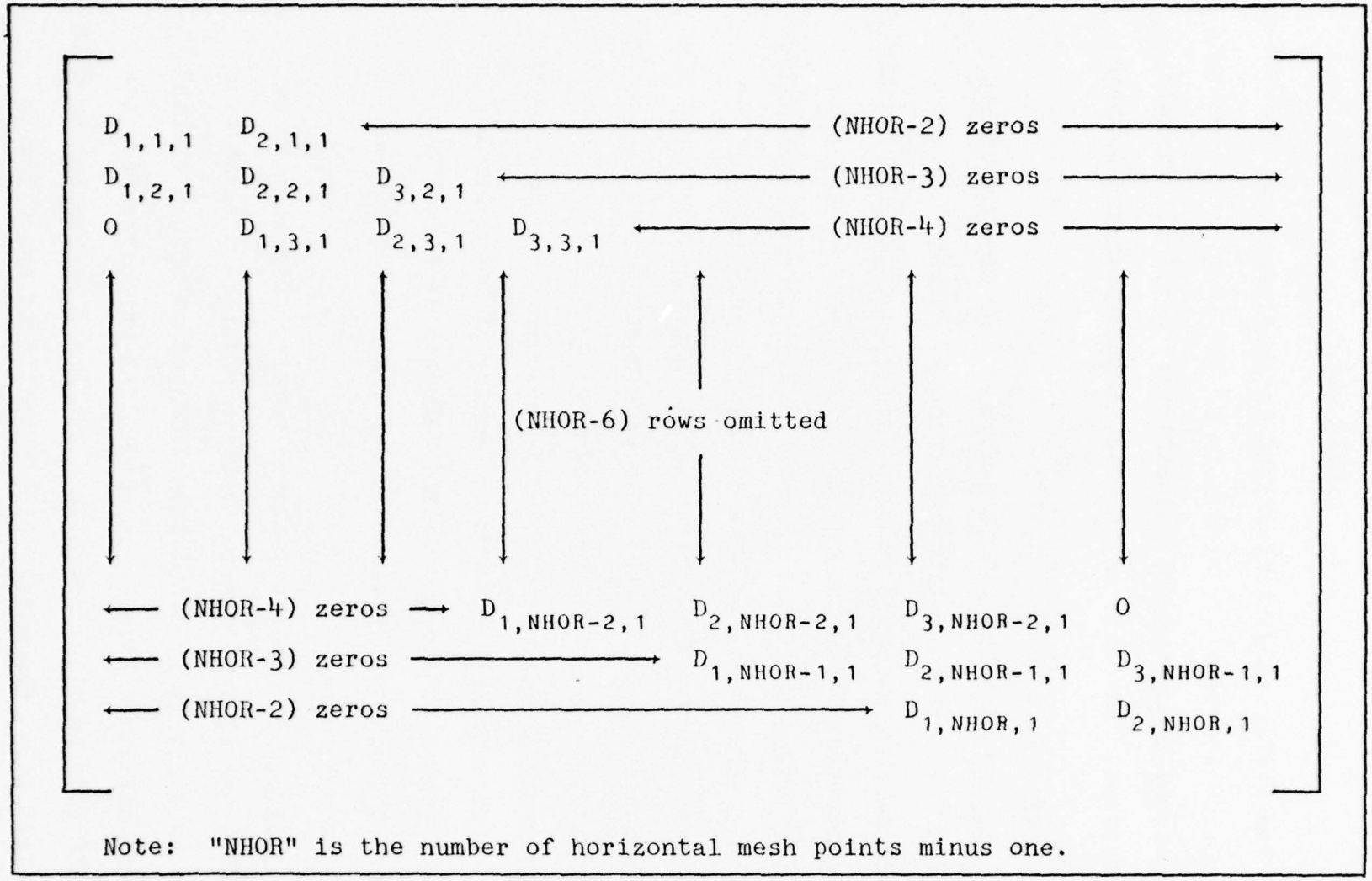

Fig. 5 The Tridiagonal Elements of a Block Matrix.

III. AIRDIF CODE

The AIRDIF code is described in this section. The discussion includes the structure of the code, computer operational requirements, capabilities, applications and limitations. The code is written in ANSI standard Fortran.

Structure

Modularity. The AIRDIF code consists of 43 modules. The modules are the calling program, 39 subroutine subprograms including an abort routine, and 3 function subprograms. The structure of the program is shown in the module flow diagram (Figs. 6 and 7). A brief description of each module is given in Appendix A. The calling program (AIRDIF) initiates execution of the program by calling the subroutine EXEC and stops execution of the code upon regaining control. Program execution can also be terminated by the subroutine ABORT, if an error is discovered by any subprogram during execution. The subroutine EXEC controls sequencing of the remaining modules. Variables are passed and returned as formal parameters through call statements between subprograms and their calling subprogram.

Hierarchy. In a structured modular program such as AIRDIF, the flow of control between modules is first from left to right by file and then from top to bottom by rank within any given file. The sequencing of control for the AIRDIF code is illustrated in Figs. 6 and 7. Beginning with the left file, the module AIRDIF initiates execution by

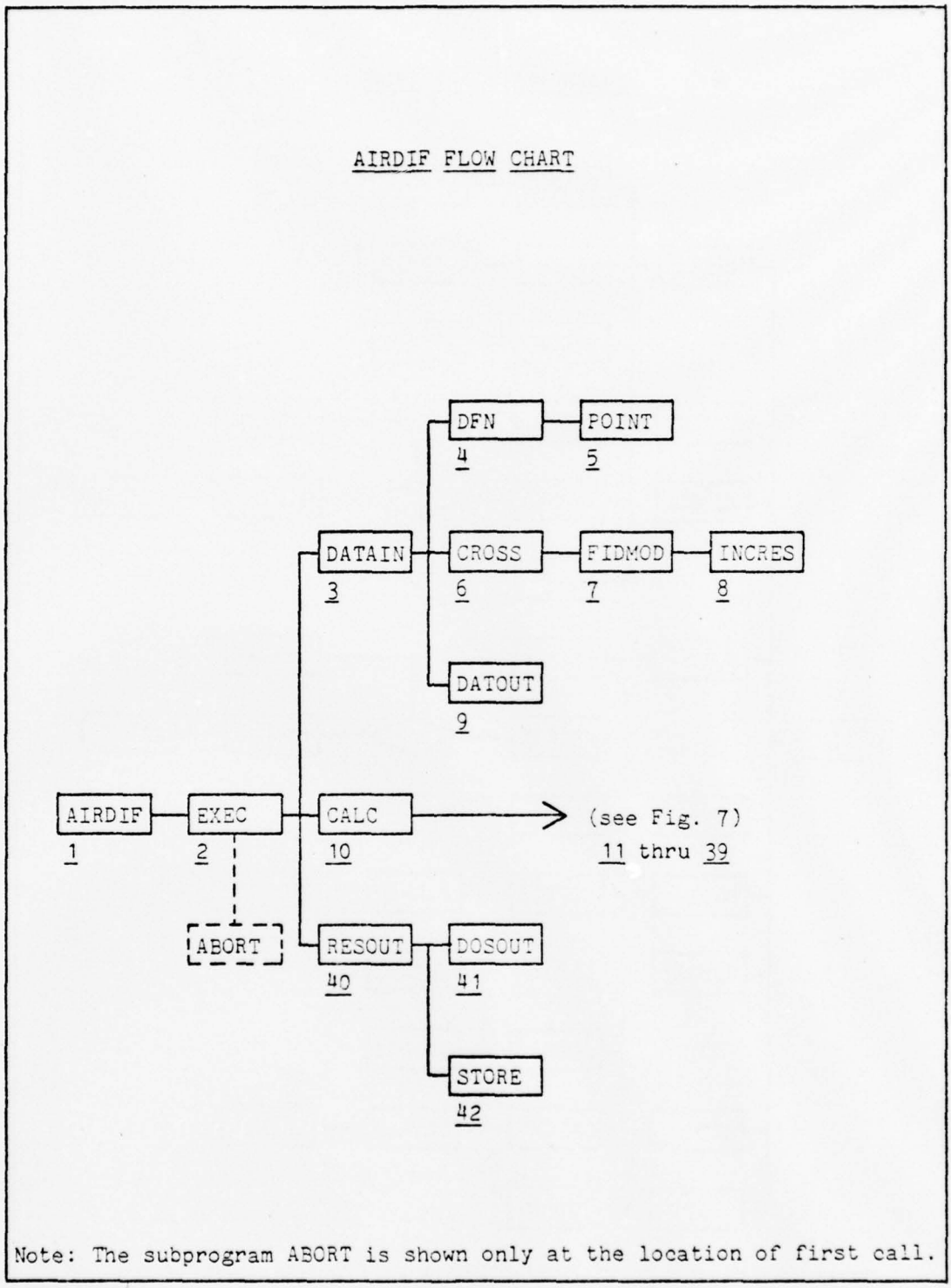

Fig. 6. AIRDIF Module Flow Diagram

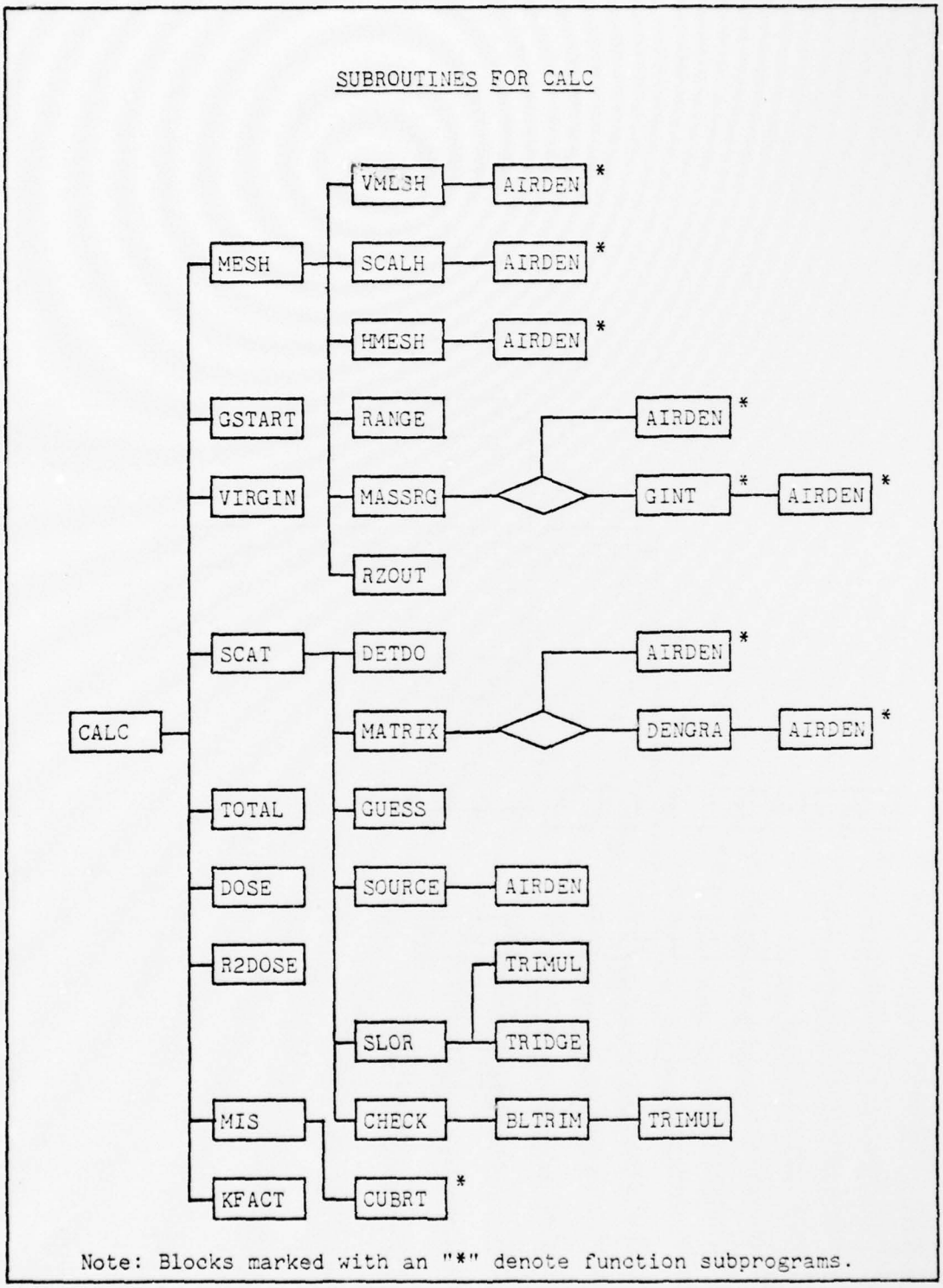

Fig. 7. Flow Diagram (Modules Subordinate to CALC)

calling the subprogram EXEC. Flow is again from left to right by file. The third file contains the modules DATAIN, CALC, and RESOUT. Within the file flow goes from top to bottom by rank. Therefore, DATAIN gains control next. As flow is always from left to right first and then from top to bottom, control would next be passed DFN, etc. The exact sequence of modular flow control by standard hierarchy is given by the underlined numbers below each of the modules in Fig. 6.

Versatility. The modularity of a structured code lends great versatility to the program. Since each subprogram is a separate module, any module can be replaced or modified without affecting the operation of the remaining modules. For example, AIRDIF in its present form employs a special form of diffusion theory for the basic calculations of the collided fluence. The only module that is unique to diffusion theory within AIRDIF is the subroutine MATRIX which defines the coefficients for the finite differenced diffusion equations. A higher order transport method such as Roberd's synthesis method (Ref 6) could be incorporated into AIRDIF by replacing this routine with one based on the finite differencing of the synthesis equation.

Each of the AIRDIF modules has been checked independently. In addition, independent checks were made on groups of modules. For example, the subroutine SLOR and its associated modules perform the iterative solution of the matrix equations. This algorithm was verified by comparing the

iterative solution for a number of relatively small matrix equations to the known, exact solution. The subroutine DATAIN, which reads in the problem data, and its associated subroutines were checked independently for their ability to read, process, and output data. The subroutine MESH and its associated routines were checked for their ability to collapse the coordinate system to normal cylindrical coordinates for one dimensional homogeneous air calculations. The performance of checks such as these not only eliminates problems during code development, but also enhances the credibility of the results when the code becomes operational.

Computer Requirements

The major determining factors in the computation of computer costs are execution time and memory (storage) requirements. AIRDIF has been run on both the CDC 7600 and the CDC 6600 computer systems at Kirtland AFB, N.M. and the CDC 6600 at Wright-Patterson AFB, Ohio.

Time (CPU). Execution times vary depending on the problem. The major factors causing variation in the time are the number of mesh points, the number of energy groups, and the rate of convergence of the iterative solution. Typical times for execution on the CDC 7600 are on the order of 60 seconds for 1500 mesh points and 58 energy groups. Execution on the CDC 6600 typically takes four to five times longer than the CDC 7600.

Storage. The memory requirement for the CDC 6600 is

approximately 200 K OCTAL[†]. This provides adequate storage for 1500 mesh points and 61 particle energy groups. A maximum of 40 neutron groups and 21 gamma groups can be used.

The AIRDIF program requires 15 magnetic disc files for local storage of calculated quantities and output. The use of these files allows multiple use of many of the large arrays during various steps of operation of the calculational algorithms. This greatly reduces the computer memory requirements. The data output (storage file #21) can be made into a permanent file for later access of information by edit codes. This is done through the use of the proper control cards, which on most systems consist of a permanent file request card before compilation and a catalog card after execution. In addition, a "1" must be specified on the third entry of data card #4 (see the data card instructions in Sec IV). A list of the usage of each of the disc files is presented in Table I.

Associated Edit Programs

Several data editing codes were developed to access and use the data generated by AIRDIF. The functions of these programs could have been included as modules in the main program but were made separate entities to reduce computer time and storage requirements of the main program. This, of course, results in savings of real turn around time for the user by increasing the job priority on time sharing systems.

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† The CDC 7600 requires 220 K OCTAL LCM and 33 K OCTAL SCM for 5000 mesh points and 61 particle energy groups.

Table I
Disc File Usage

Disc File #	Usage
5	Program input file
6	Program output file
10	Cross section storage
11	Direct fluences storage
12	Slant range storage
13	Horizontal ranges storage
14	Mass range storage
15	Collided fluences storage
16	Total fluences storage
17 (temporary)	Group doses storage
17 - Record #1	Neutron doses storage
17 - Record #2	Gamma doses storage
18 - Record #1	$4\pi r^2$ neutron doses storage (2-D)
18 - Record #2	$4\pi r^2$ gamma doses storage (2-D)
19 - Record #1	$4\pi r^2$ neutron doses storage (1-D)
19 - Record #2	$4\pi r^2$ gamma doses storage (1-D)
20 - Record #1	Neutron K-Factor storage
20 - Record #2	Gamma K-Factor storage
21	Problem parameters, total fluences, and meshing information for the permanent data file.

Two edit codes, MISFIT and DOSCOMP, were written to be used in conjunction with AIRDIF. Basic theory, descriptions, and user guides for these codes are included in Appendices B and C. Only a brief description of these edit codes is provided here.

The MISFIT edit code is utilized to access a 1-D infinite homogeneous air data file produced by AIRDIF. MISFIT first uses the AIRDIF data to compute doses and then least squares fits the doses to Murphy's radiation transmission equation (Ref 7:36). Murphy's radiation transmission equation is given by

$$\ln(T) = A_1+A_2X+A_3X^2+A_4(X)^{3/2}+A_5(X)^{1/2}+A_6(X)^{1/3}+A_7\ln(X) \quad (19)$$

where T is the $4\pi r^2$ dose at mass range X, and A_1 thru A_7 are the coefficients. These coefficients (MIS coefficients) are then used as part of the input for the 2-D variable density air AIRDIF run (Ref card #10 and 11). AIRDIF utilizes these coefficients and Murphy's transmission equation to compute the 1-D MIS dose which is required in the computation of K-Factors. Fig. 8 illustrates the sequence for the use of the MISFIT edit program with AIRDIF and the associated input and output for MISFIT.

