Personnel Exposure from Right Cylindrical Sources (PERCS)

The Theory, the Code, and Examples

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Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory
Commission

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Manuscript Completed: November 1983
Date Published: January 1984

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Prepared for
Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FINs B2412, B2429

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1.0 INTRODUCTION

Personnel Exposure From Right Cylindrical Sources (PERCS) is a point kernel shielding code developed at Pacific Northwest Laboratory.^(a) PERCS was written to assist in quantifying the radiation dose rate around reactor piping to facilitate study of the effects of decontamination and shielding. This code computes doses incurred from gamma rays emanating from activated corrosion products located on the interior surfaces of primary piping at nuclear power plants. PERCS calculates the self-shielding provided by the walls and fill material (water, steam, etc.) of each source pipe and includes the shielding from all other pipes and ancillary shields, such as concrete shielding walls or lead blankets.

The program calculates the dose from up to twenty distributed cylindrical sources for any number of dose points, allowing any configuration of cylindrical or rectangular slab shields. PERCS offers many improvements over current point kernel shielding codes, such as ISOSHLD, or Monte Carlo codes, such as MORSE, for this particular geometry. Some of the principal advantages are as follows:

1. Completely arbitrary geometry is allowed in pipe location, pipe sizes, source distribution (both spatially and isotopically), composition of material inside the pipe, composition of pipe wall, and placement of auxiliary shields.
2. The location of the dose point is completely arbitrary, including, within a pipe, within a pipe wall, or within an auxiliary shield. A single exception is the placement of the dose point exactly on the centerline of the source pipe.
3. The shielding of the distributed source by the source pipe and its contents is calculated.
4. All other pipes and shields on a line-of-sight between the differential source point and the dose point are included in the shielding and buildup calculation.
5. A special program interactively prompts the user for the necessary data, builds the appropriate shielding and nuclide libraries and writes the information to output files ready for use in the main program. This same interactive program can easily modify existing output files for different cases.
6. The graphical output of PERCS allows the user to see quickly the relation of a dose point to the various pipes and shields within a plane.

(a) The Pacific Northwest Laboratory is operated by Battelle Memorial Institute.

7. The required execution time for PERCS is much shorter than for currently used point kernel shielding codes. For example, a case consisting of one distributed source and one dose point, typically is run five to ten times faster by PERCS than by other codes.

For every dose point, PERCS evaluates the contribution of each source pipe and for each pipe calculates all the parameters, such as upper and lower limits of integration, needed to initiate the numerical integration of the point kernel. The double integration through angle and length of pipe is done by spline quadrature routines or eight-panel Newton-Cotes quadrature routines, depending on the location of the dose point relative to the source pipe. As each differential source element is chosen, all the pipes and auxiliary shields are checked to determine if they lie between the source element and dose point. A tally is kept of the contribution to optical thickness and the relative location of each shield.

After these geometric calculations are done, the concentration of each isotope in the differential area is computed and each gamma energy and yield for that isotope is used, along with the calculated buildup factor, to evaluate the point kernel. The quadrature routines are then used to calculate the integral with respect to all angles around the pipe and these integrals are used to compute the integral along the length of the pipe.

After this, the next source pipe is chosen and the calculations outlined above are repeated. A running sum is kept of the dose from each pipe to give the total dose for that point. The total dose for the chosen point is printed, the next dose point is prompted from the user, and all calculations are repeated until terminated by the user. A schematic of the sequence of calculation steps in PERCS is presented in Figure 1.1.

Each of the major routines shown in Figure 1.1 is explained and listed in a separate section of this document. A brief discussion of the mathematics behind each routine is presented and the major variables used in each routine are identified. Following these discussions, a complete example is presented including how to use PERCSLIB to create the necessary input libraries.

FIGURE 1.1. Schematic of Calculation Sequence in PERCS

2.0 PERCSLIB

PERCSLIB is a quick and efficient method of entering the data required by the program PERCS. PERCSLIB interactively prompts the user for specific information which it stores in one of four files. In many cases, the user is assisted with examples of the correct input format. Simple methods are provided for the correction or modification of existing data without requiring the user to re-enter all the information.

The data files created by PERCSLIB and required by PERCS are organized into four libraries. These are a shield library, an isotope library, a program input library, and a source library.

2.1 SHIELD LIBRARY - SUBROUTINE SHLIB

PERCSLIB gives the user the option of using or modifying a previous shield library or creating a new one. If an old library is requested, the data contained in file FOR011.DAT is read. If a new library is desired, the user is prompted for the pertinent information which is then written into a new file, FOR011.DAT.

The shielding library contains a maximum of ten shielding materials. The following information is required, by subroutine SHLIB, for each material:

1. Name of the shield material.
2. Atomic number of the shield material.
3. Linear absorption coefficient (μ) for each of eight energies. The energies (given in MeV) are: 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, and 1.4. The absorption coefficient must be input in units of inverse centimeters.

The current data is listed on the terminal screen after a new file is created or an old file is called up. The user is given the opportunity to add another shield, delete a shield, change some or all of the information for a particular shield, or write the current information into a data file.

2.2 ISOTOPE LIBRARY - SUBROUTINE ISOLIB

The procedure for creating or editing the isotope library is similar to that for the shield library. The user has the option of editing an old isotope library or creating a new library. If an old library is requested, the file FOR010.DAT is read. If a new library is desired, a new file of the same name is created and the user is prompted for the proper information.

A maximum of ten isotopes is permitted in the isotope library. The following information is requested, by subroutine ISOLIB, for each isotope:

1. Atomic symbol.
2. Number of gammas emitted per disintegration (maximum of 5 gammas).
3. Energy of each gamma (in MeV).
4. Yield of each gamma.

The above information is displayed after it has been entered into the program, or after an existing file has been called. The user is then given the option of adding or deleting an isotope or changing some or all of the parameters for a specific isotope.

2.3 INPUT LIBRARY - SUBROUTINE INDAT

The input library contains information regarding the location, dimensions, and materials of composition for each pipe and each shield. The input subroutine INDAT calls the source library subroutine SRCLIB to create a source description for each pipe.

The user has the option of creating a new input file or editing an old file. If the user requests an old file, FOR013.DAT is opened along with the corresponding source library FOR012.DAT. If a new input library is desired, the program creates a new file FOR013.DAT for the input parameters and file FOR012.DAT for the source parameters.

The input library considers up to 50 pipes, 20 different sources, and 10 shields. The following information is requested by the subroutine:

1. Title to be printed at the start of a PERCS run
2. Number of pipes
3. Coordinates describing the location of each pipe in a three-dimensional cartesian coordinate system
4. Inner radius of each pipe and thickness of the pipe walls
5. Material contained in each pipe (from those listed in the shield library)
6. Wall material of each pipe (from those listed in the shield library)
7. Switch to designate printing of input data to the user's terminal upon initiation of PERCS
8. The source number which corresponds to each pipe
9. Number of isotopes in each source
10. Number of external shields
11. Location of each external shield using cartesian coordinates

12. Half thickness of the shield

13. Shield material.

If the user desires to modify a previous input file and source library or one that has just been created, the following items may be changed:

1. title
2. pipe parameters
3. printout
4. source content
5. shield.

If the user wishes to change the pipe parameters, he has the choice of changing all the parameters or just specific parameters such as the pipe coordinates, the radius, the pipe thickness, the material the pipe is filled with, the wall material or the isotopes present in the source. Certain pipes may be altered, all the pipes may be changed or any number of pipes may be added to the input library (up to a total of 50 pipes). Likewise all shields or just specific shields may be altered. If the source content is incorrect, isotopes may be added to, or deleted from the source by specifying which source and entering the correct number of isotopes.

2.4 SOURCE LIBRARY - SUBROUTINE SRCLIB

The source distribution in each pipe is created by a call to the source library subroutine (SRCLIB) or by assigning a source that was created by a previous call to the subroutine. Thus each pipe may contain a different source, or some pipes or all of the pipes may contain the same source.

Upon entering the source subroutine, the isotope library is read and the user is given a listing of the isotopes contained in it. The user then specifies which of the isotopes are present in the source.

The user next indicates if the isotopic surface concentration of each of the source isotopes is constant or linear along the pipe. If the concentration is constant, the user is prompted for the activity (in $\mu\text{Ci}/\text{cm}^2$). If the concentration is linear, the user enters the activity at the beginning of the pipe and the activity at the end of the pipe.

The user is given the opportunity to correct mistakes made during entry of the isotope parameters. Changes to a particular isotope can be made by specifying the atomic symbol of the isotope to be altered.

Table 2.1 summarizes the parameters created by PERCSLIB and written to the output files which are used by PERCS. The table includes descriptions, dimensions, input formats and units for each parameter. Figure 2.1 illustrates some of the parameters required by the program input library.