The DOSCOMP edit program also accesses a data file produced by an AIRDIF run and computes doses using any response function desired. Additional dose calculations and K-factors (if opted) are made in seconds of computer time rather than minutes that would be required for another AIRDIF run. The

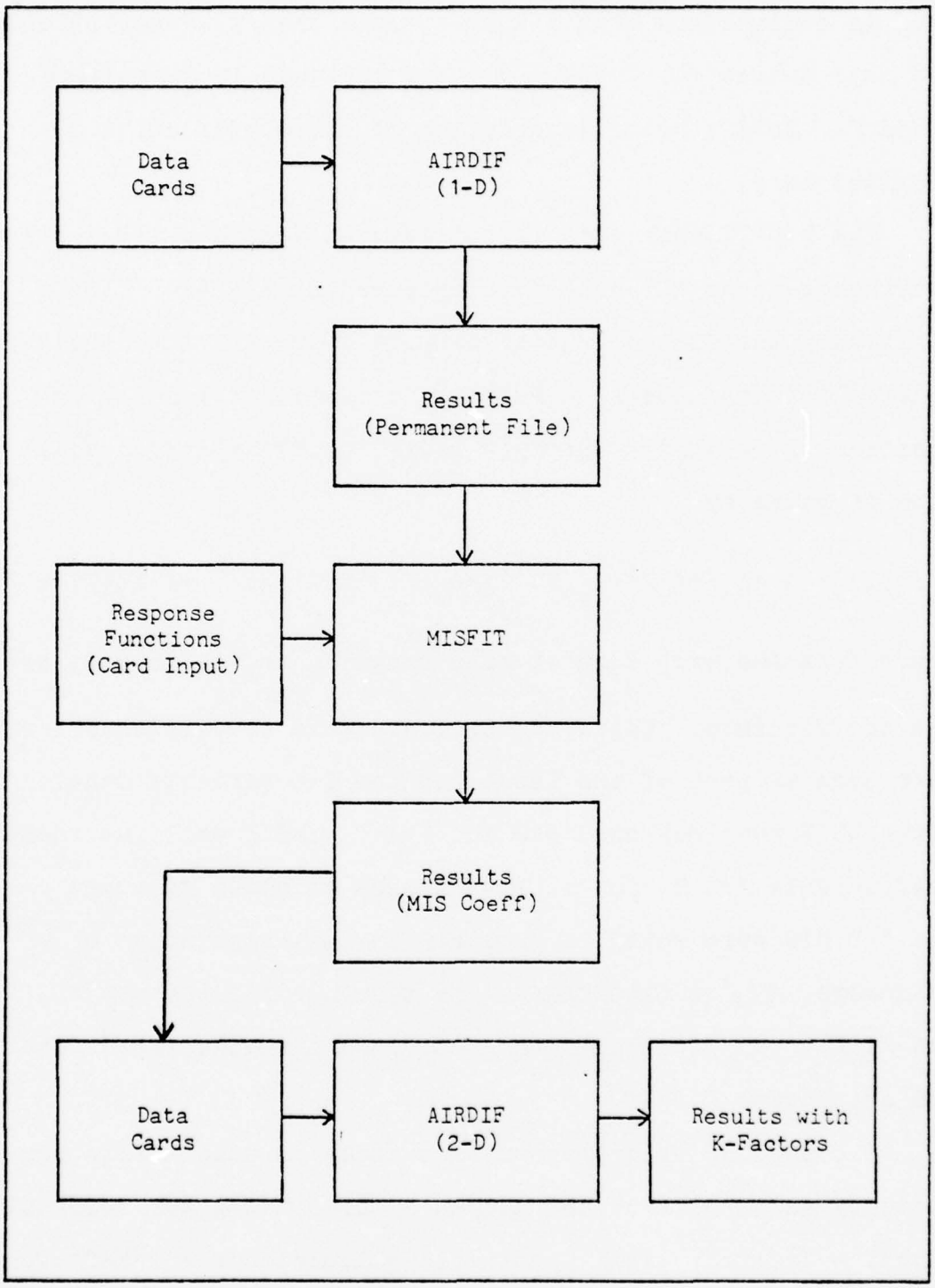

Fig. 8. MISFIT/AIRDIF Sequence Chart.

time savings are realized because DOSCOMP does not have to numerically solve the diffusion equation. Utilization of the DOSCOMP edit code with AIRDIF is illustrated for dose only computations in Fig. 9 and for dose plus K-Factor computations in Fig. 10.

AIRDIF Capabilities

Some AIRDIF code capabilities have already been mentioned briefly in the introduction. A more detailed description of the various capabilities of AIRDIF is presented here.

Operational Modes. AIRDIF can be run in either 1-D homogeneous air or 2-D variable density air. In the 1-D mode, the nonorthogonal expanding coordinate system is collapsed internally to normal cylindrical coordinates by setting the mesh expansion parameter (H) in Eqs (14) and (15) to 1×10^{10} km. In the 1-D mode, the density function f(z) is set equal to a constant which is equal to the ratio of the atmospheric densities at the source altitude and sea level. The density gradient g(z) is then internally set to zero.

In 2-D variable density air, AIRDIF can be used to compute the radiation environments and (if opted) the K-Factors. If K-Factors are desired a 1-D air run must be made first, and the 1-D data must be stored on a permanent file. MISFIT is then used to get the MIS coefficients to Murphy's transmission equation. As mentioned above, these coefficients then become part of the data for the 2-D air run.

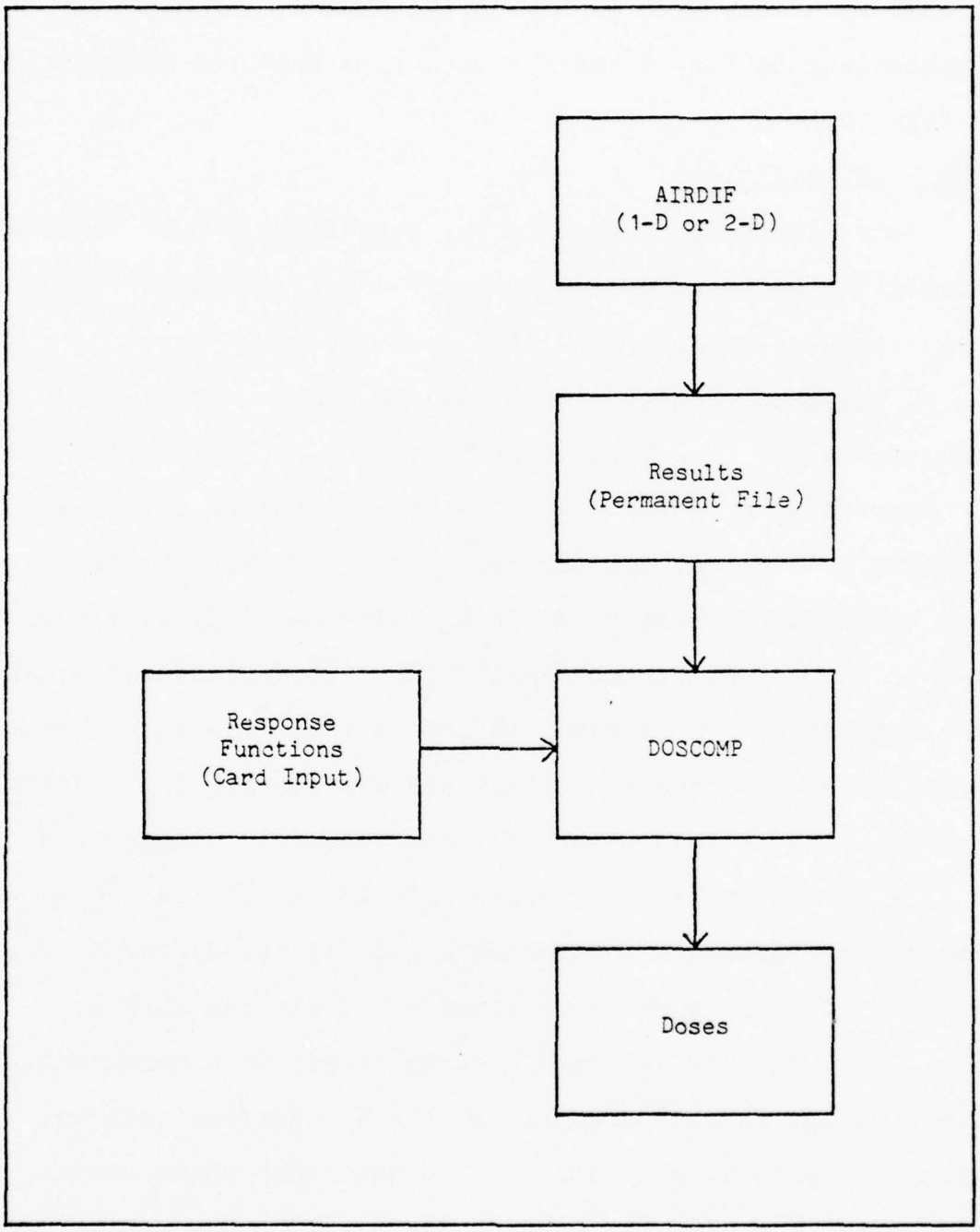

Fig. 9. DOSCOMP/AIRDIF Sequence Chart for Doses Only.

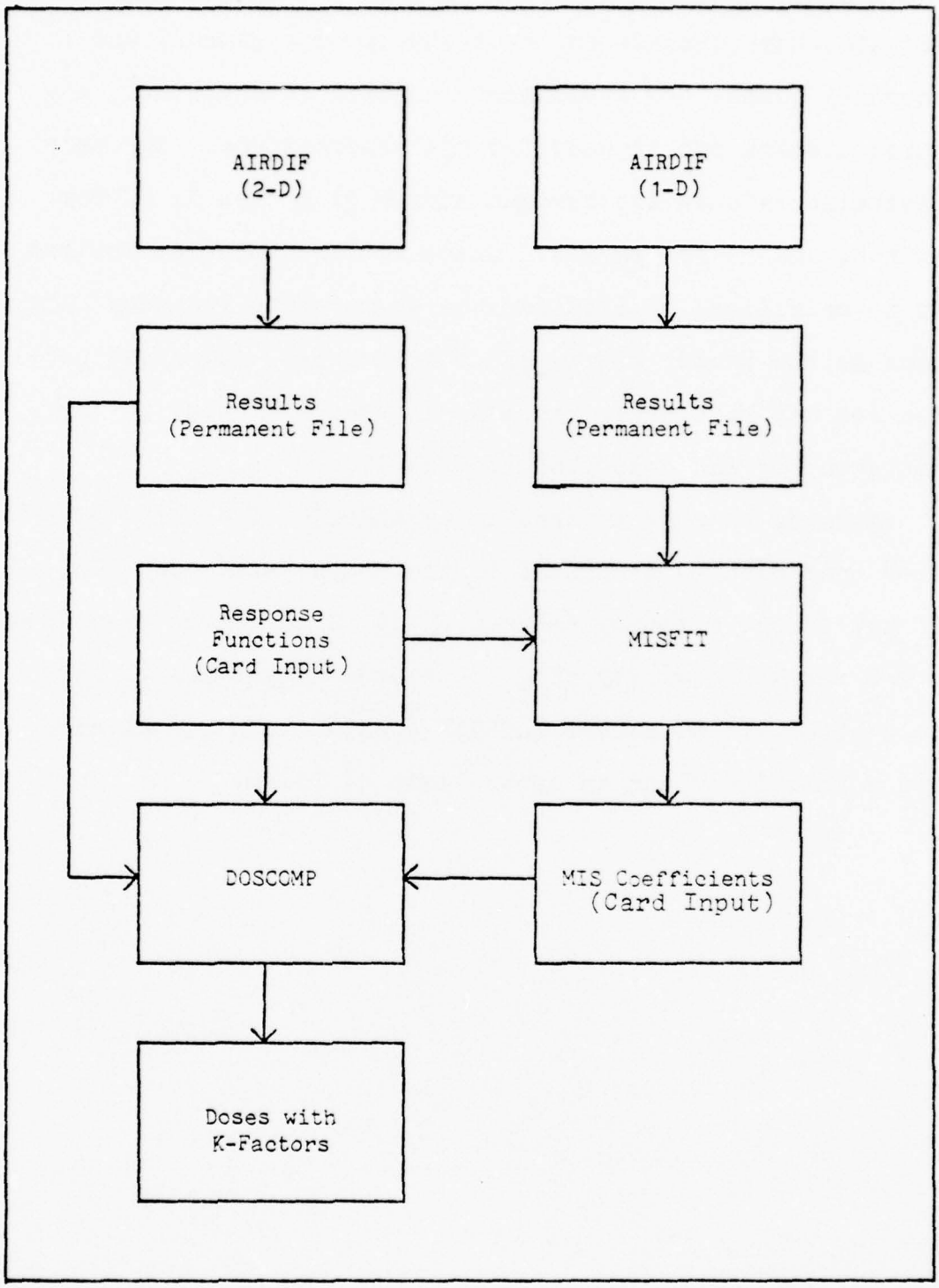

Fig. 10. MISFIT/DOSCOMP/AIRDIF Sequence Chart for Doses and K-Factors.

Problem Parameters. AIRDIF computes the free field radiation environments for neutrons, prompt gammas, and secondary gammas for atmospheric nuclear detonations. Any source spectra can be used for the computations. The only constraint is that the maximum number of groups is 40 for neutrons and 21 for gammas. Doses for any material desired can be calculated by inputing the appropriate response functions in the proper energy group structure. Any cross section set may be employed as long as they are input in the multigroup format described in Sec. IV.

Meshing is done internally by AIRDIF. The only parameter that must be specified is the source altitude. In 1-D air any source altitude between 0 and 20 km can be specified. In 2-D variable density air, the source height has a lower limit of about 300 meters (AIRDIF does not contain an air/ground interface) and an upper limit of 20 km.

IV. AIRDIF User's Guide

This section presents a user's guide for the AIRDIF code. Subsections are included on input, output, and sample problems.

INPUT

The input for the AIRDIF code consists of three types of cards. These are the control cards, the program deck, and the data cards. These basic units are ordered as shown in Fig. 11.

Control Cards. The control cards consist of cards giving the job identification, system requirements, control commands, and file separators. These cards will not be discussed because they are unique to individual computer systems.

Program Deck. The program deck contains all the program instructions. As pointed out earlier, AIRDIF is written in ANSI Standard Fortran. The program deck can be input as a source deck or as a compiled binary deck. Of course, if AIRDIF is stored on a permanent file, it can be called by control cards and the program deck would not be required.

Data Cards. Data cards contain the information necessary to define a particular problem. Problem defining parameters, cross sections, SLOR convergence factors, response functions, and MIS coefficients must be input. Detailed instructions for each data card are given in the following paragraphs.

1. Card #1: This contains the title for the problem in a

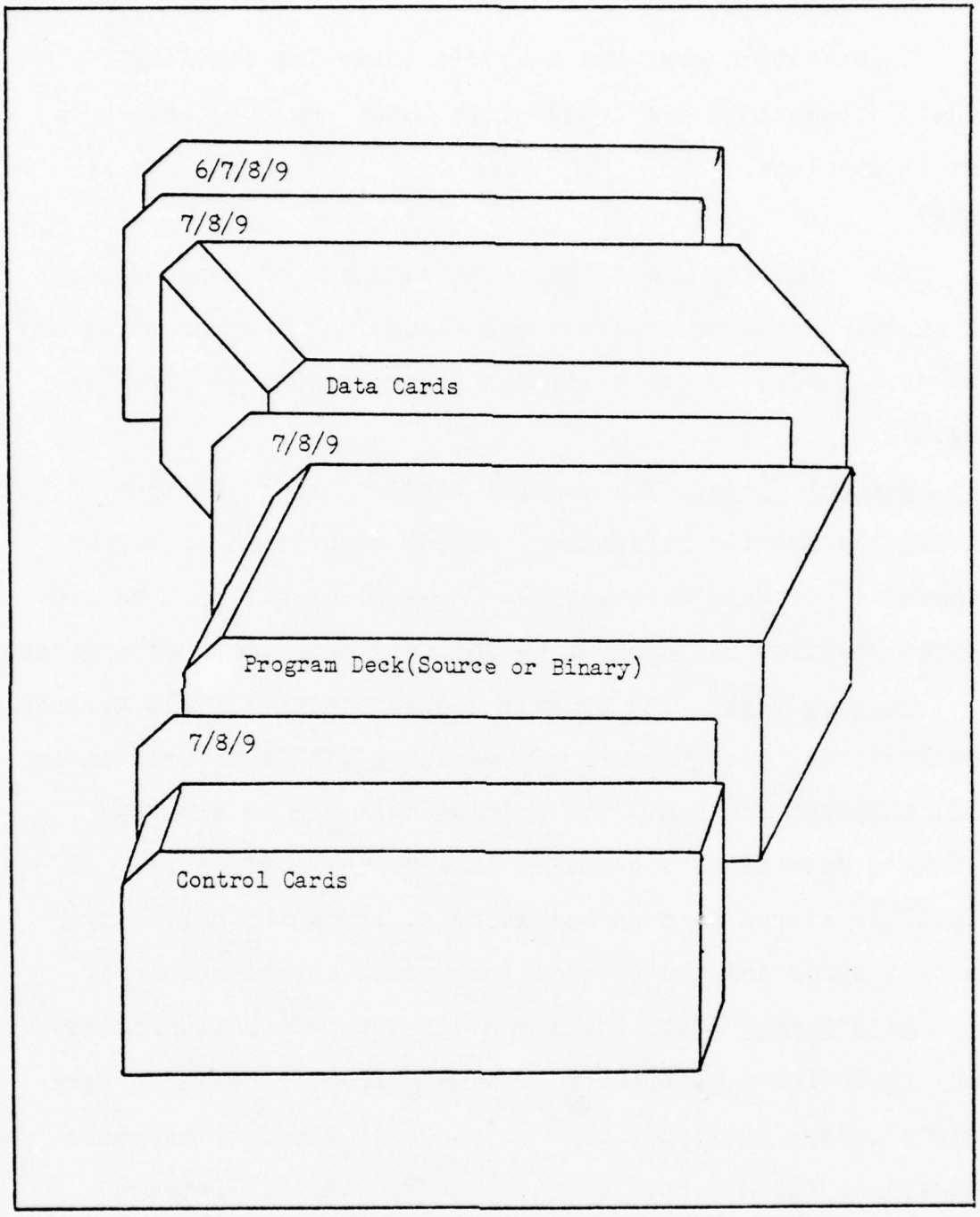

Fig. 11. AIRDIF Batch Deck Structure.

12A6 format (thus the title is entered in the first 72 columns of the first card).

2. Card #2: This card contains two integer entries in a 2I3 format. The first entry is the number of neutron energy groups, and the second entry is the number of gamma energy groups.

3. Card #3: This card has two entries in a E10.0,I3 format. The first entry is the source height (km) in E10.0 format. The second entry is the mode of operation of the code which may be either 1-D homogeneous air or 2-D variable density air. The mode is specified by either entering a "1" or a "2" for the second entry of this card in I3 format (ie., in column 13).

4. Card #4: This card contains two entries in a I3,I6 format. Entry number one is the cross section print option in I3 format. Entering a blank or a zero in column 3 results in the following action: "Do not print cross sections." Entering a "1" results in the action: "Do print cross sections." Entry number two in I6 format is the store data option. This entry allows for the storage of data on a permanent file (Tape 21) that may be accessed by edit codes after execution is completed. Entering a blank or a zero in column 9 results in the action: "Do not create a permanent file." Entering a "1" in column 9 results in the action: "Do create a permanent file." If a permanent file is to be created, most systems require a request card before

execution and a catalog card after execution in the control card section.

5. Card #5: Card number five is a deck of cards containing overrelaxation factors required by the SLOR iterative solution algorithm. The optimum SLOR factors for each energy group in the DLC-31 structure (Ref 8) were experimentally determined (Ref 3). These factors are listed in Table II and should be entered in 6E10.0 format (i.e. six entries per data card). The total number of entries must equal the total number of particle energy groups which were specified in card #2 (i.e. number of neutron groups + number of gamma groups). The neutron groups are listed first starting with the highest energy group. The first gamma group follows the last neutron group on the same card unless that card already has six entries. Each line of Table II represents the entries for one card using the DLC-31 structure mentioned above. SLOR factors for a different energy group structure can be obtained from Table II by interpolation. (See Table XVII, Appendix E, for DLC-31 energy structure.)

6. Card #6: Card number six is a deck of cards containing the source spectra in a 6E10.0 format. The source spectra for the neutrons is entered first (highest energy group first), followed immediately by the source spectra for the gamma rays (again highest energy group first). Again entries are made at the rate of six per card with the first gamma

Table II
Group SLOR Factors

1.2	1.2	1.2	1.2	1.2	1.2
1.2	1.2	1.2	1.3	1.4	1.4
1.2	1.0	1.0	1.0	1.2	1.2
1.2	1.2	1.2	1.2	1.2	1.2
1.2	1.2	1.2	1.2	1.2	1.2
1.2	1.2	1.2	1.2	1.2	1.2
1.2	1.7	1.6	1.4	1.4	1.4
1.4	1.4	1.4	1.2	1.2	1.2
1.2	1.2	1.2	1.4	1.0	1.0
1.0	1.0	1.0	1.0		

group following the last neutron group on the same card as described above. The total number of entries must be equal to the total number of particle groups as specified on card #2. Typical weapon-like energy spectra for neutrons and prompt gammas in the DLC-31 structure are included in Appendix E.

7. Card #7: On this card the title for the dose response function type is entered in 12A6 format. A representative set of tissue and silicon response functions for neutrons and gamma rays is given in Appendix E.

8. Card #8: This is a deck of cards which contains the multigroup neutron response functions. The numbers are entered in 6E10.0 format (six per card). Again, the number of entries must equal the number of neutron energy groups specified on card #2. The responses are entered in the order of decreasing energy, i.e. entry #1 is the response function for neutron group #1 which is the

highest energy group.

9. Card #9: This deck of cards contains the gamma response functions. Entries are made in the same format (6E10.0) and order, highest energy group first, as described above for card #8.

10. Card #10: The seven coefficients to the fit of the neutron dose 1-D mass integral scaled (MIS) data are entered on this card in 7E10.0 format. The coefficients as discussed in Section II are obtained from the edit program MISFIT which performs a least squares fit to the actual data from a 1-D homogenous air AIRDIF run to Murphy's radiation transmission equation (see Equation 19).

11. Card #11: The seven coefficients to the fit of the gamma dose 1-D MIS data are entered on this card in 7E10.0 format. Coefficients on cards 10 and 11 are used by AIRDIF only during 2-D air calculations where K-Factors are desired. During AIRDIF runs in which K-Factors are not desired these cards must still be included in the input deck, but blank cards may be used.

12. Card #12: This card contains the title of the cross section set in 12A6 format.

13. Card #13: This card is a deck of cards containing the multigroup cross sections for both neutrons and gammas which are read in at sea level density (ρ_0=1.225E-3 g/cm^3). The cross sections are entered in a format which is a modified version of FIDO format (Ref 7) given by

FORMAT (6(I2,A1,I6,I3),5X,I3)

This format calls for six consecutive cross sections to be entered on each card and entered in (I2,A1,I6,I3) format (12 columns each). The six cross section entries on each card are followed by five blanks (5X) in columns 73 through 77. The last three columns of each card contain the card number (I3) of the cross section deck. The format of each of the cross section entries (I2,A1, I6,I3) consists of four separate entries. The first entry (I2) designates the number of times this cross section shall be repeated. The second entry (A1) is the repeat/terminate option parameter. If this entry is a "T", cross section reading is terminated immediately. The previous cross section read would be the last in the set stored in the AIRDIF program. If this repeat/terminate option parameter is an "R", then this cross section will be entered the number of times designated in the first entry of the cross section. If this entry is a blank, then the cross section will be entered in program storage only once, the number in the first entry is ignored, and the program will advance to read the next cross section. The third number in the cross section entry is the number base of the cross section entered in I6 format. The fourth element of the cross section entry is the exponent and exponent sign of the cross section entered in I3 format. The cross sections are read group by group starting with

the highest energy neutron group, proceeding through the neutron groups, and finally proceeding on through the gamma groups, again starting with the highest energy. The order in which the cross sections must be entered for each energy group is given in Table III.

Table III
Order of Cross Sections for FIDO Format

Position	Cross Section
1	removal
2	transport
3	total
4	scatter(g→g)
5	scatter(g-1→g)
6	scatter(g-2→g)
7	scatter(g-3→g)
etc.	etc.

Note: "g" represents the energy group (#1 is highest).

Samples of the card entries for each of the 13 input data cards listed in the above data card instruction list are presented in the sample problems in Appendix D. Table IV contains a summary of the AIRDIF input data cards.

Output

The AIRDIF output consists of a cross section listing (if opted), problem definition parameters listing, input data listings, mesh information, and results in terms of particle doses and K-Factors.

Cross Section Listing. A complete listing of the cross sections used for calculations can be printed in the output,

Table IV
Summary of Input Data Cards for AIRDIF

Card #	Format	Description
1	12A6	Title card for program
2	2I3	Number of groups (neutrons/gammas)
3	E10.0,I3	Source height, dimension
4	I3,I6	Option card
5	6E10.0	SLOR convergence factors
6	6E10.0	Source spectra (neutrons/gammas)
7	12A6	Response functions title
8	6E10.0	Neutron response functions
9	6E10.0	Gamma response functions
10	7E10.0	Neutron MIS coefficients
11	7E10.0	Gamma MIS coefficients
12	12A6	Cross section title card
13	FID0	Cross sections

if the proper entry is made on the option card (card #4) as discussed in the instructions for data cards. The DLC-31 cross sections as printed in this format are given in Appendix E. Identification of the cross sections for any column (energy group) in this table (Table XX) can be made by referring to Table III.

Problem Definition Parameters Listing. The nontabular information unique to a particular problem is contained in this section of the data listing. First is the problem title exactly as entered on data card #1. The title appears in the output immediately after the cross section listing. The remaining problem definition data appear next in the following order: source height, number of neutron groups, number of gamma groups, the grid increment given in terms of mass range, the maximum horizontal range in terms of mass range, the maximum vertical range from the source in terms of mass range, and the desired dimension of the problem (1-D or 2-D). Actual examples of this output can be found in the output for the sample problems presented in Appendix D.

Input Data Listings. The next portion of the output is a listing of all the tabulated input data. The items included are group SLOR factors, neutron source spectra, gamma source spectra, neutron response functions, gamma response functions, neutron MIS coefficients, gamma MIS coefficients, and the title for the cross sections used. Actual examples of this output can be found with the sample problems presented in Appendix D.

Mesh Information. The next portion of the output is a summary of the mesh as calculated by the AIRDIF program. The following are listed: the mesh expansion parameter, mesh dimensions in terms of number of horizontal and vertical points, a summary of the horizontal mesh at sea level, a summary of the vertical mesh, and the increments (delta Z).

Results. The last section of printed output is the section containing the results. This section titled "Doses and K-Factors" lists all mesh points of the 2-D mesh scheme, line by line, beginning with the bottom line. The points on each line are given in order from the axis of symmetry (Z-axis) to the outer boundary. The horizontal point numbers are listed under column "I" and the vertical line numbers are listed under the column "J" in the output. For each point, the output listing gives the following information: altitude, horizontal range, slant range from the source, mass range from the source, doses, $4\pi r^2$ doses, and K-Factors (for both neutron and gamma particles).

There are three possible types of data which can be output in the K-Factor column. When the AIRDIF code is operated in the 1-D air mode, K-Factors are not computed and all entries under the K-Factor column are appropriately printed as unity (1.00E+00). As pointed out earlier, in the 2-D variable density air mode, AIRDIF can be used to compute environments alone or environments plus K-Factors. If K-Factors are required, the MIS coefficients must be included in the input. If the code is being used to produce environments

only, then the MIS coefficients should be input as zeros (blank cards). This action will result in all 1-D MIS doses being set equal to unity, and hence, the K-Factors will assume a pseudo value equal to the 2-D $4\pi r^2$ doses.

Another possible AIRDIF output is the error diagnostic statement. If the program detects an error at any place, execution is terminated through the subroutine ABORT. No further normal output data are printed after the point of error detection. However, the output does include a statement of error diagnosis which explains the error and gives the subroutine location of the error.

Sample Problems

To further illustrate how to use the AIRDIF code and the associated edit programs, detailed sample problems are presented in Appendix D. Both the input cards and some representative portions of the printed output are listed for each of the problems. Sample problems are included for both 1-D homogeneous air and 2-D variable density air operation. Table V summarizes the problems included in Appendix D.

Table V

Sample Problems

GIVEN:
1. A fission detonation at 5 km altitude and a thermonuclear detonation at 15 km altitude.
2. Oak Ridge unclassified normalized neutron source spectra.
3. DLC-31 (37/21) coupled neutron/gamma cross sections.
4. Silicon response functions.

FIND: Free field doses, $4\pi r^2$ doses, and K-Factors (1-D and 2-D air).

SOLUTION:
1. Follow the user's guide to enter data on cards.
2. Using the fission source, perform a 1-D AIRDIF run obtaining 1-D results and create a permanent file of the results.
3. Exercise the MISFIT program to obtain MIS coefficients.
4. Using the fission source, perform a 2-D AIRDIF run obtaining 2-D results and K-Factors.
5. Using the thermonuclear source, perform a 2-D AIRDIF run obtaining environments only.

V. Limitations

Although diffusion theory gives extremely good results at very little cost, as verified by Shulstad (Ref 1), there are certain inherent limitations to be aware of when using the code. This section briefly discusses some of these limitations.

Boundary Value Degradation

Because the angular dependence of the fluence in diffusion theory is limited to linear variations, the diffusion results become suspect and can not be used with confidence within a few mean free paths (20-30 g/cm^2) of a boundary: the conditions that are applied here (zero fluence on the sides and zero partial return current at the top and bottom) are only approximations made to close the solution. Therefore, the results on the first two rows, last two rows, and the last four points on any row should not be used.

Altitude Limits

In 1-D air, AIRDIF may be run at any altitude between 0 and 20 km. In 2-D air, restrictions are imposed on the lowest and highest source altitudes. The limitation of the lowest altitude arises from the fact that AIRDIF does not contain an air/ground interface. In meshing down from the source height, AIRDIF will set the lower altitude boundary at 250 g/cm^2 below the source altitude but never lower than 50 g/cm^2 above ground (Z=0). The user should restrict the

source altitude during 2-D runs to altitudes greater than 300 meters. The upper source altitude limit is 20 km (can be equal to 20 km). This limitation arises from the inability of simple diffusion theory to treat streaming radiation which characterizes particle transport at high altitudes where the air density is very low.

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Appendix A

Module Descriptions

This appendix contains brief descriptions of the modules in the AIRDIF program. For each module, the purpose, a brief summary of the calculations performed within, and the sequential relationship to other modules is discussed. The order of presentation of module descriptions is governed by the hierarchy depicted in the module flow diagram in Figs. 6 and 7. The exception is that the three function subprograms are given last.

Program AIRDIF

AIRDIF is the main program which initiates execution of all remaining modules. Through the program statement, this module acquires and attaches all necessary disc files. The calling program passes control to the executive routine, EXEC, through a call statement and terminates the program upon return of control. The subprogram EXEC is the only external subroutine connected directly to the main program.

Subroutine Subprograms

EXEC. This is the executive routine for the AIRDIF program. EXEC receives its control from the main program and transfers control as necessary for data acquisition, calculation, or proper disposition of results. This is accomplished by calling DATAIN, CALC, and RESOUT respectively. EXEC also reserves the required memory for the entire program by initializing and dimensioning the arrays and setting their

maximum sizes. Data input cards #1 and #2 are also read by this routine.

ABORT. The routine ABORT can be called from any place in the program where an error is detected. The type of error is printed upon detection and the module which detected the error is identified. Program execution is then terminated by ABORT.

DATAIN. DATAIN is called by EXEC. This is the command routine for initiating the reading of problem definition data, source spectra, response functions, SLOR convergence factors, and cross sections. The only card actually read by this subroutine is #12, the cross section title. The storing of cross sections on disc file #10 also takes place under the command of this routine. This routine has three externals which are DFN, CROSS, and DATOUT.

DFN. This routine is called by DATAIN. Input data cards #3 through #11 are read by this routine. The maximum ranges in terms of mass units (ρr), the horizontal mass range at coaltitude, and the vertical range up and down from the source are determined by DFN. The mesh interval or mesh point increment is also determined here. The only external to this routine is POINT.

POINT. This is a routine called by DFN to determine the number of mesh points. POINT determines the number of points up and down from the source, the number of horizontal points, and the total number of points. A check is also made to

assure maximum array sizes are not violated by the meshing.

CROSS. CROSS is called by DATAIN to store the cross sections in memory in the order shown in Table II. CROSS calls the external FIDMOD.

FIDMOD. FIDMOD is called by CROSS during the reading of the cross sections (Card #13) to interpret the FIDO format. FIDMOD then passes the cross section to CROSS for storage. INCRES is the only external called by FIDMOD.

INCRES. The routine INCRES is called by FIDMOD to increase the group and position counters to insure storage of cross section in the correct storage locations.

DATOUT. DATOUT is the routine called by DATAIN to print the information read from the input cards. The meshing information is also printed.

CALC. CALC, called by EXEC, is the command and control routine for performing calculations. All group calculations are performed within CALC. For a summary of the theory, see Sec II of this report. CALC passes control to other subroutines for many of the specialized computations. Nine externals are called by CALC: MESH, GSTART, VIRGIN, SCAT, TOTAL, DOSE, R2DOSE, MIS, and KFACT.

MESH. The routine MESH, called by CALC, is the executive routine for determining the mesh. Calculations are not performed by this routine, but accomplished by calling five externals: VMESH for the vertical mesh, SCALH for the mesh expansion parameter, HMESH for the horizontal mesh, RANGE for the distances in cm, MASSRG for the distances in terms

of mass units. Finally, RZOUT is called to print a mesh summary. In addition, the function subprogram AIRDEN is attached by VMESH, SCALH, and HMESH. The subroutine MESH also insures that the source height is between 0 and 20 km. Otherwise, a diagnostic message is printed and control passed to ABORT.

GSTART. The routine GSTART is called by CALC to determine the energy group to start calculations. This routine determines the highest energy group containing particles and initiates the calculations with that group.

VIRGIN. VIRGIN is called by CALC to compute the uncollided fluence at each point of the entire mesh for every energy group. The computation is made using Eq. (1).

SCAT. SCAT is the routine called by CALC to determine the collided fluence at each mesh point of the entire spatial domain for all energy groups. The solution is done group by group, one at a time, beginning with the highest energy group containing particles using successive line overrelaxation. SCAT is the command and control routine for the calculations which are performed by calling the externals: DETDO, MATRIX, GUESS, SOURCE, SLOR, and CHECK.

DETDO. The routine DETDO is called by SCAT to compute the group diffusion coefficients. Eq. (6) is used to perform the computation.