TABLE 2.1. PERCS Data Libraries

<u>Parameter</u>	<u>Description</u>	<u>Dimension Range</u>	<u>Input Format</u>	<u>Units</u>
<u>Shield Library - SHLIB</u>				
TITLE2(I)	Name of ith shield material	I = 1,10	CHARACTER*16	-
ZLIST(I)	Atomic Number of ith shield material	I = 1,10	Free format	-
DMULB(I,J)	Linear absorption coefficient (mu) of the ith material for each of "j" energies (given in MeV): 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2 and 1.4	I = 1,10 J = 1,8	Free format	cm ⁻¹
<u>Isotope Library - ISOLIB</u>				
TITLE1(I)	Atomic symbol of ith isotope	I = 1,10	CHARACTER	-
NMEV(I)	Number of gammas present in a disintegration of the ith isotope (maximum is 5)	I = 1,10	Free format	-
ENERGY(I,J,1)	Energy of jth gamma in ith isotope	I = 1,10 J = 1,5	Free format	MeV
ENERGY(I,J,2)	Yield of jth gamma of ith isotope	I = 1,10 J = 1,5	Free format	-
<u>Input Library - INDAT</u>				
TITLE	Title of current run	-	CHARACTER*16	-
NPIPES	Number of pipes	-	Free format	-
X(I,1),X(I,2),X(I,3)	Coordinates describing location of the start of ith pipe's centerline (using a three-dimensional cartesian coordinate system)	I = 1,50	Free format	cm
X(I,4),X(I,5),X(I,6)	Coordinates describing location of the end of the ith pipe's centerline	I = 1,50	Free format	cm
X(I,7)	Radius of ith pipe	I = 1,50	E12.3	cm
X(I,8)	Thickness of the ith pipe	I = 1,50	E12.3	cm
X(I,9)	Material ith pipe is filled with (number corresponds to entry in the shield material library)	I = 1,50	Free format	-
X(I,10)	Wall material of ith pipe (number corresponds to entry in the shield material library)	I = 1,50	Free format	-
X(I,11)	Source number of ith pipe	I = 1,50	Free format	-

TABLE 2.1. (continued)

Parameter	Description	Dimension Range	Input Format	Units
NLIB	Switch to designate printing of input data to the user's terminal upon initiation of PERCS	-	Free format	-
ISHLD	Number of external shields	-	Free format	-
SH(I,1)	X1-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,2)	Y1-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,3)	X2-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,4)	Y2-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,5)	Z low-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,6)	Z high-coordinate for ith shield	I = 1,10	E12.3	cm
SH(I,7)	Half thickness of ith pipe	I = 1,10	E12.3	cm
SH(I,8)	Shield material for ith shield (number corresponds to entry in the shield material library)	I = 1,10	Free format	-
NSI = MNSI in PERCS	Number of sources	-	Free format	-
<u>Source Library - SRCLIB</u>				
SRC(I,J,1)	C designates a constant geometry for activity of jth isotope in isotope library for ith source L designates a linear geometry for activity of jth isotope in library for ith source	I = 1,20 J = 1,10	A2	-
SRC(I,J,2)	Concentration of jth isotope in the source throughout the pipe if constant geometry or at beginning point if linear geometry	I = 1,20 J = 1,10	Free format	$\mu\text{Ci}/\text{cm}^2$
SRC(I,J,3)	Concentration of jth isotope in ith source at the final end point for linear geometry	I = 1,20	Free format	$\mu\text{Ci}/\text{cm}^2$

FIGURE 2.1. Coordinate Labeling for Pipes and Shields

```

C      PROGRAM PERCSLIB
C
C                                          7/12/82
C  THIS PROGRAM CREATES LIBRARIES AND INPUT DATA WHICH
C  ARE READ INTO THE PROGRAM PERCS.  THE OPTIONS TO BE
C  SELECTED ARE 1--SHIELD LIBRARY, 2--SOURCE LIBRARY,
C  3--ISOTOPE-ENERGY LIBRARY, AND 4--INPUT DATA.
C
3      WRITE(6,1)
      READ(5,*) IOP
      IF((IOP.GT.5).OR.(IOP.LT.1)) GOTO 400
      GOTO (100,200,300,400), IOP
C
100     CALL SHLIB
      GOTO 3
C
C
200     CALL ISOLIB
      GOTO 3
C
300     CALL INDAT
      GOTO 3
C
400     STOP
1      FORMAT(/, ' WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)'
&      ,/, 5X, '1--SHIELD',/, 5X, '2--ISOTOPE',/, 5X,
&      '3--PROGRAM INPUT DATA',/, 5X, '4--TO EXIT')
      END
C
C***** SHIELD LIBRARY *****
C
      SUBROUTINE SHLIB
C
C  SUBROUTINE TO CREATE AND REVISE SHIELD LIBRARY
C
      CHARACTER*16 TITLE2(10)
      DIMENSION ZLIST(10), DMULB(10,8), ELIST(8)
      DATA ELIST/.5,.6,.7,.8,.9,1.,1.2,1.4/
C
      WRITE(6,*) ' IS THERE AN OLD SHIELD FILE ON THE SYSTEM?
&      (TYPE Y OR N)'
      READ(5,200) IAN
      IF(IAN.EQ.2HY ) THEN
          OPEN(UNIT=11, STATUS='OLD')
          READ(11,210) NSH
          DO 5 L=1, NSH
              READ(11,145) TITLE2(L)
              READ(11,215) ZLIST(L)
              READ(11,220) (DMULB(L,I), I=1,8)
5      CONTINUE

```

```

        READ(11,220) (ELIST(I), I=1,8)
        REWIND(11)
        GOTO 20
    END IF
    OPEN(UNIT=11, STATUS='NEW')
C
    WRITE(6,*) 'NUMBER OF SHIELD MATERIALS?'
    READ(5,*) NSH
C
    DO 15 K=1, NSH
        WRITE(6,140) K
        READ(5,145) TITLE2(K)
        WRITE(6,155)
        READ(5,*) ZLIST(K)
        DO 10 J=1,8
            WRITE(6,160) K, ELIST(J)
            READ(5,*) DMULB(K, J)
10        CONTINUE
15    CONTINUE
C
20    WRITE(6,*) ' CURRENT DATA IS THE FOLLOWING: '
        WRITE(6,165)
        DO 25 L=1, NSH
            WRITE(6,170) L, TITLE2(L)
            WRITE(6,175) ZLIST(L)
            WRITE(6,180) (ELIST(I), I=1,8)
            WRITE(6,185) (DMULB(L, I), I=1,8)
25        CONTINUE
30    WRITE(6,135)
        READ(5,*) IOPT
        IF((IOPT.GT.4).OR.(IOPT.LT.1)) GOTO 205
        GOTO (35,50,90,125) IOPT
C
C
35    WRITE(6,*) 'ENTER NUMBER OF SHIELDS TO BE ADDED'
        READ(5,*) NSD
        DO 45 K=NSH+1, NSH+NSD
            WRITE(6,140) K
            READ(5,145) TITLE2(K)
            WRITE(6,150) TITLE2(K)
            WRITE(6,155)
            READ(5,*) ZLIST(K)
            DO 40 J=1,8
                WRITE(6,160) K, ELIST(J)
                READ(5,*) DMULB(K, J)
40            CONTINUE
45        CONTINUE
        NSH=NSH+NSD
        GOTO 20

```



```

C
C
50  WRITE(6,*) ' ENTER SHIELD NUMBER TO BE DELETED '
    READ(5,*) K
    IF(K.EQ.NSH) GOTO 70
    DO 65 J=K, NSH-1
      TITLE2(J)=TITLE2(J+1)
      ZLIST(J)=ZLIST(J+1)
    DO 60 I=1, 8
60   DMULB(J, I)=DMULB(J+1, I)
65   CONTINUE
70   TITLE2(NSH)='
      ZLIST(NSH)=2H
      DO 80 I=1, 8
        DMULB(NSH, I)=2H
80   CONTINUE
      NSH=NSH-1
      GOTO 20

C
C
90  WRITE(6,*) ' ENTER SHIELD NUMBER TO BE CHANGED '
    READ(5,*) K
95  WRITE(6,170) K, TITLE2(K)
    WRITE(6,175) ZLIST(K)
    WRITE(6,180) (ELIST(I), I=1, 8)
    WRITE(6,185) (DMULB(K, I), I=1, 8)
      WRITE(6,*) ' ENTER ITEM YOU WANT CHANGED--BY NUMBER '
    WRITE(6,195)
    READ(5,*) IOPP
    IF((IOPP.GT.4).OR.(IOPP.LT.1)) GOTO 30
    GOTO (100,105,110,120), IOPP
100 WRITE(6,150) TITLE2(K)
    WRITE(6,*) ' ENTER CORRECT LINE '
    READ(5,145) TITLE2(K)
    GOTO 95
105 WRITE(6,175) ZLIST(K)
    WRITE(6,*) ' ENTER CORRECT LINE '
    READ(5,*) ZLIST(K)
    GOTO 95
110 WRITE(6,185) (DMULB(K, I), I=1, 8)
    WRITE(6,*) ' ENTER CORRECT LINE '
    DO 115 M=1, 8
      WRITE(6,160) K, ELIST(M)
      READ(5,*) DMULB(K, M)
115  CONTINUE
      GOTO 95
120  CONTINUE
      GOTO 20
125  CONTINUE