MATRIX. This routine is called by SCAT to determine the elements of the block tridiagonal matrix. These are the coefficients of the finite differenced diffusion equation.

The elements are stored in the order discussed in Sec. II and illustrated by Figs. 3, 4, and 5. MATRIX calls the function subprograms AIRDEN and GINT.

DENGRA. This routine is called by MATRIX to compute the density gradient g(z) at altitude (z) for each mesh row.

GUESS. GUESS is the routine called by SCAT to make the initial guess for the iterative solution of each energy group. For the first group (highest energy) the guess is set equal to twice the uncollided fluence for the corresponding uncollided fluence in this group. For other groups, the answer for the previous group is used as the initial guess.

SOURCE. This is the routine called by SCAT to compute the source particles for each energy group as discussed in Sec. II. SOURCE calls the function subprogram AIRDEN.

SLOR. SLOR is the routine called by SCAT to find the solution for the collided fluence at each mesh point for each energy group. This routine uses a block iterative method called successive line overrelaxation (SLOR) to solve the matrix equation $\underline{A}*\underline{F} = \underline{S}$. SLOR checks for convergence by using Eq (18). The error must be less than or equal to 0.01 for five consecutive iterations. SLOR calls the two routines TRIDGE and TRIMUL.

TRIMUL. TRIMUL is called by both SLOR and BLTRIM. This routine is a special routine for multiplying a tridiagonal matrix by a vector.

TRIDGE. The subroutine TRIDGE is called by SLOR and contains a special form of Gaussian elimination for equations containing a tridiagonal matrix.

CHECK. CHECK is called by SCAT to check for proper convergence of the entire matrix equation. The check is made by comparing the two sides of the equation $\underline{A}\,\underline{F} = \underline{S}$ for the last iteration. If the difference is greater than 0.10, additional iterations are required by SLOR. CHECK calls the subroutine BLTRIM.

BLTRIM. BLTRIM is called by CHECK. This routine multiplies a vector by a block tridiagonal banded matrix. The routine TRIMUL is called by BLTRIM.

TOTAL. The subroutine TOTAL is called by CALC to find the total fluences. This is accomplished by addition of the collided and uncollided fluences at each mesh point for each energy group.

DOSE. DOSE is called by CALC to compute doses. The total fluences at each mesh point are multiplied by the proper response functions to give the dose for each group at that point. The total dose summed over all groups is computed in CALC.

R2DOSE. This routine is called by CALC to compute the $4\pi r^2$ doses. The computation is accomplished by multiplying total doses at each mesh point by $4\pi r^2$ where r is the slant range.

MIS. MIS is a routine called by CALC to compute the 1-D MIS $4\pi r^2$ doses using Eq (19) and the coefficients that were input (cards #10 and #11). The function subprogram CUBRT is called by MIS.

KFACT. The routine KFACT is called by CALC to compute

K-Factors. This is done by computing the ratio of the 2-D variable density air $4\pi r^2$ doses divided by the 1-D MIS $4\pi r^2$ doses.

RESOUT. RESOUT is called by EXEC to perform disposition of the results of the computations. RESOUT calls DOSOUT to print the doses and K-Factors. If the store option on input card #4 is exercised, STORE is called to write group fluences and mesh information on a permanent file for future editing operations.

Function Subprograms

GINT. GINT is a function subprogram called by MASSRG. GINT performs Gaussian/Legendre quadrature integration on the AIRDEN function to compute mass integrals for variable density air (Ref 4:153-159) and (Ref 9:196).

AIRDEN. AIRDEN is a function subprogram called by VMESH, SCALH, HMESH, MASSRG, GINT, MATRIX, DENGRA, and SOURCE. AIRDEN calculations the relative air density $\rho(z)/\rho(0)$ as a function of geometric altitude. The calculations are based on the 1962 U.S. Standard Atmosphere (Ref 2) and are valid over the altitude range from 5 km below sea level through 70 km above sea level, inclusive.

CUBRT. The function subprogram CUBRT is used by MIS in computation of the cube root of a given quantity.

Appendix B

MISFIT Edit Program

The purpose of the edit program MISFIT is to produce the MIS coefficients which are required input (cards #10 and #11) for 2-D air AIRDIF runs where K-Factor computation is required. The computation of K-Factors requires the actions summarized in Fig. 12.

1. Perform computation of environments using AIRDIF operated in the 1-D air mode for source spectra of interest.
2. Create a permanent file containing the information computed in step #1 (see options on AIRDIF input card #4 in Section IV).
3. MISFIT accesses stored data file.
4. MISFIT converts multigroup fluences to $4\pi r^2$ doses.
5. MISFIT performs a least squares fit of the ln ($4\pi r^2$ doses) as a function of mass range (X) to Murphy's transmission equation (Ref 7:36), which is given by Eq. (19).
6. The MIS coefficients are printed.
7. Perform 2-D AIRDIF computations using the coefficients of step #6 as part of the input data.
8. K-Factors are produced as part of the AIRDIF output.

Fig. 12. K-Factor Production Steps Using MISFIT.

Description

The edit code MISFIT, like AIRDIF, is a structured modular code employing standard hierarchy. The program consists of the calling program, nine subroutine subprograms including an abort routine, and three function subprograms. Fig. 13 is the module flow diagram for MISFIT.

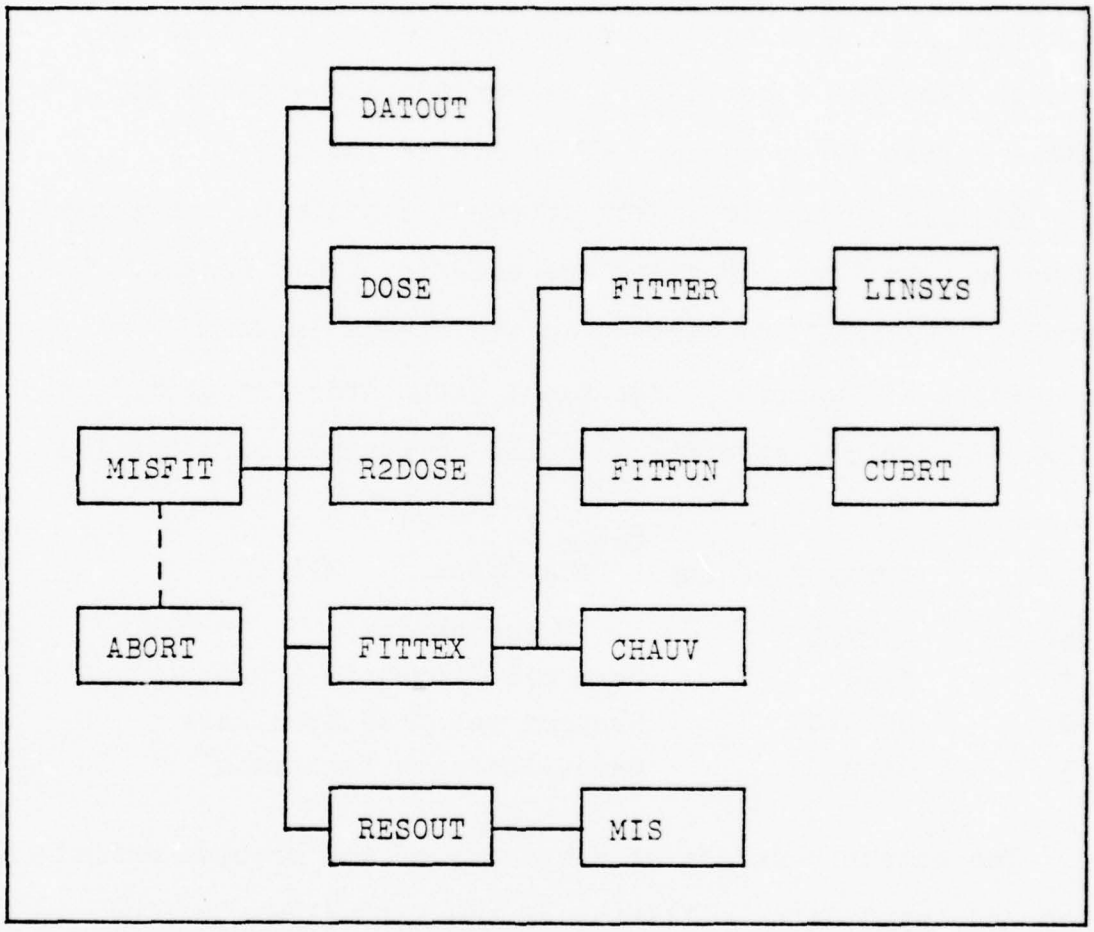

Fig. 13. Module Flow Diagram for MISFIT.

User's Guide

This section provides instructions for preparation of the input cards for MISFIT and presents examples of a typical input data deck and a listing of the output. The basic

structure of the deck is the same as for the AIRDIF code shown in Fig. 11. There are three input data cards. Instructions are given for each card individually below.

Card #1. This is the title card for the response function type. The entry is alphameric in 12A6 format (same as card #7 in AIRDIF input).

Card #2. This is a deck of cards which contains the neutron response functions. The numbers are entered in 6E10.0 format (same as card #8 in AIRDIF input).

Card #3. This is a deck of cards containing the gamma response functions. Entries are made in 6E10.0 format. This card is identical to card #9 in the AIRDIF input.

Table VI summarizes the input data cards for MISFIT, and Table VII depicts specific examples of punched card entries.

Table VI
Summary of Input Data Cards for MISFIT

Card #	Format	Description
1	12A6	Response functions title
2	6E10.0	Neutron response functions
3	6E10.0	Gamma response functions

The output consists of a summary of the problem definition and input data, a listing of the fit values for the $4\pi r^2$ doses at various distances in terms of mass range (ρr), and listing of the MIS coefficients for neutrons and gammas. The listing of MIS coefficients also gives information on the maximum deviation and the standard deviation of the fit and the number of points rejected. A sample of the printed output is given in Table VIII.

Table VII

MISFIT Punched Card Input Data

Card #	Format	Punched Entries
1	12A6	MURPHY/BARTINE SILICON RESPONSE FUNCTIONS
2	6E10.0	1.9106E-09 1.7792E-09 1.6818E-09 1.6231E-09 1.5144E-09 1.3851E-09
		↓ ↓
		4 cards omitted (From Table XIX of Appendix E)
		↑ ↑
		1.4421E-14 4.5895E-15 3.9377E-15 5.6286E-15 9.4023E-15 1.5390E-14
		7.4244E-13
3	6E10.0	3.4184E-09 2.5712E-09 2.1612E-09 1.8991E-09 1.6367E-09 1.3835E-09
		↓ ↓
		2 cards omitted (From Table XIX of Appendix E)
		↑ ↑
		3.4411E-10 8.2679E-10 2.6493E-09

Table VIII

Output Data Listing for MISFIT

Fission Source at 5 km, Homo Air

INPUT DATA

SOURCE HEIGHT	=	5.0000E+00 KM
NEUTRON GROUPS	=	37
GAMMA GROUPS	=	21
TOTAL GROUPS	=	58
HORIZ POINTS	=	27

Note: See list on page 64 for notes applicable to Table VII.
This MISFIT run accessed the permanent file created in sample problem #1, Appendix D.

Table VIII (cont)

```
                VERT ROWS  =  52
      TOTAL NUMBER OF POINTS  =  1404
                DIMENSION  =  1-D AIR

MURPHY/BARTINE SILICON RESPONSE FUNCTIONS

NEUTRON RESPONSE FUNCTIONS
      1.9106E-09  1.7792E-09  1.6818E-09  → 4 columns omitted ←  1.0530E-09  8.7897E-10  7.9629E-10
      7.8141E-10  4.7092E-10  2.1394E-10  →                   ←  8.2995E-11  9.4778E-11  6.5328E-11
      4.9785E-11  3.1515E-11  1.7897E-12  →                   ←  2.9804E-13  1.0498E-13  4.3305E-14
      1.4421E-14  4.5895E-15  3.9377E-15  →                   ←

GAMMA RESPONSE FUNCTIONS
      3.4184E-09  2.5712E-09  2.1612E-09  → 4 columns omitted ←  9.4334E-10  8.2033E-10  6.8343E-10
      5.2846E-10  3.8505E-10  2.7122E-10  →                   ←  1.4543E-10  3.4411E-10  8.2679E-10
      2.6493E-09

FIT INFORMATION
      X = RHOR
      F = 4PIR2 DOSE
      F = EXP(A1+A2X+A3X**2+A4X**3/2+A5X**1/2+A6X**1/3+A7LN(X))

    DID FIT OF 1404 POINTS WITH SIG OF 1.0264E-01
    MAX ERROR BY CHAUV IS 2.9303E-01
              ↓                    ↓
                5 fit groups omitted                    (neutron fit data)
              ↑                    ↑
    DID FIT OF 1269 POINTS WITH SIG OF 4.9275E-02
    MAX ERROR BY CHAUV IS 1.3963E-01

    THE NUMBER OF POINTS REJECTED IN THE FIT WAS 135
```

Table VIII (cont)

```
DID FIT OF 1404 POINTS WITH SIG OF 1.2250E-01
MAX ERROR BY CHAUV IS 3.4975E-01

DID FIT OF 1356 POINTS WITH SIG OF 6.6708E-02
MAX ERROR BY CHAUV IS 1.8996E-01

          ↓                    ↓
            8 fit groups omitted                    (gamma fit data)
          ↑                    ↑

DID FIT OF 1256 POINTS WITH SIG OF 3.6642E-02
MAX ERROR BY CHAUV IS 1.0375E-01

THE NUMBER OF POINTS REJECTED IN THE FIT WAS 148

NEUTRON MIS COEFF ARE     SIGMA = 4.92702E-02
-3.1381E+01  -1.3613E-01  -1.1575E-04  5.4085E-03  -1.8866E+00  1.0587E+01  -3.2596E+0

RHOR(G/CM2)      4PIR2DOSE

1.00000E+00      1.24011E-10
2.00000E+00      8.18493E-11
3.00000E+00      7.29742E-11
4.00000E+00      7.09438E-11
   ↓                   ↓
     26 lines omitted
   ↑                   ↑
7.00000E+02      5.39756E-27
7.50000E+02      9.25018E-29
8.00000E+02      1.25767E-30
8.50000E+02      1.34437E-32
```

Table VIII (cont)

GAMMA MIS COEFFICIENTS ARE SIGMA = 3.66424E-02

8.9611E+00 -8.1014E-01 -3.5829E-04 2.4386E-02 2.7964E+01 -6.5736E+01 1.1543E+01

RHOR(G/CM2)	4PIR2DOSE
1.00000E+00	1.40103E-13
2.00000E+00	7.91224E-13
3.00000E+00	1.81187E-12
4.00000E+00	3.07116E-12
5.00000E+00	4.50788E-12
6.00000E+00	6.09166E-12
↓	↓
22 lines omitted	
↑	↑
6.00000E+02	1.52782E-19
6.50000E+02	5.76377E-21
7.00000E+02	1.49888E-22
7.50000E+02	2.60261E-24
8.00000E+02	2.92787E-26
8.50000E+02	2.07413E-28

Appendix C

DOSCOMP Edit Program

The primary purpose of the DOSCOMP program is to compute doses with a minimum expenditure of computer resources. The AIRDIF program is still needed to make the basic computation of group fluences at the mesh points. However, doses for only one kind of dose response can be obtained from a single AIRDIF execution. Doses for the same source but of a second material response would require another complete execution of AIRDIF which requires approximately 4 to 5 minutes on the CDC 6600. DOSCOMP eliminates this needless expenditure of computer time by accessing a permanent file containing data from the first AIRDIF execution. The reduced time and decreased storage requirements of DOSCOMP greatly decrease the turn-around time for computers on a time sharing system. Herein lies the strength of the DOSCOMP edit program - it allows the computation of additional doses and K-Factors with a substantial decrease in computer storage and time requirements, and a large reduction of real time.

Description

The DOSCOMP program, like AIRDIF, is a fully structured modular program utilizing standard hierarchy. The program consists of 13 modules, many of which were extracted directly from AIRDIF. A module flow diagram for the DOSCOMP program is presented in Fig. 14.

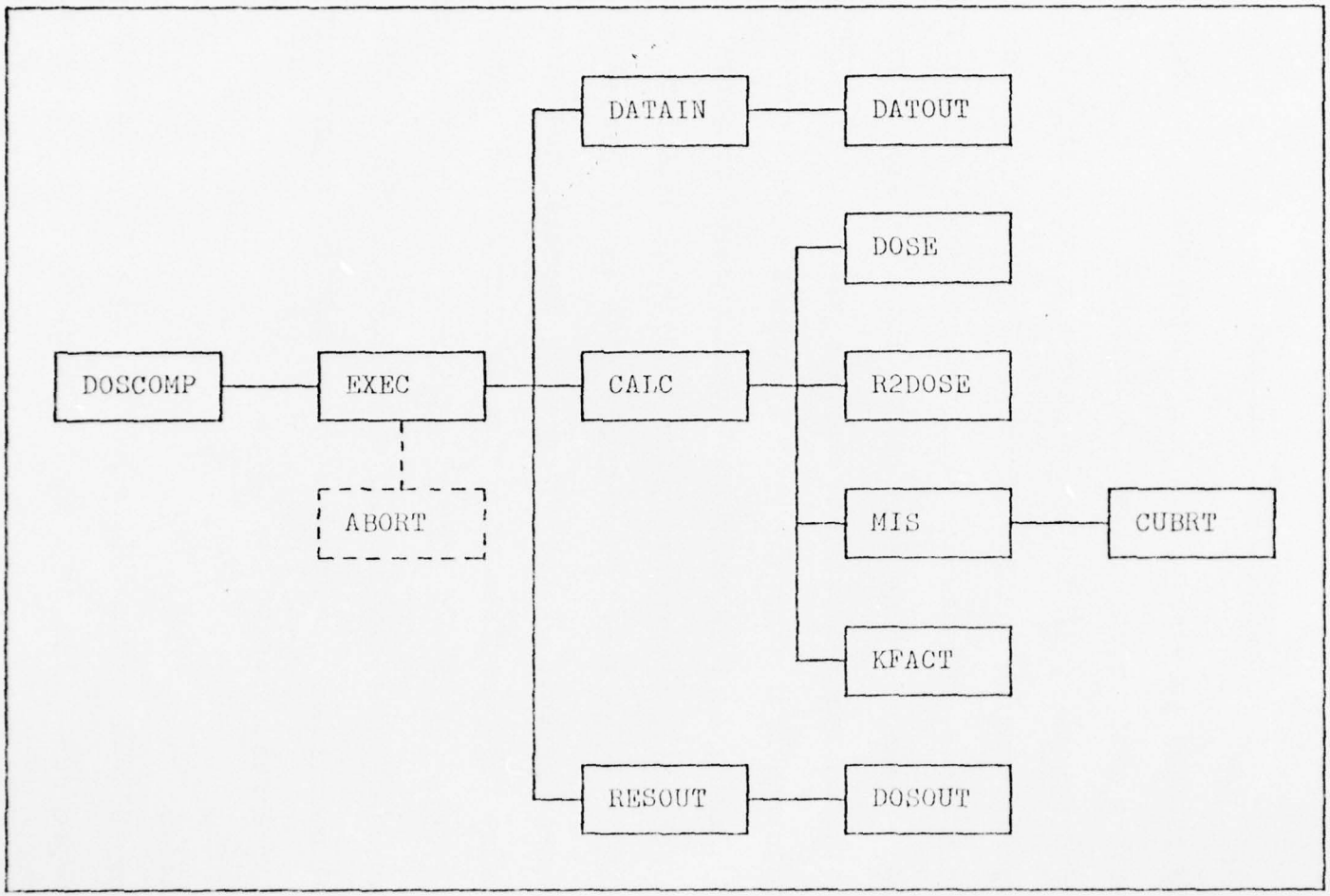

Fig. 14. Module Flow Diagram for DOSCOMP.

There are three basic sections to the program. These are the input, calculation, and output sections. When control is passed to the input section, data from input cards and a permanent file are read into computer storage. Next, control is passed to the calculation sections. The group fluences are then used to compute doses, $4\pi r^2$ doses, and K-Factors if opted. Finally, the results are printed. Due to the modular construction of the program, plot subroutines could easily be added to the output section.

User's Guide

The basic structure of the complete card deck is the same as given in Fig. 11 for the AIRDIF program. The permanent file with AIRDIF data must be accessed using the proper control cards. Instructions are given below for the input data cards.

Card #1. This is the title card for the response function type. The entry is alphameric in 12A6 format and is identical to card #7 of the AIRDIF input.

Card #2. This is a deck of cards which contains the neutron response functions. The numbers are entered in 6E10.0 format. This is identical to card #8 in the required AIRDIF input.

Card #3. This deck of cards contains the gamma response functions. Entries are made in 6E10.0 format exactly as accomplished for card #9 of the AIRDIF input.

Card #4. The neutron coefficients for Murphy's transmission equation are entered on this card in 7E10.0 format.

The coefficients are obtained from the edit program MISFIT which uses the actual data from a 1-D AIRDIF problem solution to perform a fit of the data. This card is identical to card #10 in the AIRDIF input.

Card #5. The gamma MIS coefficients for Murphy's transmission equation are entered on this card in 7E10.0 format. This card is identical to card #11 required in the AIRDIF input. Coefficients on cards #4 and #5 are used only during 2-D operation when K-Factors are to be computed. During 1-D runs or 2-D runs where environments only are required, these cards must be included but may be blanks.

Card #6. This is the print option card using I3 format. If a zero or a blank is entered in columns 1 through 3 of this card, the action "Do not print output data" will result. If any number from 1 through 999 is entered, the action "Do print output data" will result.

Tables IX and X present a summary of DOSCOMP data cards and a sample set of punched input data cards for DOSCOMP. The output for DOSCOMP appears in almost the same order and format as the output for the AIRDIF program as described in section IV. For examples of this output refer to Tables XII, XIV, and XVI in Appendix D.

Table IX
Summary of DOSCOMP Input Data Cards

Card #	Format	Description
1	12A6	Response function title
2	6E10.0	Neutron response functions
3	6E10.0	Gamma response functions
4	7E10.0	Neutron MIS coefficients
5	7E10.0	Gamma MIS coefficients
6	I3	Print option card

Table X
DOSCOMP Punched Input Data Cards

Card #	Format	Punched cards
1	12A6	MURPHY/BARTINE SILICON RESPONSE FUNCTIONS
2	6E10.0	same as card #8-Problem #1, App. D
3	6E10.0	same as card #9-Problem #1, App. D
4	7E10.0	same as card #10-Problem #1, App. D
5	7E10.0	same as card #11-Problem #1, App. D
6	I3	bb1

Appendix D

Sample Problems

This appendix presents sample problems which further illustrate how to use the AIRDIF code. The problems in this appendix exercise the AIRDIF program in the 1-D mode and in the 2-D mode for both K-Factor production and environments only runs. The edit codes MISFIT and DOSCOMP are used in sequence with AIRDIF to obtain MIS coefficients to Murphy's transmission equation and to produce doses for additional responses respectively. Sample problems for the edit codes were given with their respective descriptions in Appendices B and C. Complete sets of data cards for these problems are presented in Tables XI, XIII, and XV. For detailed instructions of each card see Table IV and the user's guide in Section IV. The following list of statements apply to Tables VII, X, XI, XIII, and XV.

1. The column labeled "Punched Entries" contains characters exactly as entered on the actual data cards.
2. Except for alphameric formats, blank entries are read as zeros.
3. The symbol "b" is occasionally used to represent the absence of a punched entry within a series of numeric data.
4. All data card entries begin in column #1. One symbol is shown for each column through the last symbol of the last entry of the card.
5. The symbol "," is used to separate entries as an aid to the reader and is not punched on the data cards.

Output for these problems are shown in Tables XII, XIV, and XVI. Although all output sections are included, only limited portions of lengthy sections are included.

Problem #1

The problem statement in terms of given quantities and desired results is given in Fig. 15. Solution instructions are also given in Fig. 15. The entries for the input data cards to this problem are given in Table XI. A sample of the output from this problem is given in Table XII. The cross section listing is deleted from Table XII, but is presented in Table XX in Appendix E.

Problem #2

The problem statement in terms of given quantities and desired results is given in Fig. 16. Instructions for the problem solution are also given in Fig. 16. The input data card entries for this problem are given in Table XIII. The output from this problem is shown in Table XIV.

Problem #3

The problem statement is given in Fig. 17 in terms of given quantities and desired results. The steps for the solution are also given in Fig. 17 for problem #3. The input data card entries for this problem are given in Table XV. The output is shown in Table XVI.

AIRDIF - Problem #1

GIVEN:
1. A fission detonation at 5 km altitude.
2. Oak Ridge unclassified normalized neutron source spectra (Table XVIII, Appendix E).
3. DLC-31 (37/21) coupled neutron/gamma cross sections (Table XX, Appendix E).
4. Silicon response functions (Table XIX, Appendix E).

FIND:
1. 1-D homogeneous air neutron and secondary gamma environments.
2. Create a permanent file of results for later access by edit codes.

SOLUTION:
1. Follow the user's guide to enter data on input cards.
2. Use blank cards for the MIS coefficients.
3. Use appropriate "Request" and "Catalog" cards to create the permanent file.

Fig. 15. AIRDIF Problem #1 - Homogeneous Air.

Table XI
Problem #1 Input Data

Card #	Format	Punched Entris
1	12A6	FISSION SOURCE AT 5 KM, HOMO AIR
2	2I3	b37b21
3	E10.0,I3	5.0000E+00bb1
4	5I3	bb1bbbbb1bbbbbb
5	6E10.0	1.2000E+001.2000E+001.2000E+001.2000E+001.2000E+001.2000E+00
		1.2000E+001.2000E+001.2000E+001.3000E+001.4000E+001.4000E+00
		↓ ↓
		6 cards omitted (FROM TABLE II)
		↑ ↑
		1.2000E+001.2000E+001.2000E+001.4000E+001.0000E+001.0000E+00
		1.0000E+001.0000E+001.0000E+001.0000E+00
6	6E10.0	0.0 0.0 0.0 0.0 0.0 0.0
		0.0 0.0 3.8395E-033.5015E-035.3892E-037.3490E-03
		1.8367E-023.2495E-038.4688E-035.5002E-023.2435E-021.0578E-02
		9.7236E-021.4677E-012.1567E-011.5018E-011.9297E-021.2098E-01
		5.7292E-025.9991E-032.3997E-021.4398E-020.0 0.0
		↓ ↓
		5 blank cards (FROM TABLE XVIII)
		↑ ↑
7	12A6	MURPHY/BARTINE SILICON RESPONSE FUNCTIONS
8	6E10.0	1.9106E-091.7792E-091.6818E-091.6231E-091.5144E-091.3851E-09

Table XI (cont)

Card #	Format	Punched Entries
		1.2370E-091.0530E-098.7897E-107.9629E-107.8141E-104.7092E-10
		↓ ↓
		4 cards omitted (FROM TABLE XIX)
		↑ ↑
		7.4244E-13
9	6E10.0	3.4184E-092.5712E-092.1612E-091.8991E-091.6367E-091.3835E-09
		↓ ↓
		2 cards omitted (FROM TABLE XIX)
		↑ ↑
		3.4411E-108.2679E-102.6493E-09
10	7E10.0	blank card
11	7E10.0	blank card
12	12A6	37/21 DLC-31 FISSION WTD CROSS SECTION SET
13	FIDO	b0bb41531-09b0bb46222-09b0bb80538-09b0bb39007-0957Rbbbbb0bb0b0bb47084b-9bbbbb001
		b0bb50846b-9b0bb81211b-9b0bb34127b-9b0bb90288-1056Rbbbbb0bb0b0bb55893b-9bbbbb002
		↓ ↓
		195 cards omitted (FROM TABLE XX)
		↑ ↑
		b0bb46066b-8b0bb47592b-8b0bb20569b-8b0bb26761b-956Rbbbbb0bb0b0bb16224b-7bbbbb198
		b0bb18426b-7b0bb18495b-7b0bb22715b-8b0bb18273b-956Rbbbbb0bb0bbTbbbbbbbbbbbbbbb199

Table XII

Problem #1 Output Data

FISSION SOURCE AT 5 KM, HOMO AIR

INPUT DATA

SOURCE HEIGHT = 5.0000E+00 KM
NEUTRON GROUPS = 37
GAMMA GROUPS = 21
TOTAL GROUPS = 58
DELG = 1.0000E+01 G/CM2
GHOR = 2.7000E+02 G/CM2
GDOWN = 2.5000E+02 G/CM2
DESIRED DIMENSION = 1-D AIR

GROUP SLOR FACTORS

1.2000E+00	1.2000E+00	1.2000E+00	→	4 columns omitted	←	1.2000E+00	1.2000E+00	1.2000E+00
1.4000E+00	1.4000E+00	1.2000E+00	→		←	1.2000E+00	1.2000E+00	1.2000E+00
1.2000E+00	1.2000E+00	1.2000E+00	→		←	1.2000E+00	1.2000E+00	1.2000E+00
1.2000E+00	1.2000E+00	1.2000E+00	→		←	1.7000E+00	1.6000E+00	1.4000E+00
1.4000E+00	1.4000E+00	1.4000E+00	→		←	1.2000E+00	1.2000E+00	1.2000E+00
1.2000E+00	1.4000E+00	1.0000E+00	→		←	1.0000E+00		

NEUTRON SOURCE

0.	0.	0.	→	4 columns omitted	←	0.	3.8395E-03	3.5015E-03
5.3892E-03	7.3490E-03	1.8367E-02	→		←	1.0578E-02	9.7236E-02	1.4677E-01
2.1567E-01	1.5018E-01	1.9297E-02	→		←	1.4399E-02	0.	0.
0.	0.	0.	→		←			

GAMMA SOURCE

0.	0.	0.	→	4 columns omitted	←	0.	0.	0.
0.	0.	0.	→		←	0.	0.	0.
0.								

Table XII (cont)

MURPHY/BARTINE SILICON RESPONSE FUNCTIONS

NEUTRON RESPONSE FUNCTIONS

1.9106E-09	1.7792E-09	1.6818E-09	→ 4 columns omitted ←	1.0530E-09	8.7897E-10	7.9629E-10
7.8141E-10	4.7092E-10	2.1394E-10	→	8.2995E-11	9.4778E-11	6.5328E-11
4.9785E-11	3.1515E-11	1.7897E-12	→	2.9804E-13	1.0498E-13	4.3305E-14
1.4421E-14	4.5895E-15	3.9377E-15	→	←		

GAMMA RESPONSE FUNCTIONS

3.4184E-09	2.5712E-09	2.1612E-09	→ 4 columns omitted ←	9.4334E-10	8.2033E-10	6.8343E-10
5.2846E-10	3.8505E-10	2.7122E-10	→	1.4543E-10	3.4411E-10	8.2679E-10
2.6493E-09						

NEUTRON MASS INTEGRAL SCALING COEFFICIENTS

0.	0.	0.	0.	0.	0.	0.

GAMMA MASS INTEGRAL SCALING COEFFICIENTS

0.	0.	0.	0.	0.	0.	0.

37/21 DLC-31 FISSION WTD CROSS SECTION SET

MESH INFORMATION FOLLOWS

MESH PARAMETER = 1.0000E+10 KM

MESH DIMENSIONS

NHOR = 28 POINTS
NUP = 26 POINTS
NDOWN = 26 POINTS
NROW = 52 POINTS

Table XII (cont)

SUMMARY OF HORIZONTAL MESH (AT Z=0)

RMIN = 0. CM
RMAX = 3.6663E+05 CM
DELR = 1.3579E+04 CM

SUMMARY OF VERTICAL MESH

ZMIN = 1.5373E+05 CM
SOURCE HEIGHT = 5.0000E+05 CM
ZMAX = 8.4627E+05 CM

DELTA Z INCREMENTS IN KM

.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579
.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579
.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579
.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579
.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579	.13579
.13579									

DOSES AND KFACTORS

						+++++++NEUTRONS+++++++			+++++++GAMMAS+++++++		
I	J	Z(KM)	HR(KM)	SR(KM)	RHOR(G/CM2)	DOSE	4PIR2DOSE	KFACT	DOSE	4PIR2DOSE	KFACT
1	1	1.5373+00	0.	3.4626+00	2.5500+02	3.45-27	5.20-15	1.00+00	4.88-25	7.36-13	1.00+00
2	1	1.5373+00	1.3579-01	3.4653+00	2.5519+02	3.36-27	5.08-15	1.00+00	4.80-25	7.24-13	1.00+00
3	1	1.5373+00	2.7158-01	3.4732+00	2.5578+02	3.23-27	4.89-15	1.00+00	4.66-25	7.07-13	1.00+00
4	1	1.5373+00	4.0737-01	3.4865+00	2.5675+02	3.02-27	4.62-15	1.00+00	4.46-25	6.82-13	1.00+00
5	1	1.5373+00	5.4316-01	3.5050+00	2.5811+02	2.77-27	4.28-15	1.00+00	4.20-25	6.49-13	1.00+00
					↓		↓				
					19 lines omitted						
					↑		↑				
25	1	1.5373+00	3.2589+00	4.7550+00	3.5017+02	1.07-29	3.05-17	1.00+00	7.87-27	2.23-14	1.00+00
26	1	1.5373+00	3.3947+00	4.8491+00	3.5710+02	6.33-30	1.87-17	1.00+00	4.92-27	1.46-14	1.00+00
27	1	1.5373+00	3.5305+00	4.9451+00	3.6417+02	2.92-30	8.98-18	1.00+00	2.35-27	7.23-15	1.00+00

Table XII (cont)

I	J	Z(KM)	HR(KM)	SR(KM)	RHOR(G/CM2)	++++++NEUTRONS++++++++ DOSE	4PIR2DOSE	KFACT	++++++++GAMMAS++++++++ DOSE	4PIR2DOSE	KFACT
					↓		↓				
					25 altitude line groups omitted						
					↑		↑				
1	27	5.0679+00	0.	6.7895-02	5.0000+00	1.23-19	7.13-11	1.00+00	7.86-21	4.55-12	1.00+00
2	27	5.0679+00	1.3579-01	1.5181-01	1.1180+01	2.69-20	7.79-11	1.00+00	5.35-21	1.55-11	1.00+00
3	27	5.0679+00	2.7158-01	2.7993-01	2.0615+01	8.83-21	8.69-11	1.00+00	3.95-21	3.89-11	1.00+00
4	27	5.0679+00	4.0737-01	4.1299-01	3.0413+01	3.76-21	8.07-11	1.00+00	2.93-21	6.28-11	1.00+00
5	27	5.0679+00	5.4316-01	5.4738-01	4.0311+01	1.77-21	6.68-11	1.00+00	2.14-21	8.05-11	1.00+00
6	27	5.0679+00	6.7895-01	6.8233-01	5.0249+01	8.80-22	5.15-11	1.00+00	1.53-21	8.97-11	1.00+00
7	27	5.0679+00	8.1474-01	8.1756-01	6.0208+01	4.50-22	3.78-11	1.00+00	1.08-21	9.09-11	1.00+00
8	27	5.0679+00	9.5053-01	9.5295-01	7.0178+01	2.36-22	2.69-11	1.00+00	7.54-22	8.60-11	1.00+00
9	27	5.0679+00	1.0863+00	1.0884+00	8.0156+01	1.25-22	1.86-11	1.00+00	5.20-22	7.74-11	1.00+00
10	27	5.0679+00	1.2221+00	1.2240+00	9.0138+01	6.72-23	1.27-11	1.00+00	3.55-22	6.69-11	1.00+00
					↓		↓				
					11 lines omitted						
					↑		↑				
22	27	5.0679+00	2.8516+00	2.8524+00	2.1006+02	5.87-26	6.00-14	1.00+00	2.87-24	2.94-12	1.00+00
23	27	5.0679+00	2.9873+00	2.9881+00	2.2005+02	3.32-26	3.73-14	1.00+00	1.90-24	2.13-12	1.00+00
24	27	5.0679+00	3.1231+00	3.1239+00	2.3005+02	1.87-26	2.30-14	1.00+00	1.24-24	1.52-12	1.00+00
25	27	5.0679+00	3.2589+00	3.2596+00	2.4005+02	1.04-26	1.39-14	1.00+00	7.82-25	1.04-12	1.00+00
26	27	5.0679+00	3.3947+00	3.3954+00	2.5005+02	5.47-27	7.93-15	1.00+00	4.56-25	6.61-13	1.00+00
27	27	5.0679+00	3.5305+00	3.5312+00	2.6004+02	2.34-27	3.66-15	1.00+00	2.09-25	3.27-13	1.00+00
					↓		↓				
					25 altitude line groups omitted						
					↑		↑				

Notes: 1. Range entries contain 5 significant figures on the actual printout in the "DOSES AND KFACTORS" section of this table.