```

```

C
C      READ DATA TO FILE
WRITE(11,210) NSH
DO 130 L=1,NSH
    WRITE(11,145) TITLE2(L)
    WRITE(11,215) ZLIST(L)
    WRITE(11,220) (DMULB(L,I),I=1,8)
130  CONTINUE
    WRITE(11,220) (ELIST(I),I=1,8)
    CLOSE(UNIT=11)
    REWIND(11)
    RETURN
C
135  FORMAT(1X,'OPTIONS: ',/,5X,'1--ADD',/,5X,'2--DELETE',/,
    & 5X,'3--CHANGE',/,5X,'4--TO EXIT')
140  FORMAT(2X,'NAME OF MATERIAL ',I2,'?      '*)
145  FORMAT(A)
150  FORMAT(2X,A)
155  FORMAT(2X,'FOR THIS MATERIAL ATOMIC NUMBER Z IS...?      '*)
160  FORMAT(2X,'FOR MATERIAL ',I2,', AND ENERGY ',
    &F3.1,' MU=?      '*)
165  FORMAT(/,12X,'SHIELDING LIBRARY',/)
170  FORMAT(2X,'FOR MATERIAL ',I2,'--',A)
175  FORMAT(2X,'ATOMIC NUMBER (Z) IS',1PE11.3)
180  FORMAT(1X,'FOR ENERGY (IN MEV)',BF7.3)
185  FORMAT(1X,'MU (IN CM(-1)) IS ',BF7.3,/)
190  FORMAT(I2)
195  FORMAT(5X,'1--TITLE',/,5X,'2--ZLIST',/,5X,'3--DMULB',
    & /,5X,'4--NO MORE CHANGES')
200  FORMAT(A2)
205  WRITE(6,*)' I DO NOT UNDERSTAND
210  FORMAT(I2)
215  FORMAT(1PE12.3)
220  FORMAT(BF7.3)
    GO TO 30
    END
C
C***** ENERGY-ISOTOPE LIBRARY *****
C
C      SUBROUTINE ISOLIB
C
C      SUBROUTINE TO CREATE AND REVISE ENERGY-ISOTOPE LIBRARY
C
C      CHARACTER*6 TITLE1(10),DTITLE
C      DIMENSION NMEV(10),ENERGY(10,5,2)
C
C      IF THERE IS AN OLD ISOTOPE FILE - READ IT.
C      IF NOT - CREATE ONE
C

```

```

WRITE(6,*)' IS THERE AN OLD ISOTOPE FILE ON THE SYSTEM?
& (TYPE Y OR N)'
READ(5,175) IAN
IF(IAN.EQ.2HY ) THEN
2   OPEN(UNIT=10,STATUS='OLD')
    READ(10,170)ISO
    READ(10,180)(NMEV(L),L=1,ISO)
    DO 4 L=1,ISO
        READ(10,135) TITLE1(L)
        DO 3 N=1,NMEV(L)
            READ(10,190)ENERGY(L,N,1),ENERGY(L,N,2)
3        CONTINUE
4    CONTINUE
    REWIND(10)
    GO TO 20
ELSE
    OPEN(UNIT=10,STATUS='NEW')
END IF

C
C ENTER NEW INFORMATION
C
    WRITE(6,5)
5    FORMAT(2X,'ENTER NUMBER OF ISOTOPES      '$)
    READ(5,*)ISO
C
    DO 10 II=1,ISO
        WRITE(6,130)II
        READ(5,135) TITLE1(II)
C
        WRITE(6,140)
        READ(5,*)NMEV(II)
        DO 8 N=1,NMEV(II)
            WRITE(6,145)N
            READ(5,*)ENERGY(II,N,1)
            WRITE(6,150)
            READ(5,*)ENERGY(II,N,2)
8        CONTINUE
10    CONTINUE
C
C PRINT CURRENT DATA TO THE SCREEN
C
20    WRITE(6,*)' CURRENT DATA IS THE FOLLOWING:'
    WRITE(6,155)
    DO 30 L=1,ISO
        WRITE(6,160)L, TITLE1(L)
        DO 25 N=1,NMEV(L)
            WRITE(6,165)N,ENERGY(L,N,1),ENERGY(L,N,2)
25        CONTINUE
30    CONTINUE

```

```

C
C  OPTION
C
35  WRITE(6,125)
    READ(5,*) IOPT
    IF((IOPT.GT.4).OR.(IOPT.LT.1)) GOTO 120
    GOTO (40,55,90,120), IOPT
C
C  ADD ISOTOPES TO THE LIBRARY
C
40  WRITE(6,*) ' ENTER NUMBER OF ISOTOPES TO BE ADDED '
    READ(5,*) NISO
    DO 50 K=ISO+1, ISO+NISO
      WRITE(6,130) K
      READ(5,135) TITLE1(K)
      WRITE(6,140)
      READ(5,*) NMEV(K)
      DO 45 N=1, NMEV(K)
        WRITE(6,145) N
        READ(5,*) ENERGY(K, N, 1)
        WRITE(6,150)
        READ(5,*) ENERGY(K, N, 2)
45    CONTINUE
50    CONTINUE
    ISO=ISO+NISO
    GOTO 20
C
C  DELETE ISOTOPES FROM THE LIBRARY
C
55  WRITE(6,*) ' ENTER ATOMIC SYMBOL OF ISOTOPE TO BE DELETED '
    READ(5,135) DTITLE
    DO 65 I=1, ISO
      IF (LLT(DTITLE, TITLE1(I))) GO TO 65
      IF (LGT(DTITLE, TITLE1(I))) GO TO 65
      K=I
      GO TO 70
65    CONTINUE
    WRITE(6,124) DTITLE
    GO TO 55
70    DO 80 L=K, ISO-1
      TITLE1(L)=TITLE1(L+1)
      NMEV(L) = NMEV(L+1)
      DO 75 N=1, 5
        ENERGY(L, N, 1) = ENERGY(L+1, N, 1)
        ENERGY(L, N, 2) = ENERGY(L+1, N, 2)
75    CONTINUE
80    CONTINUE
    TITLE1(ISO)='
    NMEV(ISO)=0

```

```

      DO 85 M=1,5
        ENERGY(ISO,M,1)=0.0
        ENERGY(ISO,M,2)=0.0
85    CONTINUE
      ISO=ISO-1
      GOTO 20
C
C  CHANGE ISOTOPE TITLE, ENERGY, OR YIELD
C
90    WRITE(6,*) ' ENTER ISOTOPE NUMBER TO BE CHANGED '
      READ(5,*) K
95    WRITE(6,160) K,TITLE1(K)
      DO 100 N=1,NMEV(K)
        WRITE(6,165)N,ENERGY(K,N,1),ENERGY(K,N,2)
100   CONTINUE
      WRITE(6,*) ' ENTER ITEM YOU WANT CHANGED--BY NUMBER '
      WRITE(6,185)
      READ(5,*) IOPP
      IF((IOPP.GT.3).OR.(IOPP.LT.1)) GOTO 35
      GOTO (105,110,115),IOPP
105   WRITE(6,160)K,TITLE1(K)
      WRITE(6,*) ' ENTER CORRECT LINE '
      READ(5,135)TITLE1(K)
      GOTO 95
110   WRITE(6,*) ' ENTER GAMMA/DISINTEGRATION NUMBER '
      READ(5,*) NUM
      WRITE(6,165) NUM,ENERGY(K,NUM,1),ENERGY(K,NUM,2)
      WRITE(6,*) ' ENTER CORRECT ENERGY (IN MeV) '
      READ(5,*) ENERGY(K,NUM,1)
      WRITE(6,*) ' ENTER CORRECT YIELD '
      READ(5,*) ENERGY(K,NUM,2)
      GOTO 95
115   GOTO 20
C
C  WRITE LIBRARY TO TAPE 10
C
120   WRITE(10,170) ISO
      WRITE(10,180) (NMEV(L),L=1,ISO)
      DO 123 L=1,ISO
        WRITE(10,135)TITLE1(L)
        DO 121 N=1,NMEV(L)
          WRITE(10,190) ENERGY(L,N,1),ENERGY(L,N,2)
121   CONTINUE
123   CONTINUE
      CLOSE(UNIT=10)
      REWIND(10)
      ISOL=ISO
      RETURN
C