2. The "E" for the exponent has been dropped from the "DOSES AND KFACTORS" section of this table.

AIRDIF - Problem #2

GIVEN:
1. A fission detonation at 5 km altitude.
2. Oak Ridge unclassified normalized neutron source spectra (Table XVIII. Appendix E).
3. DLC-31 (37/21) coupled neutron/gamma cross sections (Table XX, Appendix E).
4. Silicon response functions (Table XIX, Appendix E).
5. The permanent file created from AIRDIF Problem #1.

FIND:
1. Neutron and secondary gamma environments for 2-D variable density air.
2. Produce K-Factors.

SOLUTION:
1. Perform a MISFIT run using the given response functions and the permanent file from Problem #1. (See Table VIII)
2. Perform the 2-D AIRDIF run following the user's guide to enter data on the input cards.
3. Desired results are printed.

Fig. 16. AIRDIF Problem #2 - Variable Density Air with K-Factors.

Table XIII
Problem #2 Input Data

Card #	Format	Punched Entries
1	12A6	FISSION SOURCE AT 5 KM, REAL AIR
2	2I3	b37b21
3	E10.0,I3	5.0000E+00bb2
4	5I3	blank card
5	6E10.0	same as card #5, problem #1
6	6E10.0	same as card #6, problem #1
7	12A6	same as card #7, problem #1
8	6E10.0	same as card #8, problem #1
9	6E10.0	same as card #9, problem #1
10	7E10.0	-3.1381E+1-1.3613E-1-1.1575E-4b5.4085E-3-1.8866E+0b1.0587E+1-3.2596E+0*
11	7E10.0	b8.9611E+0-8.1014E-1-3.5829E-4b2.4386E-2b2.7964E+1-6.5736E+1b1.1543E+1*
12	12A6	same as card #12, problem #1
13	FIDO	same as card #13, problem #1

* Coefficients are obtained from MISFIT results (see Table VIII).

Table XIV
Problem #2 Output Listing

FISSION SOURCE AT 5 KM, REAL AIR

INPUT DATA

SOURCE HEIGHT	=	5.0000E+00 KM
NEUTRON GROUPS	=	37
GAMMA GROUPS	=	21
TOTAL GROUPS	=	58
DELG	=	1.0000E+01 G/CM2
GHOR	=	2.7000E+02 G/CM2
GDOWN	=	2.5000E+02 G/CM2
DESIRED DIMENSION	=	2-D AIR

GROUP SLOR FACTORS (see Problem #1 printout in Table XII)

NEUTRON SOURCE

0.	0.	0.	→ 4 columns omitted ←	0.	3.8395E-03	3.5015E-03	
5.3892E-03	7.3490E-03	1.8367E-02	→	←	1.0578E-02	9.7236E-02	1.4677E-01
2.1567E-01	1.5018E-01	1.9297E-02	→	←	1.4399E-02	0.	0.
0.	0.	0.	→	←			

GAMMA SOURCE

0.	0.	0.	→ 4 columns omitted ←	0.	0.	0.	
0.	0.	0.	→	←	0.	0.	0.
0.							

MURPHY/BARTINE SILICON RESPONSE FUNCTIONS

NEUTRON RESPONSE FUNCTIONS (see Problem #1 printout in Table XII)

GAMMA RESPONSE FUNCTIONS (see Problem #1 printout in Table XII)

NEUTRON MASS INTEGRAL SCALING COEFFICIENTS

-3.1381E+01 -1.3613E-01 -1.1575E-04 5.4085E-03 -1.8866E+00 1.0587E+01 -3.2596E+00

Table XIV (cont)

GAMMA MASS INTEGRAL SCALING COEFFICIENTS

8.9611E+00 -8.1014E-01 -3.5829E-04 2.4386E-02 2.7964E+01 -6.5736E+01 1.1543E+01

37/21 DLC-31 FISSION WTD CROSS SECTION SET

MESH INFORMATION FOLLOWS

MESH PARAMETER = 9.5844E+00 KM

MESH DIMENSIONS

NHOR = 28 POINTS
NUP = 26 POINTS
NDOWN = 26 POINTS
NROW = 52 POINTS

SUMMARY OF HORIZONTAL MESH (AT Z=0)

RMIN = 0. CM
RMAX = 2.1761E+05 CM
DELR = 8.0594E+03 CM

SUMMARY OF VERTICAL MESH

ZMIN = 2.1448E+05 CM
SOURCE HEIGHT = 5.0000E+05 CM
ZMAX = 9.8908E+05 CM

DELTA Z INCREMENTS IN KM

.09261	.09385	.09512	.09642	.09777	.09915	.10057	.10203	.10353	.10508
.10668	.10832	.11002	.11177	.11358	.11545	.11737	.11937	.12143	.12357
.12578	.12808	.13046	.13293	.13549	.13816	.14093	.14381	.14682	.14996
.15323	.15665	.16022	.16396	.16788	.17199	.17631	.18085	.18563	.19067
.19599	.20162	.20758	.21390	.22062	.22778	.23541	.24358	.25233	.26174
.27187									

Table XIV (cont)

DOSES AND KFACTORS

I	J	Z(KM)	HR(KM)	SR(KM)	RHOR(G/CM2)	NEUTRONS DOSE	NEUTRONS 4PIR2DOSE	NEUTRONS KFACT	GAMMAS DOSE	GAMMAS 4PIR2DOSE	GAMMAS KFACT
					↓		↓				
					26 altitude line groups omitted						
					↑		↑				
1	27	5.0694+00	0.	6.9418-02	5.0930+00	1.18-19	7.12-11	9.99-1	7.62-21	4.61-12	9.93-1
2	27	5.0694+00	1.3677-01	1.5338-01	1.1253+01	2.61-20	7.73-11	9.37-1	5.20-21	1.54-11	9.43-1
3	27	5.0694+00	2.7355-01	2.8222-01	2.0706+01	8.59-21	8.60-11	9.55-1	3.84-21	3.84-11	9.71-1
4	27	5.0694+00	4.1033-01	4.1616-01	3.0532+01	3.66-21	7.96-11	9.59-1	2.84-21	6.19-11	9.66-1
5	27	5.0694+00	5.4711-01	5.5149-01	4.0461+01	1.72-21	6.58-11	9.59-1	2.07-21	7.92-11	9.55-1
6	27	5.0694+00	6.8388-01	6.8740-01	5.0432+01	8.53-22	5.06-11	9.61-1	1.48-21	8.81-11	9.48-1
7	27	5.0694+00	8.2066-01	8.2359-01	6.0425+01	4.36-22	3.72-11	9.64-1	1.05-21	8.92-11	9.44-1
8	27	5.0694+00	9.5744-01	9.5995-01	7.0429+01	2.28-22	2.64-11	9.68-1	7.28-22	8.43-11	9.44-1
					↓		↓				
					11 lines omitted						
					↑		↑				
20	27	5.0694+00	2.5987+00	2.5997+00	1.9073+02	1.78-25	1.51-13	1.02+0	6.27-24	5.33-12	9.83-1
21	27	5.0694+00	2.7355+00	2.7364+00	2.0076+02	1.00-25	9.45-14	1.02+0	4.18-24	3.93-12	9.83-1
22	27	5.0694+00	2.8723+00	2.8731+00	2.1079+02	5.69-26	5.91-14	1.03+0	2.78-24	2.88-12	9.81-1
23	27	5.0694+00	3.0091+00	3.0099+00	2.2082+02	3.23-26	3.68-14	1.04+0	1.83-24	2.09-12	9.71-1
24	27	5.0694+00	3.1458+00	3.1466+00	2.3086+02	1.82-26	2.27-14	1.05+0	1.19-24	1.48-12	9.48-1
25	27	5.0694+00	3.2826+00	3.2833+00	2.4089+02	1.01-26	1.37-14	1.03+0	7.48-25	1.01-12	8.94-1
26	27	5.0694+00	3.4194+00	3.4201+00	2.5092+02	5.26-27	7.73-15	9.56-1	4.32-25	6.35-13	7.75-1
27	27	5.0694+00	3.5562+00	3.5568+00	2.6096+02	2.21-27	3.51-15	7.14-1	1.94-25	3.08-13	5.23-1
					↓		↓				
					25 altitude line groups omitted						
					↑		↑				

Notes: 1. Range entries contain 5 significant figures on the actual printout in the "DOSES AND KFACTORS" section of this table.
2. The "E" for the exponent has been dropped from the "DOSES AND KFACTORS" section of this table.

AIRDIF - Problem #3

GIVEN:
1. A thermonuclear detonation at 15 km altitude.
2. Oak Ridge unclassified normalized neutron source spectra (Table XVIII, Appendix E).
3. DLC-31 (37/21) coupled neutron/gamma cross sections (Table XX, Appendix E).
4. Silicon response functions (Table XIX, Appendix E).

FIND:
1. Neutron and secondary gamma environments only for 2-D variable density air.

SOLUTION:
1. Follow the user's guide to enter data on input cards.
2. Use blank cards for the MIS coefficients.
3. Desired results are printed.

Fig. 17. AIRDIF Problem #3 - Variable Density Air with Environments Only.

Table XV
Problem #3 Input Data

Card #	Format	Punched Entries
1	12A6	TN SOURCE AT 15 KM, REAL AIR
2	2I3	b37b21
3	E10.0,I3	1.5000E+01bb2
4	5I3	blank card
5	6E10.0	same as card #5, problem #1
6	6E10.0	0.0 0.0 1.8871E-02 9.3425E-03 2.6617E-02 1.6662E-02
		9 cards omitted
7	12A6	MURPHY/BARTINE SILICON RESPONSE FUNCTIONS
8	6E10.0	same as card #8, problem #1
9	6E10.0	same as card #9, problem #1
10	7E10.0	blank card
11	7E10.0	blank card
12	12A6	same as card #12, problem #1
13	FIDO	same as card #13, problem #1

Table XVI
Problem #3 Output Listing

TN SOURCE AT 15 KM, REAL AIR

INPUT DATA

SOURCE HEIGHT	=	1.5000E+01 KM
NEUTRON GROUPS	=	37
GAMMA GROUPS	=	21
TOTAL GROUPS	=	58
DELG	=	1.0000E+01 G/CM2
GHOR	=	2.7000E+02 G/CM2
GDOWN	=	2.5000E+02 G/CM2
DESIRED DIMENSION	=	2-D AIR

GROUP SIOR FACTORS (see Problem #1 - Table XII)

NEUTRON SOURCE

0.	0.	1.8871E-02	→ 4 columns omitted ←	1.2397E-02	7.4826E-03	6.8232E-03
6.7752E-03	1.0320E-02	1.8071E-02	→	3.7466E-03	2.5642E-02	6.4447E-02
8.8495E-02	9.1377E-02	1.1634E-02	→	1.1627E-01	7.3817E-02	2.3245E-02
2.0281E-02	1.9015E-03	0.	→	←		

GAMMA SOURCE

0.	0.	0.	→ 4 columns omitted ←	0.	0.	0.
0.	0.	0.	→	0.	0.	0.
0.						

MURPHY/BARTINE SILICON RESPONSE FUNCTIONS

NEUTRON RESPONSE FUNCTIONS (see Problem #1 - Table XII)

GAMMA RESPONSE FUNCTIONS (see Problem #1 - Table XII)

NEUTRON MASS INTEGRAL SCALING COEFFICIENTS

0.	0.	0.	0.	0.	0.	0.

Table XVI (cont)

```
GAMMA MASS INTEGRAL SCALING COEFFICIENTS
      0.          0.          0.          0.          0.          0.          0.

37/21 DLC-31 FISSION WTD CROSS SECTION SET

MESH INFORMATION FOLLOWS

MESH PARAMETER  =  1.9536E+01 KM

MESH DIMENSIONS
      NHOR  =  28 POINTS
      NUP   =  11 POINTS
      NDOWN =  26 POINTS
      NROW  =  37 POINTS

SUMMARY OF HORIZONTAL MESH  (AT Z=0)
      RMIN  =  0.          CM
      RMAX  =  6.4331E+05 CM
      DELR  =  2.3826E+04 CM

SUMMARY OF VERTICAL MESH
      ZMIN  =  7.0920E+05 CM
      SOURCE HEIGHT  =  1.5000E+06 CM
      ZMAX  =  2.8701E+06 CM

DELTA Z INCREMENTS IN KM
   .18860    .19318    .19930    .20513    .21130    .21785    .22483    .23226    .24021    .24872
   .25785    .26768    .27829    .28977    .30224    .31584    .33071    .34706    .36511    .38513
   .40748    .43259    .46100    .49340    .53070    .57410    .62524    .68639    .76082    .85337
   .97159   1.12792   1.34439   1.66417   2.18514   3.18916
```

Table XVI (cont)

DOSES AND KFACTORS

I	J	Z(KM)	HR(KM)	SR(KM)	RHOR(G/CM2)	NEUTRONS DOSE	NEUTRONS 4PIR2DOSE	NEUTRONS KFACT	GAMMAS DOSE	GAMMAS 4PIR2DOSE	GAMMAS KFACT
					↓		↓				
					26 altitude line groups omitted						
					↑		↑				
1	27	1.5292+01	0.	2.9291-01	5.5755+00	1.62-20	1.74-10	1.74-10	1.83-21	1.97-11	1.97-11
2	27	1.5292+01	5.2122-01	5.9788-01	1.1380+01	3.56-21	1.60-10	1.60-10	1.06-21	4.76-11	4.76-11
3	27	1.5292+01	1.0424+00	1.0828+00	2.0611+01	1.01-21	1.49-10	1.49-10	6.64-22	9.78-11	9.78-11
4	27	1.5292+01	1.5636+00	1.5908+00	3.0281+01	4.00-22	1.27-10	1.27-10	4.26-22	1.35-10	1.35-10
5	27	1.5292+01	2.0848+00	2.1053+00	4.0074+01	1.81-22	1.01-10	1.01-10	2.75-22	1.53-10	1.53-10
6	27	1.5292+01	2.6061+00	2.6225+00	4.9918+01	8.83-23	7.63-11	7.63-11	1.78-22	1.54-10	1.54-10
7	27	1.5292+01	3.1273+00	3.1410+00	5.9788+01	4.52-23	5.60-11	5.60-11	1.16-22	1.44-10	1.44-10
8	27	1.5292+01	3.6485+00	3.6602+00	6.9672+01	2.39-23	4.02-11	4.02-11	7.56-23	1.27-10	1.27-10
					↓		↓				
					11 lines omitted						
					↑		↑				
20	27	1.5292+01	9.9032+00	9.9075+00	1.8858+02	5.03-26	6.20-13	6.20-13	7.25-25	8.94-12	8.94-12
21	27	1.5292+01	1.0424+01	1.0428+01	1.9850+02	3.30-26	4.50-13	4.50-13	5.17-25	7.06-12	7.06-12
22	27	1.5292+01	1.0945+01	1.0949+01	2.0842+02	2.18-26	3.29-13	3.29-13	3.69-25	5.57-12	5.57-12
23	27	1.5292+01	1.1466+01	1.1470+01	2.1833+02	1.46-26	2.41-13	2.41-13	2.64-25	4.36-12	4.36-12
24	27	1.5292+01	1.1988+01	1.1991+01	2.2825+02	9.27-27	1.76-13	1.76-13	1.86-25	3.36-12	3.36-12
25	27	1.5292+01	1.2509+01	1.2512+01	2.3817+02	6.35-27	1.25-13	1.25-13	1.27-25	2.50-12	2.50-12
26	27	1.5292+01	1.3030+01	1.3033+01	2.4809+02	3.87-27	8.26-14	8.26-14	7.93-26	1.69-12	1.69-12
27	27	1.5292+01	1.3551+01	1.3554+01	2.5801+02	1.86-27	4.30-14	4.30-14	3.83-26	8.85-13	8.85-13
					↓		↓				
					10 altitude line groups omitted						
					↑		↑				

Notes: 1. Range entries contain 5 significant figures on the actual printout in the "DOSES AND KFACTORS" section of this table.
2. The "E" for the exponent has been dropped from the "DOSES AND KFACTORS" section of this table.

Appendix E

Sample Input

The energy group structure used in the sample problems and listed in Table XVII is the DLC-31 (37/21) multigroup structure (Ref 8). Source spectra corresponding to these energy groupings are given in Table XVIII for neutrons (Ref 10) and prompt gamma particles (Ref 3). The response functions used are listed in Table XIX for both neutrons and gammas (Refs 11, 12, and 13). Table XX is a listing of the cross sections used in the sample problems. These are the diffusion theory cross sections from the Oak Ridge, DNA approved, DLC-31 (37/21) coupled neutron/gamma multigroup cross section set (Ref 7).

Table XVII
DLC-31 Energy Groups*

Group	Neutron Energy (Mev)	Group	Neutron Energy (Mev)	Group	Gamma Energy (Mev)
1	1.6905+01 - 1.9640+01	21	5.5023-01 - 1.1080+00	41	6.0000+00 - 7.0000+00
2	1.4918+01 - 1.6905+01	22	1.5764-01 - 5.5023-01	42	5.0000+00 - 6.0000+00
3	1.4191+01 - 1.4918+01	23	1.1109-01 - 1.5764-01	43	4.0000+00 - 5.0000+00
4	1.3840+01 - 1.4191+01	24	5.2475-02 - 1.1109-01	44	3.0000+00 - 4.0000+00
5	1.2840+01 - 1.3840+01	25	2.4788-02 - 5.2475-02	45	2.5000+00 - 3.0000+00
6	1.2214+01 - 1.2840+01	26	2.1875-02 - 2.4788-02	46	2.0000+00 - 2.5000+00
7	1.1052+01 - 1.2214+01	27	1.0333-02 - 2.1875-02	47	1.5000+00 - 2.0000+00
8	1.0000+01 - 1.1052+01	28	3.3546-03 - 1.0333-02	48	1.0000+00 - 1.5000+00
9	9.0484+00 - 1.0000+01	29	1.2341-03 - 3.3546-03	49	7.0000-01 - 1.0000+00
10	8.1873+00 - 9.0484+00	30	5.8295-04 - 1.2341-03	50	4.5000-01 - 7.0000-01
11	7.4082+00 - 8.1873+00	31	1.0130-04 - 5.8295-04	51	3.0000-01 - 4.5000-01
12	6.3763+00 - 7.4082+00	32	2.9023-05 - 1.0130-04	52	1.5000-01 - 3.0000-01
13	4.9659+00 - 6.3763+00	33	1.0677-05 - 2.9023-05	53	1.0000-01 - 1.5000-01
14	4.7237+00 - 4.9659+00	34	3.0590-06 - 1.0677-05	54	7.0000-02 - 1.0000-01
15	4.0657+00 - 4.7237+00	35	1.1254-06 - 3.0590-06	55	4.5000-02 - 7.0000-02
16	3.0119+00 - 4.0657+00	36	4.1400-07 - 1.1254-06	56	3.0000-02 - 4.5000-02
17	2.3852+00 - 3.0119+00	37	1.0000-11 - 4.1400-07	57	2.0000-02 - 3.0000-02
18	2.3069+00 - 2.3852+00	38	1.0000+01 - 1.4000+01	58	1.0000-02 - 2.0000-02
19	1.8268+00 - 2.3069+00	39	8.0000+00 - 1.0000+01		
20	1.1080+00 - 1.8268+00	40	7.0000+00 - 8.0000+00		

* Groups 38 through 58 are the prompt gamma energy groups.

(From Ref 8)

Table XVIII
Neutron and Prompt Gamma* Source Spectra

Group	Thermonuclear	Fission	Group	Thermonuclear	Fission	Group	Fission
1	0.0	0.0	21	8.84954-02	2.15670-01	41	9.07541-04
2	0.0	0.0	22	9.13765-02	1.50179-01	42	2.72640-03
3	1.88714-02	0.0	23	1.16335-02	1.92973-02	43	8.19057-03
4	9.34254-03	0.0	24	1.10777-01	1.20983-01	44	2.46058-02
5	2.66169-02	0.0	25	5.40049-02	5.72919-02	45	2.70447-02
6	1.66622-02	0.0	26	5.68196-03	5.99914-03	46	4.68753-02
7	1.68678-02	0.0	27	9.26377-02	2.39968-02	47	8.12469-02
8	1.23974-02	0.0	28	1.16267-01	1.43980-02	48	1.40821-01
9	7.48258-03	3.83946-03	29	7.38166-02	0.0	49	1.30142-01
10	6.82320-03	3.50150-03	30	2.32454-02	0.0	50	1.46558-01
11	6.77521-03	5.38923-03	31	2.02810-02	0.0	51	1.09353-01
12	1.03201-02	7.34895-03	32	1.90145-03	0.0	52	1.28970-01
13	1.80706-02	1.83674-02	33	0.0	0.0	53	4.79404-02
14	3.61700-03	3.24954-03	34	0.0	0.0	54	3.00557-02
15	1.24302-02	8.46880-03	35	0.0	0.0	55	2.58153-02
16	2.60380-02	5.50022-02	36	0.0	0.0	56	1.58334-02
17	2.37305-02	3.24354-02	37	0.0	0.0	57	1.07017-02
18	3.74662-03	1.05785-02	38		1.64966-05	58	1.08200-02
19	2.56418-02	9.72362-02	39		1.34031-04		
20	6.44472-02	1.46769-01	40		3.02094-04		

* Groups 38 through 58 are the prompt gamma spectra.

(From Ref 10 and Ref 3)

Table XIX

Neutron and Gamma* Response Functions (rad/(particle/cm^2))

Group	Tissue	Silicon	Group	Tissue	Silicon	Group	Tissue	Silicon
1	8.6724-09	1.9106-09	21	2.0569-09	4.9785-11	41	1.7922-09	1.8992-09
2	7.4190-09	1.7792-09	22	1.3330-09	3.1515-11	42	1.5928-09	1.6367-09
3	6.8115-09	1.6818-09	23	7.6228-10	1.7897-12	43	1.3897-09	1.3835-09
4	6.5447-09	1.6231-09	24	5.4890-10	2.8022-12	44	1.1803-09	1.1335-09
5	6.1473-09	1.5144-09	25	3.1164-10	1.2327-12	45	1.0098-09	9.4334-10
6	5.9548-09	1.3851-09	26	2.0739-10	7.9084-13	46	8.8320-10	8.2034-10
7	5.8936-09	1.2370-09	27	1.4662-10	5.8930-13	47	7.4281-10	6.8343-10
8	5.5508-09	1.0530-09	28	6.6143-11	2.9804-13	48	5.8030-10	5.2846-10
9	5.2882-09	8.7897-10	29	2.2758-11	1.0498-13	49	4.2393-10	3.8505-10
10	5.0473-09	7.9629-10	30	9.1315-12	4.3305-14	50	2.9695-10	2.7122-10
11	5.0045-09	7.8141-10	31	3.6633-12	1.4421-14	51	1.9283-10	1.7772-10
12	4.7595-09	4.7092-10	32	1.1759-12	4.5895-15	52	1.0770-10	1.0459-10
13	4.4831-09	2.1394-10	33	1.1095-12	3.9377-15	53	4.9383-11	6.8510-11
14	4.2531-09	1.8267-10	34	1.6117-12	5.6286-15	54	3.4315-11	7.9854-11
15	4.1711-09	1.4195-10	35	2.7416-12	9.4023-15	55	2.9479-11	1.4543-10
16	3.9784-09	1.0582-10	36	4.4570-12	1.5380-14	56	4.3750-11	3.4411-10
17	3.3905-09	1.0006-10	37	1.1238-11	7.4244-13	57	9.6647-11	8.2679-10
18	3.1377-09	8.2995-11	38	2.7431-09	3.4184-09	58	3.2504-10	2.6493-09
19	3.0345-09	9.4778-11	39	2.2564-09	2.5712-09			
20	2.6393-09	6.5328-11	40	1.9840-09	2.1612-09			

*Groups 38 through 58 are the gamma response functions.

(From Refs 11, 12, and 13)

Table XX

DLC-31 37/21 Coupled Neutron/Gamma Cross Section Set

(See Table III for Format Description)

POS.	ENG GRP 1	ENG GRP 2	ENG GRP 3	ENG GRP 4	ENG GRP 5	ENG GRP 6	ENG GRP 7	ENG GRP 8
1	4.1531E-05	4.7604E-05	5.5893E-05	6.2650E-05	5.3803E-05	5.8892E-05	5.0693E-05	4.8628E-05
2	4.6222E-05	5.0846E-05	5.7586E-05	6.3446E-05	5.5931E-05	5.8423E-05	5.3293E-05	5.0937E-05
3	8.0538E-05	8.1211E-05	8.1820E-05	8.0853E-05	8.0534E-05	8.0188E-05	7.6140E-05	7.1557E-05
4	3.9007E-05	3.4427E-05	2.5927E-05	1.8203E-05	2.0731E-05	2.3276E-05	2.5447E-05	2.2928E-05
5	0.	5.0288E-06	6.7187E-06	7.5883E-06	1.7359E-05	8.2466E-06	1.5220E-05	1.1468E-05
6	0.	0.	1.0066E-05	1.7413E-06	7.1931E-06	4.8114E-06	8.1518E-06	7.2485E-06
7	0.	0.	0.	3.3630E-07	3.2721E-06	3.1810E-06	4.6736E-06	3.0804E-06
8	0.	0.	0.	0.	6.4638E-07	1.1459E-06	2.8110E-06	1.2174E-06
9	0.	0.	0.	0.	0.	2.5447E-07	7.1907E-07	4.6916E-07
10	0.	0.	0.	0.	0.	0.	1.1181E-06	3.7930E-07
11	0.	0.	0.	0.	0.	0.	0.	1.6264E-06
12	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.
46	0.	0.	0.	0.	0.	0.	0.	0.
47	0.	0.	0.	0.	0.	0.	0.	0.
48	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.
52	0.	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.	0.	0.	0.
55	0.	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

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Table XX (cont)

POS.	ENG GRP 9	ENG GRP 10	ENG GRP 11	ENG GRP 12	ENG GRP 13	ENG GRP 14	ENG GRP 15	ENG GRP 16
1	4.5586E-05	4.3477E-05	5.0532E-05	4.2015E-05	3.6458E-05	4.1106E-05	5.4482E-05	5.0602E-05
2	4.7868E-05	4.7581E-05	5.2911E-05	4.5629E-05	4.7652E-05	4.7449E-05	6.1452E-05	7.2095E-05
3	6.9560E-05	6.4455E-05	7.1885E-05	6.4055E-05	7.0952E-05	5.6620E-05	8.9793E-05	9.7190E-05
4	2.0672E-05	1.9784E-05	2.1153E-05	2.2534E-05	3.4240E-05	1.5711E-05	3.4990E-05	4.6388E-05
5	1.1617E-05	1.2726E-05	1.3031E-05	2.2634E-05	2.7151E-05	7.5221E-06	2.0675E-05	3.7443E-05
6	8.6628E-06	8.6416E-06	9.8499E-06	1.4293E-05	9.1216E-06	2.3259E-07	1.5059E-05	7.5863E-06
7	2.1258E-06	1.7596E-06	2.2607E-06	2.7539E-06	8.9334E-07	1.4497E-07	9.8863E-06	2.6655E-06
8	7.4643E-07	2.0446E-07	1.6532E-07	2.4462E-07	3.6009E-07	0.	2.6603E-07	3.6885E-07
9	3.0063E-06	2.1362E-07	2.4774E-07	7.3344E-07	1.3477E-05	3.2375E-07	3.7623E-07	1.0658E-06
10	3.0995E-07	7.1774E-07	6.6138E-07	1.0836E-05	2.3444E-06	2.1754E-07	9.4567E-07	2.2766E-06
11	1.2216E-05	6.3322E-07	1.1143E-05	2.0977E-05	6.3426E-06	6.5706E-07	1.2704E-06	2.0993E-06
12	1.5762E-06	1.3644E-05	1.2712E-06	3.0804E-06	4.6815E-05	7.3137E-07	3.0339E-06	4.0865E-06
13	0.	1.0424E-06	1.9170E-06	3.0114E-06	3.0614E-06	5.6325E-07	2.3509E-06	3.3682E-06
14	0.	0.	0.	2.2384E-06	4.0133E-06	1.7033E-06	1.8279E-05	3.1064E-06
15	0.	0.	0.8966E-07	7.6836E-07	2.7162E-06	6.3877E-07	2.2699E-05	4.6029E-06
16	0.	0.	0.	0.	1.2387E-06	2.8657E-07	2.1926E-06	3.6729E-06
17	0.	0.	0.	0.	0.	2.9956E-07	1.1716E-06	2.9607E-06
18	0.	0.	0.	0.	0.	0.	1.0085E-06	2.4105E-06
19	0.	0.	0.	0.	0.	0.	0.	2.5706E-06
20	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.
46	0.	0.	0.	0.	0.	0.	0.	0.
47	0.	0.	0.	0.	0.	0.	0.	0.
48	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.
52	0.	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.	0.	0.	0.
55	0.	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

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UNCLASSIFIED AFWL-TR-77-29 NL

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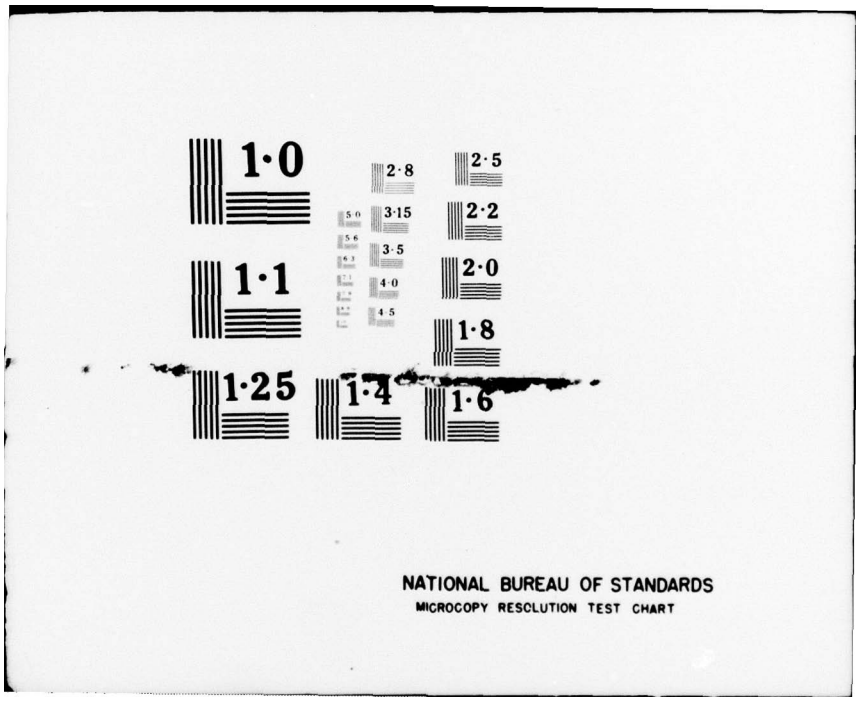
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4·5
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Table XX (cont)

POS.	ENG GRP 17	ENG GRP 18	ENG GRP 19	ENG GRP 20	ENG GRP 21	ENG GRP 22	ENG GRP 23	ENG GRP 24
1	4.3900E-05	5.0732E-05	4.7780E-05	3.2071E-05	2.4220E-05	2.0604E-05	8.0022E-05	4.4586E-05
2	5.4797E-05	5.7071E-05	6.3453E-05	4.5670E-05	9.8179E-05	1.6443E-04	1.7210E-04	2.1199E-04
3	6.9340E-05	6.1706E-05	8.2804E-05	1.1024E-04	1.1149E-04	1.7847E-04	2.0198E-04	2.3380E-04
4	2.5455E-05	4.9713E-06	3.5024E-05	7.8174E-05	8.7200E-05	1.5761E-04	1.2176E-04	1.8928E-04
5	3.4073E-05	6.9855E-06	4.4756E-05	4.4074E-05	2.9194E-05	2.2635E-05	2.0274E-05	7.9952E-05
6	0.	1.6383E-06	2.9219E-05	7.9230E-06	0.	0.	0.	0.
7	0.	0.	2.9184E-07	2.4474E-07	0.	0.	0.	0.
8	2.7336E-07	0.	1.5399E-07	8.2946E-08	0.	0.	0.	0.
9	1.3315E-06	3.6143E-08	5.2506E-07	3.2128E-07	1.2534E-07	2.7128E-08	0.	0.
10	1.1076E-06	2.9966E-07	1.7196E-07	0.	0.	1.2641E-08	1.9956E-09	0.
11	1.8399E-06	2.4981E-07	1.5333E-06	1.0095E-06	6.0001E-07	4.0205E-07	0.	1.8273E-09
12	3.0933E-06	2.0547E-07	1.4434E-06	1.1511E-06	9.0281E-07	5.1516E-07	2.1392E-08	0.
13	2.0382E-06	3.8042E-07	2.6531E-06	3.1160E-06	1.4603E-06	1.5916E-07	0.	1.3136E-08
14	2.6189E-06	1.9248E-07	1.4074E-06	2.5073E-06	1.8053E-06	6.5259E-07	1.0892E-08	0.
15	3.2329E-06	4.0553E-07	1.1274E-06	1.1211E-06	6.2713E-07	3.5794E-07	1.7813E-08	1.1134E-08
16	2.3071E-06	3.1511E-07	1.9855E-06	2.1370E-06	7.7463E-07	1.9245E-07	1.4450E-08	9.5276E-09
17	1.8302E-06	2.6960E-07	1.6897E-06	2.2753E-06	1.5696E-06	4.5455E-07	1.8466E-08	1.1967E-08
18	1.8649E-06	1.6780E-07	1.4249E-06	2.0097E-06	1.0899E-06	5.6158E-07	1.6043E-08	1.5265E-08
19	1.7039E-06	2.7015E-07	1.3475E-06	1.6333E-06	6.9390E-07	4.8417E-07	3.1064E-08	3.1277E-08
20	2.3528E-06	2.5229E-07	1.7348E-06	2.2305E-06	1.1322E-06	5.5414E-07	5.1103E-08	4.6498E-08
21	0.	3.1740E-07	1.5295E-06	1.6145E-06	8.2006E-07	5.4393E-07	4.2008E-08	2.6619E-08
22	0.	0.	2.1272E-06	2.9103E-06	1.5676E-06	8.6140E-07	3.9819E-08	3.8143E-08
23	0.	0.	0.	3.3621E-06	2.1692E-06	7.8106E-07	1.0541E-08	3.1554E-08
24	0.	0.	0.	0.	2.2895E-06	9.3411E-07	5.6416E-08	8.6907E-09
25	0.	0.	0.	0.	0.	8.6550E-07	3.3737E-08	4.0265E-08
26	0.	0.	0.	0.	0.	0.	4.0863E-08	2.3466E-08
27	0.	0.	0.	0.	0.	0.	0.	1.7483E-08
28	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.
46	0.	0.	0.	0.	0.	0.	0.	0.
47	0.	0.	0.	0.	0.	0.	0.	0.
48	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.
52	0.	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.	0.	0.	0.
55	0.	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