```

```

C   FORMAT STATEMENTS
C
124  FORMAT(2X,A,' IS NOT IN THE LIBRARY')
125  FORMAT(/,1X,'OPTIONS: ',/,5X,'1--ADD',/,5X,'2--DELETE',/,
    & 5X,'3--CHANGE',/,5X,'4--TO EXIT')
130  FORMAT(2X,'ENTER TITLE FOR ISOTOPE',I2,' '$)
135  FORMAT(A)
140  FORMAT(2X,'ENTER NUMBER OF GAMMAS/DISINTEGRATION '$)
145  FORMAT(2X,'ENTER ENERGY(MEV) FOR GAMMA',I2,' '$)
150  FORMAT(2X,'YIELD FOR THIS ENERGY? '$)
155  FORMAT(/,16X,'ISOTOPE LIBRARY',/)
160  FORMAT(/,2X,I2,4X,A,/)
165  FORMAT(2X,'FOR GAMMA',I2,' ENERGY IS',1PE11.3,5X,'YIELD IS',
    &1PE11.3)
170  FORMAT(I2)
175  FORMAT(A2)
180  FORMAT(10I2)
185  FORMAT(5X,'1--TITLE',/,5X,'2--ENERGY',/,5X,'3--NO MORE CHANGES')
190  FORMAT(2PE11.3)
    END
C
C*****
C
    SUBROUTINE SRCLIB(NSI)
C
C   SUBROUTINE TO CREATE SOURCE LIBRARY
C
    CHARACTER*6 TITLE1(10),CTITLE
    DIMENSION SRC(20,10,6),X(50,11),ISN(10),NMEV(10)
    DIMENSION ENERGY(10,5,2)
    COMMON IFLAG,NLIB,ISOTP,IX,SRC,X,NT1,IS1,ISFLAG
C
C   OPEN ISOTOPE LIBRARY
C
    OPEN(UNIT=10,STATUS='OLD')
    READ(10,250) ISOL
    READ(10,25)(NMEV(L),L=1,ISOL)
25  FORMAT(10I2)
    DO 40 L=1,ISOL
        READ(10,183) TITLE1(L)
        DO 30 K=1,NMEV(L)
            READ(10,35) ENERGY(L,K,1),ENERGY(L,K,2)
30        CONTINUE
35        FORMAT(2PE11.3)
40        CONTINUE
    REWIND(10)
C
C   ZERO ISN ARRAY
    DO 45 I=1,10

```



```

        ISN(I)=0
45  CONTINUE
C
C  IF ADDING OR DELETING ISOTOPES IN SOURCE - FILL ISN(I) TO
C  KEEP TRACK OF WHICH ISOTOPES ARE PRESENT IN THE SOURCE.
C
        IF (ISFLAG.EQ.0) GO TO 55
        I=1
        DO 50 J=1,10
            IF (SRC(NSI,J,1).NE.0.) THEN
                ISN(I) = J
                I=I+1
            END IF
50      CONTINUE
        ISOTP=I-1
C
C  PRINT THE CURRENT DATA ON THE SCREEN
C
145  WRITE(6,144)
144  FORMAT(/)
        WRITE(6,*) ' CURRENT DATA IS THE FOLLOWING - '
        DO 170 K=1, ISOTP
            IF (SRC(NSI,ISN(K),1).EQ.1.) THEN
                WRITE(6,150) TITLE1(ISN(K))
150      FORMAT(/,1X, ' ISOTOPE ',A, ' HAS A CONSTANT CONCENTRATION')
                WRITE(6,155) SRC(NSI,ISN(K),2)
155      FORMAT(10X, ' OF ',1PE12.3, ' MICROCURIES/SQUARE CM')
                GO TO 170
            ELSE
                WRITE(6,160) TITLE1(ISN(K))
160      FORMAT(/,1X, ' ISOTOPE ',A, ' HAS A LINEAR CONCENTRATION')
                WRITE(6,165) SRC(NSI,ISN(K),2), SRC(NSI,ISN(K),3)
165      FORMAT ( ' RANGING FROM ',1PE11.3, ' TO ',1PE11.3, ' MICROCURIES/
                $SQUARE CM')
            END IF
170  CONTINUE
C
C
51  WRITE(6,52)
52  FORMAT(1X, 'OPTIONS: ',/,5X, '1--ADD AN ISOTOPE',/,5X,
        $ '2--DELETE AN ISOTOPE',/,5X, '3--CHANGE AN ISOTOPE',
        $ /,5X, '4--CONTINUE')
        READ(5,*) IOPT
        IF ((IOPT.GT.4).OR.(IOPT.LT.1)) THEN
            WRITE(6,*) ' INCORRECT INPUT - RESPECIFY'
            GO TO 51
        END IF
        GO TO (227,195,179,270)IOPT

```

```

C
C  CREATE SOURCE LIBRARY
C    - SPECIFY ISOTOPES
C
55  WRITE(6,60) ISOTP
60  FORMAT(/,2X,' SPECIFY THE ',I2,' ISOTOPES DESIRED BY ENTERING')
    WRITE(6,*)'      THE CORRESPONDING NUMBER - SEPARATE BY COMMAS'
    WRITE(6,*)'      EXAMPLE - 1,2,3'
    WRITE(6,63)
63  FORMAT(/,2X,' CHOICES ARE -')
    DO 65 I=1,ISOL
        WRITE(6,260) I,TITLE1(I)
65  CONTINUE
    READ(5,*) (ISN(I),I=1,ISOTP)
C
C  - SPECIFY TITLE AND SURFACE CONCENTRATION
C
    WRITE(6,72) NSI
72  FORMAT(2X,'FOR SOURCE MODEL NUMBER',I3)
    ISOI=1
    ISO=ISOTP
75  DO 135 IS=ISOI,ISO
        DO 70 I=1,ISOL+1
            IF (ISN(IS).EQ.I) GOTO 80
70  CONTINUE
        IF (I.EQ.11) THEN
            WRITE(6,77) ISN(IS)
77  FORMAT(/,2X,A,' IS NOT IN THE LIBRARY - PLEASE RE-')
            GO TO 55
        END IF
80  NISO=I
C
85  WRITE(6,87) TITLE1(NISO)
87  FORMAT(/,2X,' FOR ',A)
90  WRITE(6,93)
93  FORMAT(2X,' IS THE ISOTOPIIC SURFACE CONCENTRATION CONSTANT OR',/,
&5X,'LINEAR ALONG THE PIPE? (C OR L) ',%)
    READ(5,95) ICL
95  FORMAT(A2)
    IF(ICL.EQ.2HC) GO TO 110
    IF(ICL.EQ.2HL) GO TO 120
    WRITE(6,100)
100  FORMAT(2X,' SORRY I DONT UNDERSTAND, PLEASE TYPE C OR L')
    GO TO 90
110  SRC(NSI,NISO,1)=1.
    WRITE(6,115) TITLE1(NISO)
115  FORMAT(2X,'WHAT IS THE CONCENTRATION OF ',A,
&' IN',/,BX,'MICROCURIES/SQUARE CM? ',%)
    READ(5,*) SRC(NSI,NISO,2)

```

```

      GO TO 135
120  SRC(NSI,NISO,1)=2.
      WRITE(6,125)(X(IX,L),L=1,3),TITLE1(NISO)
125  FORMAT(2X,'AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE: '
      &,/,2X,1P3E11.3,/,2X,
      &'WHAT IS THE CONCENTRATION OF '
      &,A,' IN',/,8X,'MICROCURIES/SQUARE CM? ',*)
      READ(5,*)SRC(NSI,NISO,2)
      WRITE(6,130)(X(IX,L),L=4,6),TITLE1(NISO)
130  FORMAT(2X,'AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE: '
      &,/,2X,1P3E11.3,/,2X,
      &'WHAT IS THE CONCENTRATION OF '
      &,A,' IN',/,8X,'MICROCURIES/SQUARE CM? ',*)
      READ(5,*)SRC(NSI,NISO,3)
135  CONTINUE
140  CONTINUE
      GO TO 145
C
C  CHANGE THE ISOTOPE PARAMETERS
C
179  WRITE(6,181)
181  FORMAT(/,2X,'WHAT ISOTOPE DO YOU NEED TO CHANGE?',*)
      WRITE(6,*) '      ENTER THE ISOTOPE TITLE (EXAMPLE - CR-51)'
      READ(5,183)CTITLE
183  FORMAT(A)
      DO 185 I=1,ISOL
          IF (LLT(TITLE1(I),CTITLE)) GOTO 185
          IF (LGT(TITLE1(I),CTITLE)) GO TO 185
          ISOI=I
          ISO=I
          NISO=I
          GO TO 85
185  CONTINUE
      WRITE(6,190) CTITLE
190  FORMAT(/2X,A,' IS NOT IN THE SOURCE')
      GO TO 145
C
C  DELETE ISOTOPES
C
195  WRITE(6,*) ' HOW MANY ISOTOPES ARE TO BE DELETED?'
      READ(5,*) IS1
      WRITE(6,200)IS1,NSI
200  FORMAT(/,2X,' SPECIFY THE NUMBER OF THE ',I2,' ISOTOPES TO BE',
      &/,6X,' DELETED FROM SOURCE NUMBER ',I2)
      WRITE(6,*) '      - ONE PER LINE, <CR> IN BETWEEN'
      WRITE(6,*) ' CURRENT ISOTOPES ARE -'
      DO 205 I=1,ISOTP
          WRITE(6,260) I,TITLE1(ISN(I))

```

```

205     CONTINUE
      DO 215 N=1, IS1
        READ(5,*) IDN
        DO 210 M=1, 6
          SRC(NSI, ISN(IDN), M)=0.0
210     CONTINUE
        ISN(IDN)=0
215     CONTINUE
      L=1
      DO 225 J=1, ISOTP
        IF (ISN(L).NE.0) THEN
          L=L+1
          GO TO 225
        ELSE
          DO 220, K=L, 9
220         ISN(K) = ISN(K+1)
          END IF
225     CONTINUE
      ISOTP= ISOTP-IS1
      GO TO 145

C
C  ADD ISOTOPES
C
227  WRITE(6,*) ' HOW MANY ISOTOPES ARE TO BE ADDED?'
      READ(5,*) IS1
      WRITE(6,*) ' CURRENT ISOTOPES ARE - '
      DO 230 I=1, ISOTP
        WRITE(6,260) I, TITLE1(ISN(I))
230     CONTINUE
      WRITE(6,235) IS1, NSI
235     FORMAT(/, 2X, ' SPECIFY THE NUMBER OF THE ', I2, ' ISOTOPES TO BE ',
           &/, 6X, 'ADDED TO SOURCE NUMBER ', I2, ' SEPARATE BY COMMAS', /)
      WRITE(6,*) '          EXAMPLE:   1, 2, 3'
      DO 240 I=1, ISOL
        WRITE(6,260) I, TITLE1(I)
240     CONTINUE
      ISOI=ISOTP + 1
      ISO=ISOTP + IS1
      READ(5,*) (ISN(I), I=ISOI, ISO)
      ISOTP=ISO
      GO TO 75
250     FORMAT(I2)
260     FORMAT(2X, I2, ' - ', A)
C
C  CLOSE THE ISOTOPE LIBRARY (UNIT=10)
C
270     CLOSE(UNIT=10)
      REWIND(10)
      RETURN

```

```

      END
C
C *****
C      SUBROUTINE INDAT
C
C      SUBROUTINE TO CREATE AND REVISE INPUT DATA.
C
C      CHARACTER*60 TITLE
C      CHARACTER*16 TITLE2(10)
C      DIMENSION X(50,11), SH(10,8), ZLIST(10)
C      DIMENSION SRC(20,10,6), DMULB(10,8)
C      COMMON IFLAG, NTIME, ISOTP, IX, SRC, X, NT1, IS1, ISFLAG
C
C      ISFLAG=0
C      NSTRT=1
C      IFLAG=0
C
C      OPEN(UNIT=11, STATUS='OLD')
C      READ(11,21) NSH
C      DO 350 L=1, NSH
C          READ(11,275) TITLE2(L)
C          READ(11,24) ZLIST(L)
C          READ(11,26) (DMULB(L,I), I=1,8)
350  CONTINUE
C      CLOSE (UNIT=11)
C      REWIND(11)
C
C      WRITE(6,*) ' IS THERE A CURRENT FILE ON THE SYSTEM? (Y OR N)'
C      READ(5,280) IAN
C      IF(IAN.EQ.2HN) GOTO 2
C      IFLAG=1
C      READ(13)NPIPES, NLIB, ISHLD, X, SH, TITLE, NSI
C      REWIND(13)
C      OPEN(UNIT=12, STATUS='OLD')
C      DO 4 I=1,20
C          DO 4 J=1,10
C              READ(12,*) (SRC(I,J,K), K=1,6)
4      CONTINUE
C      REWIND(12)
C      GO TO 1
2      OPEN(UNIT=12, STATUS='NEW')
C      GO TO 5
1      WRITE(6,285)
3      READ(5,*) IOPP
C      GOTO (5,10,120,160,190,215,250), IOPP
C      WRITE(6,*) ' INCORRECT INPUT - RE-ENTER NUMBER '
C      GO TO 3
C
C      IF(IFLAG.EQ.0)GOTO 6
5

```

```

WRITE(6,*) ' CURRENT TITLE IS..... '
WRITE(6,7) TITLE
7  FORMAT(2X,A)
6  WRITE(6,*) ' ENTER A NEW TITLE '
   READ(5,275) TITLE
   WRITE(6,270)
   IF(IFLAG.EQ.1)GO TO 1
C
10  IF(IFLAG.EQ.0) GOTO 20
   DO 15 I=1,NPIPES
   WRITE(6,*) ' PIPE # ',I
   WRITE(6,290)(X(I,K),K=1,11)
15  CONTINUE
   WRITE(6,270)
17  WRITE(6,*) ' CHANGE: 1- ALL PIPES, 2 - A SPECIFIC ONE, OR
   & 3 - NO CHANGES (CHOOSE NUMBER) '
   READ(5,*) IAS
   GOTO (20,50,1), IAS
   WRITE(6,*) ' INCORRECT INPUT RESPECIFY 1,2 OR 3 TO '
   GO TO 17
20  WRITE(6,*) ' ENTER NUMBER OF PIPES '
   READ(5,*) NPIPES
   NEND=NPIPES
   NSI=0
25  DO 40 I=NSTRT,NEND
   WRITE(6,27)I
27  FORMAT(/,2X,'FOR PIPE NUMBER ',I2)
   WRITE(6,*) ' INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT '
   WRITE(6,*) ' ONE FOR START OF CENTERLINE, ONE SET FOR END '
   WRITE(6,*) ' MEASUREMENTS ARE IN CENTIMETERS '
   WRITE(6,*) ' EXAMPLE - 0.0,10.0,0.0 '
   WRITE(6,*) ' 0.0,40.0,0.0 '
   READ(5,*)X(I,1),X(I,2),X(I,3)
   READ(5,*)X(I,4),X(I,5),X(I,6)
   WRITE(6,*) ' ENTER RADIUS (IN CM) '
   READ(5,265) X(I,7)
   WRITE(6,*) ' ENTER THICKNESS (IN CM) '
   READ(5,265) X(I,8)
   WRITE(6,*) ' ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH '
   WRITE(6,*) ' CHOICES ARE - '
   DO 33 L=1,NSH
   WRITE(6,310) L,TITLE2(L)
33  CONTINUE
   READ(5,*) X(I,9)
   WRITE(6,*) ' ENTER NUMBER FOR WALL MATERIAL '
   READ(5,*) X(I,10)
   WRITE(6,*) ' DOES THIS PIPE CONTAIN A SOURCE? (Y OR N) '
   READ(5,280)NSS
   IF(NSS.EQ.2HY )GO TO 35