Table XX (cont)

POS.	ENG GRP 25	ENG GRP 26	ENG GRP 27	ENG GRP 28	ENG GRP 29	ENG GRP 30	ENG GRP 31	ENG GRP 32
1	5.2673E-05	2.3416E-04	6.0113E-05	4.2806E-05	5.1573E-05	7.2926E-05	3.3152E-05	4.8614E-05
2	2.5693E-04	2.5576E-04	2.9407E-04	3.2460E-04	3.4681E-04	1.0660E-04	3.9293E-04	4.0545E-04
3	2.8396E-04	3.0964E-04	3.2705E-04	3.5397E-04	3.8017E-04	4.0174E-04	4.2268E-04	4.4043E-04
4	2.3128E-04	7.4465E-05	2.6773E-04	3.1105E-04	3.2870E-04	3.2695E-04	3.8953E-04	3.9181E-04
5	4.4525E-05	3.0736E-05	2.3411E-04	6.0617E-05	4.2726E-05	5.1132E-05	7.2508E-05	3.2348E-05
6	0.	0.	1.5870E-05	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.
12	6.2497E-10	0.	0.	0.	0.	0.	0.	0.
13	0.	4.4280E-11	0.	0.	0.	0.	0.	0.
14	1.1711E-09	0.	7.2336E-11	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.
16	1.5753E-09	0.	0.	0.	0.	0.	0.	0.
17	1.0070E-09	1.7310E-13	0.	0.	0.	0.	0.	0.
18	1.3771E-09	5.1207E-13	0.	0.	0.	0.	0.	0.
19	1.4244E-09	0.	0.	0.	0.	0.	0.	0.
20	3.3143E-09	0.	0.	0.	0.	0.	0.	0.
21	2.7036E-09	0.	0.	0.	0.	0.	0.	0.
22	5.4284E-10	0.	0.	0.	0.	0.	0.	0.
23	1.7421E-09	3.5183E-11	0.	0.	0.	0.	0.	0.
24	2.1696E-09	1.1044E-10	9.6217E-11	0.	0.	0.	0.	0.
25	1.1276E-09	1.3789E-10	3.0820E-10	2.4782E-11	0.	0.	0.	0.
26	1.1623E-09	6.9675E-11	5.7694E-10	7.7664E-11	2.5185E-12	0.	0.	0.
27	7.2622E-10	6.9772E-10	1.9107E-10	9.6955E-11	7.9054E-12	3.0624E-13	0.	0.
28	4.3331E-10	7.8501E-11	1.9113E-10	4.9100E-11	9.8561E-12	9.6124E-13	8.5301E-14	0.
29	0.	2.7534E-11	1.2089E-10	4.7167E-11	5.0017E-12	1.1997E-12	2.6776E-13	0.
30	0.	0.	7.5301E-11	3.2603E-11	5.0044E-12	6.0842E-13	3.3417E-13	9.5510E-15
31	0.	0.	0.	0.	3.3215E-12	6.0702E-13	1.6741E-13	0.
32	0.	0.	0.	1.9347E-11	1.9769E-12	4.0351E-13	1.6965E-13	0.
33	0.	0.	0.	0.	0.	2.3906E-13	1.1250E-13	0.
34	0.	0.	0.	0.	0.	0.	6.6756E-14	0.
35	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.
46	0.	0.	0.	0.	0.	0.	0.	0.
47	0.	0.	0.	0.	0.	0.	0.	0.
48	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.
52	0.	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.	0.	0.	0.
55	0.	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

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Table XX (cont)

POS.	ENG GRP 33	ENG GRP 34	ENG GRP 35	ENG GRP 36	ENG GRP 37	ENG GRP 38	ENG GRP 39	ENG GRP 40
1	6.1[illegible]E-05	5.0[illegible]E-05	6.49[illegible]E-05	6.84[illegible]E-05	5.66[illegible]E-05	2.22[illegible]E-05	2.47[illegible]E-05	2.69[illegible]E-05
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.
38	0.	0.	0.	0.	0.	0.	0.	0.
39	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	0.
43	0.	0.	0.	0.	0.	0.	0.	0.
44	0.	0.	0.	0.	0.	0.	0.	0.
45	0.	0.	0.	0.	0.	0.	0.	0.
46	0.	0.	0.	0.	0.	0.	0.	0.
47	0.	0.	0.	0.	0.	0.	0.	0.
48	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.
52	0.	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.	0.	0.	0.
55	0.	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

Table XX (cont)

POS.	ENG GRP 41	ENG GRP 42	ENG GRP 43	ENG GRP 44	ENG GRP 45	ENG GRP 46	ENG GRP 47	ENG GRP 48
1	2.64	3.0	3.1	3.6	4.2	4.6	5.1	5.6
2	2.6	3.0	3.3	3.6	4.3	4.6	5.1	5.6
3	2.9	3.4	3.9	4.0	4.5	4.9	5.1	5.7
4	1.0	1.4	2.1	3.5	2.9	4.2	5.0	6.9
5	1.0	2.4	3.1	4.7	6.1	6.9	9.1	1.0
6	1.2	1.7	2.3	3.3	3.6	4.0	6.3	1.4
7	7.7	1.2	1.8	2.5	1.0	1.4	2.0	2.7
8	4.6	8.4	1.4	2.0	2.6	2.6	4.3	9.5
9	1.1	1.8	2.4	1.6	1.2	1.6	3.0	5.2
10	7.6	1.2	1.8	1.1	1.9	1.6	2.4	3.9
11	3.8	3.6	9.6	6.3	7.1	1.4	2.0	3.2
12	2.2	2.6	6.1	1.6	1.1	1.5	1.7	2.7
13	1.2	1.6	6.1	1.6	1.7	8.5	1.4	2.3	1.4
14	6.4	2.3	5.3	5.7	9.6	3.4	1.0	1.9
15	3.1	6.9	2.7	8.9	2.9	8.9	7.7	1.5
16	2.4	1.2	1.1	3.4	1.6	5.7	2.0	5.7
17	1.1	9.5	2.7	9.4	9.8	3.1	1.2	1.4
18	7.6	4.7	1.5	1.9	5.2	1.9	7.0	9.4
19	5.8	3.6	9.6	6.2	2.6	1.0	4.2	5.2
20	2.2	2.6	6.1	1.6	1.3	5.1	2.3	3.1
21	1.2	1.6	6.1	1.6	8.8	2.5	1.1	1.7
22	6.4	2.3	5.3	5.1	4.9	1.6	5.7	8.6
23	3.1	6.9	2.7	8.8	2.3	8.9	3.0	5.1
24	0.	2.4	1.1	3.4	1.6	5.7	2.0	4.2
25	0.	1.4	2.7	9.4	9.8	3.1	1.2	2.4
26	0.	9.6	1.5	1.9	5.2	1.9	7.0	1.4
27	0.	0.	9.6	6.2	2.6	1.0	4.2	6.2
28	0.	0.	0.	1.6	1.3	5.1	2.3	3.1
29	0.	0.	0.	5.1	6.5	2.5	1.1	1.7
30	0.	0.	0.	2.1	3.2	1.6	5.7	8.6
31	0.	0.	0.	8.8	1.6	8.9	3.0	5.1
32	0.	0.	0.	3.4	8.1	4.5	1.6	2.4
33	0.	0.	0.	1.6	4.0	2.3	8.3	1.4
34	0.	0.	0.	6.2	2.0	1.1	4.2	6.2
35	0.	0.	0.	2.6	1.0	5.7	2.1	3.1
36	0.	0.	0.	1.3	5.1	2.9	1.0	1.7
37	0.	0.	0.	6.5	2.5	1.4	5.3	8.6
38	0.	0.	0.	3.2	1.2	7.2	2.6	4.3
39	0.	0.	0.	1.6	6.3	3.6	1.3	2.1
40	0.	0.	0.	8.1	3.1	1.8	6.6	1.0
41	0.	0.	0.	4.0	1.6	9.0	3.3	5.4
42	0.	0.	0.	2.0	7.8	4.5	1.6	2.7
43	0.	0.	0.	1.0	3.9	2.2	8.3	1.3
44	0.	0.	0.	5.0	1.9	1.1	4.1	6.8
45	0.	0.	0.	2.5	9.8	5.6	2.0	3.4
46	0.	0.	0.	1.2	4.9	2.8	1.0	1.7
47	0.	0.	0.	6.2	2.4	1.4	5.2	8.5
48	0.	0.	0.	3.1	1.2	7.0	2.6	4.2
49	0.	0.	0.	1.5	6.1	3.5	1.3	2.1
50	0.	0.	0.	7.7	3.0	1.8	6.5	1.0
51	0.	0.	0.	3.8	1.5	8.8	3.2	5.3
52	0.	0.	0.	1.9	7.6	4.4	1.6	2.6
53	0.	0.	0.	9.6	3.8	2.2	8.1	1.3
54	0.	0.	0.	4.8	1.9	1.1	4.0	6.6
55	0.	0.	0.	2.4	9.5	5.5	2.0	3.3
56	0.	0.	0.	1.2	4.8	2.7	1.0	1.6
57	0.	0.	0.	6.0	2.4	1.4	5.0	8.2
58	0.	0.	0.	3.0	1.2	6.9	2.5	4.1
59	0.	0.	0.	1.5	5.9	3.4	1.2	2.0
60	0.	0.	0.	7.5	3.0	1.7	6.2	1.0
61	0.	0.	0.	3.7	1.5	8.6	3.1	5.1

Table XX (cont)

POS.	ENG GRP 49	ENG GRP 50	ENG GRP 51	ENG GRP 52	ENG GRP 53	ENG GRP 54	ENG GRP 55	ENG GRP 56
1	6.7674E-05	7.2170E-05	8.1273E-05	5.6826E-05	7.8588E-05	7.2666E-05	5.1403E-05	9.2725E-05
2	6.8794E-05	7.5382E-05	8.7611E-05	9.6815E-05	1.2291E-04	1.4771E-04	1.9037E-04	2.5942E-04
3	8.4455E-05	1.6084E-04	1.2014E-04	1.4510E-04	1.7142E-04	1.9283E-04	2.1969E-04	2.8102E-04
4	1.6711E-05	2.8701E-05	3.8866E-05	8.8480E-05	9.4833E-05	1.2055E-04	1.6760E-04	1.8830E-04
5	1.7226E-05	2.8547E-05	3.4913E-05	7.3456E-05	5.5547E-05	7.7241E-05	6.7878E-05	3.5055E-05
6	9.5335E-06	1.5053E-05	1.8648E-05	3.7844E-05	2.7639E-06	1.0267E-06	0.	
7	6.8427E-06	1.0533E-05	1.2504E-05	2.1074E-05	0.	0.	0.	0.
8	5.4937E-06	9.4116E-06	9.2057E-06	1.2241E-05	0.	0.	0.	0.
9	4.2873E-06	8.6914E-06	7.4604E-06	7.6274E-06	0.	0.	0.	0.
10	3.3341E-06	8.0476E-06	6.1965E-06	5.4078E-06	0.	0.	0.	0.
11	2.7719E-06	9.4761E-06	5.0551E-06	4.1416E-06	0.	0.	0.	0.
12	2.3656E-06	1.0219E-05	3.9622E-06	3.0561E-06	0.	0.	0.	0.
13	2.0644E-06	1.0734E-05	3.2805E-06	2.2244E-06	0.	0.	0.	0.
14	1.7405E-06	1.1186E-05	2.7585E-06	1.7337E-06	0.	0.	0.	0.
15	1.3366E-06	1.1212E-05	2.4402E-06	1.4251E-06	0.	0.	0.	0.
16	1.0695E-06	1.0438E-05	2.0526E-06	1.2053E-06	0.	0.	0.	0.
17	9.3640E-10	9.7768E-09	1.5609E-06	9.8693E-07	0.	0.	0.	0.
18	8.0965E-10	1.7584E-09	0.	7.1455E-07	0.	0.	0.	0.
19	3.3617E-10	1.1684E-09	0.	0.	0.	0.	0.	0.
20	2.0316E-10	8.4427E-10	0.	0.	0.	0.	0.	0.
21	1.0931E-10	3.7133E-10	0.	0.	0.	0.	0.	0.
22	5.4699E-11	2.0005E-10	0.	0.	0.	0.	0.	0.
23	2.7218E-11	1.0494E-10	0.	0.	0.	0.	0.	0.
24	1.4048E-11	5.6045E-11	0.	0.	0.	0.	0.	0.
25	1.0426E-11	3.3918E-11	0.	0.	0.	0.	0.	0.
26	6.3563E-12	1.8914E-11	0.	0.	0.	0.	0.	0.
27	4.9653E-12	1.1441E-11	0.	0.	0.	0.	0.	0.
28	3.9664E-12	8.9503E-12	0.	0.	0.	0.	0.	0.
29	2.3227E-12	7.0634E-12	0.	0.	0.	0.	0.	0.
30	8.3369E-13	4.2726E-12	0.	0.	0.	0.	0.	0.
31	5.6697E-13	2.6767E-12	0.	0.	0.	0.	0.	0.
32	3.5907E-13	9.0015E-13	0.	0.	0.	0.	0.	0.
33	2.5786E-13	0.	0.	0.	0.	0.	0.	0.
34	2.1271E-13	0.	0.	0.	0.	0.	0.	0.
35	1.9760E-13	0.	0.	0.	0.	0.	0.	0.
36	1.8677E-13	0.	0.	0.	0.	0.	0.	0.
37	1.8037E-13	0.	0.	0.	0.	0.	0.	0.
38	1.4478E-13	0.	0.	0.	0.	0.	0.	0.
39	1.3832E-13	0.	0.	0.	0.	0.	0.	0.
40	1.2803E-09	0.	0.	2.4627E-09	0.	0.	0.	0.
41	2.3501E-07	2.8440E-13	0.	1.4464E-08	0.	0.	0.	0.
42	8.1455E-07	8.3344E-07	0.	6.2209E-08	0.	0.	0.	0.
43	7.1513E-07	1.8426E-06	0.	6.2687E-08	0.	0.	0.	0.
44	7.7652E-07	1.4536E-06	0.	2.4491E-07	0.	0.	0.	0.
45	7.9126E-07	1.0375E-06	0.	1.4644E-08	0.	0.	0.	0.
46	7.4328E-07	1.0944E-06	0.	6.2209E-08	0.	0.	0.	0.
47	6.6537E-07	2.1660E-06	7.0920E-10	6.2687E-08	0.	0.	0.	0.
48	6.3665E-07	1.3112E-06	2.2834E-08	2.4491E-07	0.	0.	0.	0.
49	6.2438E-07	1.1693E-06	1.3673E-08	5.1693E-07	4.5237E-09	0.	0.	0.
50	6.3047E-07	1.1033E-06	2.0784E-08	4.0754E-07	9.2977E-08	0.	0.	0.
51	5.9330E-07	1.0377E-06	2.3305E-08	5.2600E-07	5.2843E-08	0.	0.	0.
52	4.8774E-07	8.8760E-07	2.0600E-08	5.0471E-07	4.5811E-08	0.	0.	0.
53	0.	6.3971E-07	1.4454E-08	5.7526E-07	9.6114E-08	0.	0.	0.
54	0.	0.	7.9310E-09	5.2997E-07	8.4082E-08	0.	0.	0.
55	0.	0.	0.	4.5735E-07	5.9769E-08	0.	0.	0.
56	0.	0.	0.	0.	2.3012E-08	0.	0.	0.
57	0.	0.	0.	0.	0.	0.	0.	0.
58	0.	0.	0.	0.	0.	0.	0.	0.
59	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.

Table XX (cont)

POS.	ENG GAP 57	ENG GAP 58
1	2.7624E-04	1.6424E-03
2	4.6058E-04	1.8.25E-03
3	4.7592E-04	1.8495E-03
4	2.0385E-04	2.2715E-04
5	2.0781E-05	1.8271E-05
6	0.	0.
7	0.	0.
8	0.	0.
9	0.	0.
10	0.	0.
11	0.	0.
12	0.	0.
13	0.	0.
14	0.	0.
15	0.	0.
16	0.	0.
17	0.	0.
18	0.	0.
19	0.	0.
20	0.	0.
21	0.	0.
22	0.	0.
23	0.	0.
24	0.	0.
25	0.	0.
26	0.	0.
27	0.	0.
28	0.	0.
29	0.	0.
30	0.	0.
31	0.	0.
32	0.	0.
33	0.	0.
34	0.	0.
35	0.	0.
36	0.	0.
37	0.	0.
38	0.	0.
39	0.	0.
40	0.	0.
41	0.	0.
42	0.	0.
43	0.	0.
44	0.	0.
45	0.	0.
46	0.	0.
47	0.	0.
48	0.	0.
49	0.	0.
50	0.	0.
51	0.	0.
52	0.	0.
53	0.	0.
54	0.	0.
55	0.	0.
56	0.	0.
57	0.	0.
58	0.	0.
59	0.	0.
60	0.	0.