```



```

X(I,11)=0.
GOTO 40
35 IF (NSI.EQ.0) GO TO 37
WRITE(6,*) ' DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)'
READ(5,280) IANS
IF(IANS.EQ.2HY ) THEN
    WRITE(6,*) ' WHICH ONE?'
    READ(5,*) X(I,11)
    GO TO 40
ENDIF
37 NSI=NSI+1
X(I,11)=NSI
IX=I
WRITE(6,*) ' ENTER NUMBER OF ISOTOPES IN THE SOURCE'
READ(5,*) ISOTP
CALL SRCLIB(NSI)
40 CONTINUE
45 WRITE(6,*) ' DID YOU MAKE A MISTAKE ON A PIPE? (Y OR N)'
READ(5,280) IAN
IF(IAN.EQ.2HN ) GOTO 115
50 WRITE(6,*) ' WHICH PIPE DO YOU WANT TO RE-DO? (ENTER PIPE #)'
READ(5,*) NSTRT
55 WRITE(6,60)
60 FORMAT(2X, 'WHAT WOULD YOU LIKE TO CHANGE?',/,2X, '1) EVERYTHING',/,
&2X, '2) PIPE COORDINATES',/,2X, '3) RADIUS',/,2X, '4) THICKNESS',/,2X,
&'5) MATERIAL PIPE IS FILLED WITH',/,2X, '6) WALL MATERIAL',/,2X,
&'7) SOURCE',/,2X, '8) NOTHING')
READ(5,*) ICH
GO TO (65,70,80,85,90,95,100,45), ICH
WRITE(6,*) ' INCORRECT INPUT - RESPECIFY OPTION'
GO TO 55
65 NEND=NSTRT
GOTO 25
70 WRITE(6,72) NSTRT
72 FORMAT(/,2X, ' FOR PIPE NUMBER ',I2)
WRITE(6,*) ' INPUT PIPE COORDINATES (2 SETS)'
WRITE(6,*) ' - MEASUREMENTS IN CMS'
WRITE(6,*) ' EXAMPLE - 0.0,10.0,0.0,0'
WRITE(6,*) ' 0.0,40.0,0.0,0'
READ(5,*) X(NSTRT,1), X(NSTRT,2), X(NSTRT,3)
READ(5,*) X(NSTRT,4), X(NSTRT,5), X(NSTRT,6)
GOTO 110
80 WRITE(6,*) ' ENTER RADIUS'
READ(5,265) X(NSTRT,7)
GO TO 110
85 WRITE(6,*) ' ENTER THICKNESS'
READ(5,265) X(NSTRT,8)
GO TO 110
90 WRITE(6,*) ' ENTER NUMBER OF MATERIAL PIPE IS FILLED WITH'

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```

DO 93 L=1,NSH
  WRITE(6,310) L,TITLE2(L)
93  CONTINUE
  READ(5,*) X(NSTRT,9)
  GOTO 110
95  WRITE(6,*) ' ENTER NUMBER FOR WALL MATERIAL '
  DO 97 L=1,NSH
    WRITE(6,310) L,TITLE2(L)
97  CONTINUE
  READ(5,*) X(NSTRT,10)
  GOTO 110
100 WRITE(6,*) ' DOES THIS PIPE CONTAIN A SOURCE? (Y OR N) '
  READ(5,280)ISS
  IF(ISS.EQ.2HY )GO TO 105
  X(NSTRT,11)=0.
  GO TO 110
105 WRITE(6,*) ' DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N) '
  READ(5,280)IANS
  IF (IANS.EQ.1HY ) THEN
    WRITE(6,*) ' WHICH ONE? '
    READ(5,*)X(NSTRT,11)
    GO TO 110
  ENDIF
  NSI = NSI + 1
  X(NSTRT,11)=NSI
  NS=NSI
  IX=NSTRT
  WRITE(6,*) ' ENTER NUMBER OF ISOTOPES IN THE SOURCE '
  READ(5,*) ISOTP
  CALL SRCLIB(NS)
110 WRITE(6,*) ' ANY MORE CHANGES TO THIS PIPE? (Y OR N) '
  READ(5,280)IANS
  IF(IANS.EQ.2HY )GOTO 55
  GO TO 45
115 WRITE(6,270)
  NSTRT=1
  IF(IFLAG.EQ.1) GOTO 1
  GO TO 160
C
120 NPIPES = NPIPES + 1
  NSTRT = NPIPES
  GO TO 65
C
160 WRITE(6,161)
161 FORMAT(' DO YOU WANT THE INPUT DATA TO PRINT OUT? [Y/N] ',*)
  READ(5,162)IANSW
162 FORMAT(1A2)
  NLIB=1
  IF(IANSW.EQ.2HN )NLIB=0

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```

        IF(IFLAG.EQ.1) GOTO 1
        GO TO 215
C
190  WRITE(6,*) ' ENTER NUMBER OF THE SOURCE YOU WISH TO CHANGE '
      READ(5,*) NS
      ISFLAG=1
      CALL SRCLIB(NS)
      ISFLAG=0
      WRITE(6,270)
      IF(IFLAG.EQ.1) GOTO 1
C
215  IF(IFLAG.EQ.0) GOTO 225
      DO 220 I=1,ISHLD
      WRITE(6,*) ' SHIELD # ',I
      WRITE(6,305)(SH(I,J),J=1,8)
220  CONTINUE
      WRITE(6,270)
222  WRITE(6,*) ' CHANGE: 1 - ALL SHIELDS, 2 - A SPECIFIC ONE, OR
      & 3 - NO CHANGES (CHOOSE NUMBER) '
      READ(5,*) IAS
      GOTO (225,240,1), IAS
      WRITE(6,*) ' INCORRECT INPUT - RESPECIFY 1,2 OR 3 TO '
      GO TO 222
225  WRITE(6,*) ' ENTER NUMBER OF EXTERNAL SHIELDS '
      READ(5,*) ISHLD
      NEND=ISHLD
      IF(ISHLD.LE.0) GOTO 250
230  DO 235 I=NSTRT,NEND
      WRITE(6,*) ' ENTER INPUT IN E12.3 FORMAT '
      WRITE(6,*) '          ALL MEASUREMENTS IN CENTIMETERS '
      WRITE(6,270)
      WRITE(6,*) ' ENTER COORDINATES FOR THE CENTERLINE OF THE '
      WRITE(6,*) ' LOWER SURFACE OF THE SHIELD '
      WRITE(6,*) ' ENTER X1,Y1 '
      WRITE(6,*) '     EXAMPLE - 20.0,80.0 '
      READ(5,*) SH(I,1),SH(I,2)
      WRITE(6,*) ' ENTER X2,Y2 '
      WRITE(6,*) '     EXAMPLE - 0.0,80.0 '
      READ(5,*) SH(I,3),SH(I,4)
      WRITE(6,*) ' ENTER LOWER Z-AXIS COORDINATE '
      WRITE(6,*) '     EXAMPLE - 0.0 '
      READ(5,265) SH(I,5)
      WRITE(6,*) ' ENTER UPPER Z-AXIS COORDINATE '
      WRITE(6,*) '     EXAMPLE - 70.0 '
      READ(5,265) SH(I,6)
      WRITE(6,*) ' ENTER HALF THICKNESS (IN CM) '
      READ(5,265) SH(I,7)
      WRITE(6,*) ' ENTER NUMBER TO SPECIFY SHIELD TYPE '
      DO 234 L=1,NSH

```

```

        WRITE(6,310) L, TITLE2(L)
234  CONTINUE
      READ(5,*) SH(I,8)
235  CONTINUE
      WRITE(6,*) 'DID YOU MAKE A MISTAKE ON A SHIELD? (Y OR N)'
      READ(5,280) IAN
      IF(IAN.EQ.2HN) GOTO 245
240  WRITE(6,*) 'WHICH SHIELD DO YOU WANT TO RE-DO? (ENTER SHIELD #)'
      READ(5,*) NSTRT
      NEND=NSTRT
      GOTO 230
245  NSTRT=1
      IFLAG=1
      GOTO 1
C
250  WRITE(13)NPIPES,NLIB,ISHLD,X,SH,TITLE,NSI
      REWIND(13)
      DO 252 I=1,20
        DO 252 J=1,10
          WRITE(12,*) (SRC(I,J,K),K=1,6)
252  CONTINUE
      CLOSE(UNIT=12)
      REWIND(12)
      RETURN
21   FORMAT(I2)
24   FORMAT(1PE12.3)
26   FORMAT(8F7.3)
260  FORMAT(1F7.2)
265  FORMAT(1E12.3)
270  FORMAT(/)
275  FORMAT(A)
280  FORMAT(A2)
285  FORMAT(/, ' WHICH ITEM WOULD YOU LIKE TO CHANGE?',/,5X,
&   '1--TITLE',/,5X, '2--PIPES',/,5X, '3--ADD ANOTHER PIPE',
&   /,5X, '4--PRINT OUT',/,5X, '5--SOURCE CONTENT',/,5X, '6--SHIELD',
&   /,5X, '7--NO MORE CHANGES')
290  FORMAT(6(1X,PE12.3),/,5(1X,PE12.3))
295  FORMAT(3(1X,PE12.3))
300  FORMAT(1X,F7.3)
305  FORMAT(6(1X,PE12.3),/,2(1X,PE12.3))
310  FORMAT(3X,I2,' -- ',A)
      END

```

3.0 PERCS - THE MAIN PROGRAM

The main program in PERCS collects the data from the output files created by PERCSLIB, sums the dose contribution from each source pipe, and directs the output when the dose calculation is complete.

The constants needed for the eight-panel Newton-Coates quadrature routines are calculated and passed to QUAD1 and QUAD2. The data necessary to initiate the main input routine READER is read from the output file FOR013.DAT created by PERCSLIB. Briefly, this data includes:

1. the number of pipes
2. the pipe location
3. the dimensions of the pipes
4. the materials of composition
5. the number of ancillary shields
6. the shield location and composition
7. a title for the particular calculation
8. the number of sources in the source library
9. a parameter which determines whether to suppress the printing of the libraries ready by READER or not.

The contents of this file are described in Section 2 in Table 2.1.

Next the subroutine READER is called to collect the data for the shield, isotope, and source libraries. The operation of this routine is discussed in Section 4.

A call to the graphics subroutine PGRAF scales and draws the shields and piping network for a specified x-axis plane. At this time, the user can terminate the program, specify another x-coordinate plane or continue. If the decision is made to continue, the coordinates for the chosen dose point are returned after a call to subroutine PICKPT.

The integration process is initiated by setting up a relative coordinate system for each pipe. The upper and lower limits of integration are determined using the law of cosines. The double integration is begun by calling subroutine QUAD1, which returns the results to the main program after calculations for a particular pipe are complete. The results are summed for all pipes and the graphics subroutine WRITPT is called to write the answer. WRITPT inquires whether another dose point is to be calculated, another x-coordinate plane is to be specified or if the session is to be terminated. If the latter option is chosen, a call to the graphics subroutine, GRSTOP, turns off the Tektronic graphics terminal.

```

PROGRAM PERCS
CHARACTER*1 ESC,FFD,HOM
CHARACTER*16 TITLE2(10)
DIMENSION X(50,11),P(3),YAXIS(2),ZAXIS(2)
DIMENSION ANGLE(33),SH(10,8),TITLE(15)
COMMON R,D,A,T,P,NPIPES,X
COMMON/DAN/ALOW,AHIGH,M,X9,X10,X11
COMMON/QUAD/W0,W1,W2,W3,W4,NTIME,ANGLE,NSI
COMMON/THREE/ISHLD,SH,XS,YS,ZS
DATA IPOINT/80/,IEND/69/
PARAMETER PI=3.14159265358979

C
C LOADING CONSTANTS FOR QUADRATURE ROUTINES
C
      W0=3956./14175.
      W1=23552./14175.
      W2=-3712./14175.
      W3=41984./14175.
      W4=-18160./14175.

C
      DO 1 K=1,33
      F=K-1
      ANGLE(K)=PI*F*0.0625
1      CONTINUE
C
C READ IN INPUT DATA FILLED THROUGH PERCSLIB PROGRAM
C
      READ(13)NPIPES,NLIB,ISHLD,X,SH,TITLE,MNSI
      WRITE(6,899)
899  FORMAT(/,22X,'** WELCOME TO PERCS **',/,12X,
&'WRITTEN AND TESTED BY WD REECE LAST ON 18 SEP 1983',/,/)
      WRITE(6,901)(TITLE(I),I=1,15)

C
      IF(NLIB.EQ.0)GOTO4
      DO 2 I=1,NPIPES
2      WRITE(6,906)I,(X(I,K),K=1,11)
C
      IF(ISHLD.LE.0) GO TO 4
      DO 3 L=1,ISHLD
      WRITE(6,910)L,(SH(L,K),K=1,8)
3      CONTINUE
C
4      CALL READER(NLIB,MNSI,NSH,TITLE2)
C
50     CALL PGRAF(X,SH,XC,NPIPES,YAXIS,ZAXIS,IDAT,NSH,TITLE2)
      IF(IDAT.EQ.IEND)GOTO70
      IF(IDAT.NE.IPOINT)GOTO50
60     CALL PICKPT(YAXIS,ZAXIS,XC,YC,ZC)
C

```

```

      P(1)=XC
      P(2)=YC
      P(3)=ZC
C
      SUM=0.0
C
      DO 5 M=1,NPIPES
      IF(X(M,11).EQ.0.0)GO TO 5
      P21SQ=(X(M,4)-X(M,1))**2+(X(M,5)-X(M,2))**2+(X(M,6)-X(M,3))**2
C
C  IF PIPE LENGTH IS ZERO, STOP CALCULATION
C
      IF(P21SQ.LE.0.01) GO TO 20
      P10SQ=(X(M,1)-P(1))**2+(X(M,2)-P(2))**2+(X(M,3)-P(3))**2
      P20SQ=(X(M,4)-P(1))**2+(X(M,5)-P(2))**2+(X(M,6)-P(3))**2
C
      ALLOW=(P20SQ-P10SQ-P21SQ)/(2.0*SQRT(P21SQ))
      AHIGH=SQRT(P21SQ)+ALLOW
      D=SQRT(P10SQ-ALLOW*ALLOW)
      R=X(M,7)
      T=X(M,8)
      X11=X(M,11)
C
C  START OF DOUBLE INTEGRATION
C
      NSI=X11
      CALL QUAD1(RESULT)
C
      RESULT=RESULT*0.25*R
      SUM=SUM+RESULT
C
5  CONTINUE
C
      ANSWER=SUM
519      CALL WRITPT(ANSWER,LDG,XC,YC,ZC)
      IF(LDG)50,60,70
70  CALL GRSTOP
      STOP
C
20  WRITE(6,1008) M
      STOP
900  FORMAT(15A4)
901  FORMAT(6X,15A4)
902  FORMAT(5I6)
903  FORMAT(/,2X,'FOR THIS RUN: ',/,10X,'NUMBER OF PIPES IS ',I3,/,
& /,10X,'NUMBER OF DOSE POINTS IS ',I3,/,10X,
& 'NUMBER OF TIME POINTS AT WHICH DOSE IS CALCULATED IS ',I3,/,
& 10X,'NUMBER OF ISOTOPES CONSIDERED IS ',I3,/,10X,
& 'NUMBER OF SHIELDS (NOT COUNTING PIPING) IS ',I3,/)

```

```

904  FORMAT(10F7.2)
905  FORMAT(6E12.3,/,5E12.3)
906  FORMAT(2X,'FOR PIPE ',I2,/,5X,'(X1,Y1,Z1)=',3(1PE11.3),/,
&5X,'(X2,Y2,Z2)=',3(1PE11.3),/,10X,'RADIUS IS',1PE11.3,
&10X,'PIPE THICKNESS IS',1PE11.3,/,5X,'FILLED WITH MATERIAL',
&0PF3.0,10X,'WALLS ARE MATERIAL',0PF3.0,/,2X,'SOURCE INDEX IS'
&,0PF3.0,/)
909  FORMAT(6E12.3,/,2E12.3)
910  FORMAT(/,2X,'FOR SHIELD',I2,/,2X,
&'XY COORDINATES FOR SHIELD CENTERLINE',/,2X,2(1PE11.3),/,
&2X,2(1PE11.3),/,2X,'ZHIG= ',1PE11.3,8X,'ZLOW= ',1PE11.3,
&/,2X,'HALF THICKNESS= ',1PE11.3,8X,'SHIELD INDEX= ',F3.0,/)
911  FORMAT(3E12.3)
1008 FORMAT(2X,'PIPE NUMBER',I3,' IS ZERO LENGTH. . CALCULATION STOPPED')
      END

```


4.0 SUBROUTINE READER

Subroutine READER is called by the main program in PERCS. READER will read the three libraries previously created by the program PERCSLIB. The isotope library is read from file FOR010.DAT, the shielding material library from FOR011.DAT and the source library from FOR012.DAT. The input data will automatically be listed on the terminal screen unless requested otherwise during the formation of the program input library.

READER creates an array $IIP(i,j) = k$ for the i th isotope in the j th source, where the value of IIP corresponds to the k th entry of the isotope library. READER also sets up three common blocks; LIB1 contains the shield library parameters, LIB2 consist of the isotope library parameters, and LIB3 holds the source library parameters.

```

SUBROUTINE READER(NLIB,MNSI,NSH,TITLE2)
CHARACTER*6 TITLE1(10)
CHARACTER*16 TITLE2(10)
DIMENSION SRC(20,10,6),ZLIST(10),DMULB(10,8),ELIST(8)
DIMENSION NMEV(10),ENERGY(10,5,2)
DIMENSION IIP(20,10),ISOTP(20)
COMMON/LIB1/ZLIST,DMULB,ELIST
COMMON/LIB2/NMEV,ENERGY,ISOTP,IIP
COMMON/LIB3/SRC
C
C ENERGY-ISOTOPE LIBRARY
C
      OPEN(UNIT=10,STATUS='OLD',IOSTAT=IERR,ERR=300)
      OPEN(UNIT=11,STATUS='OLD',IOSTAT=IERR,ERR=300)
      OPEN(UNIT=12,STATUS='OLD',IOSTAT=IERR,ERR=300)
C
      READ(10,21) ISO
      READ(10,22)(NMEV(L),L=1,ISO)
      DO 50 L=1,ISO
        READ(10,33)TITLE1(L)
33      FORMAT(A)
        DO 60 N=1,NMEV(L)
          READ(10,24) ENERGY(L,N,1),ENERGY(L,N,2)
60        CONTINUE
50      CONTINUE
      IF(NLIB.EQ.0)GOTO 219
      WRITE(6,16)
16      FORMAT(2X,/,16X,'ISOTOPE LIBRARY')
      DO 200 L=1,ISO
        WRITE(6,17)L,TITLE1(L)
17      FORMAT(/,2X,A,/)
        DO 210 N=1,NMEV(L)
          WRITE(6,3)ENERGY(L,N,1),ENERGY(L,N,2)
210      CONTINUE
200      CONTINUE
C
C SHIELD LIBRARY
C
219  READ(11,21) NSH
      DO 70 L=1,NSH
        READ(11,23) TITLE2(L)
        READ(11,25) ZLIST(L)
        READ(11,26) (DMULB(L,I),I=1,8)
70      CONTINUE
        READ(11,26) (ELIST(I),I=1,8)
        IF(NLIB.EQ.0)GOTO 231
        WRITE(6,*)' '
        WRITE(6,*)'      SHIELDING MATERIALS LIBRARY'
        WRITE(6,*)' '

```

```

      DO 230 L=1, NSH
      WRITE(6, 221) L, TITLE2(L)
221  FORMAT(2X, 'FOR MATERIAL ', I2, ' --', A)
      WRITE(6, 5) ZLIST(L)
      WRITE(6, 6) (ELIST(I), I=1, 8)
      WRITE(6, 7) (DMULB(L, I), I=1, 8)
230  CONTINUE
C
C SOURCE LIBRARY
C
231  DO 240 I=1, MNSI
      DO 250 J=1, 10
        READ(12, *) (SRC(I, J, K), K=1, 6)
250  CONTINUE
240  CONTINUE
C
      DO 450 I1=1, MNSI
        I2=1
        DO 430 J=1, ISO
          IF (SRC(I1, J, 1).EQ.0) GO TO 430
          IIP(I1, I2) = J
          I2=I2+1
430  CONTINUE
          ISOTP(I1) = I2-1
450  CONTINUE
C
      GO TO 260
300  WRITE(6, 310) IERR
310  FORMAT(/, ' ERROR =', I2)
260  RETURN
C
3  FORMAT(2(1X, 1PE11.3))
5  FORMAT(2X, 'ATOMIC NUMBER (Z) IS', 1PE12.3)
6  FORMAT(2X, 'FOR ENERGY (IN MEV)', 8F7.3)
7  FORMAT(2X, 'MU (IN CM(-1)) IS ', 8F7.3)
21  FORMAT(I2)
22  FORMAT(10I2)
23  FORMAT(A)
24  FORMAT(2PE11.3)
25  FORMAT(1PE12.3)
26  FORMAT(8F7.3)
400  FORMAT(I1, 5PE11.3)
END

```


5.0 SUBROUTINE PGRAF

PERCS was written as an interactive code utilizing color graphics. The graphical display quickly guides the user through complicated geometrical arrangements of pipes and shields which would be otherwise difficult to visualize. The use of color allows the user to identify the various shielding materials at a glance.

PERCSLIB, which assembles the necessary input data to run PERCS, can be run from a standard terminal. PERCS, however, must be run using an AED767 color graphics terminal. These terminals are supplied by Advanced Electronic Design of Sunnyvale, California. This should not be construed as an endorsement of any sort. Many vendors supply color terminals with equal or superior attributes. Because there are few standards in the field of computer peripherals, and certainly no "standard" color terminal, any choice must be in some sense arbitrary. In keeping with this philosophy, the graphics section of this code is made as independent as possible to ease modification of PERCS to run on another brand of terminal. The AED767 was chosen because it met the following criteria:

1. It is a raster graphics machine with built-in anti-aliasing. This makes it capable of displaying long pipes without the jaggedness inherent in displays without the anti-aliasing feature.
2. It has the capacity to display more than eight colors simultaneously.
3. It will interface directly with the computer or will communicate over a RS-232C modem line at speeds of 9600 baud or less.
4. It has stand alone graphics capabilities which permit the terminal itself to perform many of the graphics operations, increasing display speed and decreasing the CPU load on the host computer.
5. The terminal was compatible with Tektronix 4010 series commands so that it would run with the Tektronix PLOT-10 IGL (Interactive Graphics Library) software currently on our VAX-11/750.

The AED767 was deemed the most cost effective terminal available which met these requirements at the start of this project.

The present graphics routines are written in FORTRAN-77 utilizing Tektronix IGL commands as a framework and internal AED767 commands for the actual drawings. The graphics portion consists of three subroutines: PGRAF, PICKPT, and WRITPT. These routines draw the shields and pipes and allow the user to specify dose points. The calculated doses are returned to the screen.

The graphics display is limited to a two-dimensional view of three space. The yz-plane is displayed on the color monitor for a constant x coordinate value specified by the user. All dose calculations include all sources in

three-space, including those which are not seen on the monitor because they are not in the specified yz-plane. The user can view any number of yz-planes near a point of interest until the three dimensional spatial arrangement is clear.

PGRAF, the major graphics routine in PERCS, is used to draw shields and piping networks. Input comes from the arrays X and SH which contain the information necessary to draw all pipes and shields in their proper order and color. Within PGRAF the x coordinate of interest is specified by the user and the y-z projection is scaled. This information is then passed to the other graphics routines. At the beginning as PERCS prints the input parameters, the characters are written in red on a black background. When the graphics portion begins, the color is changed to green. The user is asked to specify the x constant coordinate. Then the corresponding yz-plane is displayed. The x value can be a real number or an integer, but is preferably an integer between 0 and 9999. Next the code prompts for the dimensions of the viewing window in the yz-plane (the minimum and maximum value of each direction). Integer values between -9999 and 9999 should again be entered for both y and z directions.

To assure that aspect ratios are not distorted, the code sets the horizontal axis to be 1.3 times the vertical axis--this is the suggested value for Tektronix software. Next the code finds the maximum distance in both the y and z directions and the largest undistorted window possible is created. To minimize confusion, it is recommended that the user specify the same or similar distances in both the y and z directions.

The total display surface of the AED is 1024 x 1024 pixels of which 575 (vertical) x 640 (horizontal) are shown at any one time. The user is able to view the rest of the surface by use of the pan mode. To make things simpler and avoid the need to be constantly panning the display we have limited our PERCS graphics to the 575 x 640 pixel surface seen at one time. If zoom or pan modes are used, this viewing surface may need to be realigned (easily done in pan mode).

A frame is drawn in red around the viewing surface using AED767 internal commands. All AED767 internal commands appear as a free formatted write statement to the terminal with ESC being the first character. A vertical line is drawn near the right side to separate the working surface (512 x 512 pixels in AED767 coordinates) on the left from the menu/question section on the right. Directions, questions, answers, and all other interactive communication will be displayed in this area on the right. This area is headed in red characters by the title "PERCS GRAPHIC DISPLAY."

The terminal then displays the shields and pipes that fall within the viewing window. Shields appear as rectangles with the possibility of pipes running through them. Pipes may appear as circles (outer ring of pipe material and inner circle of fill material) for pipes parallel to the x axis, as ovals for pipes striking the y-x viewing plane at different angles, or as rectangles if the pipe runs perpendicular to the x axis. The outer lines are

always drawn first, the pipe filled, and the inner lines and fill follow. Filling of shields and pipes may yield unexpected results when:

- only a portion of the pipe or shield is in the viewing window
- pipes are not totally within shields
- or possible other unusual conditions not previously encountered.

Anti-aliased lines are used for the outside of all figures drawn to eliminate the jagged lines problem. Unusual or improper color in no way effects the calculated dose rate.

To draw shields the code calculates the x,y coordinates of the four corners of the shield projection, then checks the four line segments to see if the specified x coordinate intersects any of them. If not, then the shield falls outside of our region of interest and is not drawn. If there is an intersection, the points of intersection are calculated and then it is a simple matter to draw the shield. The center point is then found, and the AED767 internal command "IFL" is used to fill the shield with color. A similar approach is used for drawing pipes but the three possibilities mentioned above must be considered. The pipes are tested to verify that they appear within the specified x coordinate plane. Those pipes in the plane often appear as ellipses, and occasionally as circles or rectangles. The outer surface of the pipe is drawn first, the center point found, and the pipe filled with the color appropriate for the wall material. The inner edge of the pipe is then drawn and is filled with the color indicating the pipe contents. Occasionally only a thin slice of the edge of a pipe is within the plane and it appears as a solid color representing the wall material.

After the shields and pipes are drawn, a color key is displayed in the right hand box indicating the materials they represent. Currently the code is set up to use 6 colors, but additional colors can be defined. Materials are defined by corresponding number in PERCSLIB. Table 5.1 shows the current color setup.

TABLE 5.1. Color Assigned to Shielding Materials

<u>Material #</u>	<u>Color</u>
1	Cyan
2	Yellow
3	Magenta
4	Blue
5	Green
6	Red

The anti-aliasing feature uses color shading to make jagged lines appear smooth. This feature requires color ramps to be defined. The color ramps for the 6 colors of Table 5.1 already exist and need not be defined. If additional colors are defined and anti-aliasing is to be used, these color ramps

must be defined using AED767 commands. It should also be noted that the anti-aliasing feature only works on a black background.

Once the drawing and color codes are in place the writing color returns to green and asks the user for instruction. The user may specify a point at which the dose will be calculated, he may specify "continue" and then choose another x coordinate plane, or he can end the PERCS run. The program prompts for a single key response of P, C, or E and defaults a point dose calculation if any other key is entered. If carriage return (CR) is entered, it will interrupt the code and it is necessary to enter an additional alpha-numeric key to recover. PGRAF passes this response back to the main code and ends.


```

C*****GRAPHICS SUBROUTINES FOR PERCS*****
C
C SUBROUTINE PGRAF
C     ROUTINE TO SCALE AND DRAW SHIELDS AND PIPES
C
C     SUBROUTINE PGRAF(X,SH,XC,NPIPES,YAXIS,ZAXIS,IDAT,NSH,TITLE2)
C
C     CHARACTER*1 ESC,FFD,CR,ICOL(6)
C     CHARACTER*4 JX1,JX2
C     CHARACTER*16 TITLE2(10)
C     DIMENSION X(50,11),SH(10,8),YAXIS(2),ZAXIS(2),XX(5),YY(5),YR(4)
C     COMMON/THREE/ISHLD
C
C     DATA     ESC/27/,FFD/12/,CR/13/
C     DATA     COLORS/CYAN,YELLOW,MAGENTA,BLUE,GREEN,RED/
C     DATA     ICOL/54,51,53,52,50,49/
C     PARAMETER      PI=3.14159265358979
C
C     CLEAR AND INITIALIZE FORMAT FOR AED767 MONITOR
C
C     WRITE(5,*) ESC,'SEN3DDDNHOMERSSEC2.XXX'
C     WRITE(5,10)
10  FORMAT(20X,'PERCS - GRAPHICS DISPLAY',///)
C     WRITE(5,15)
15  FORMAT('$','  ENTER X-PLANE COORDINATE FOR Y-Z DIPLAY : ')
C     READ (6,*) XC
C
C     WRITE(5,20)
20  FORMAT('  TO DEFINE DISPLAY WINDOW ENTER THE FOLLOWING: ')
25  WRITE(5,30)
30  FORMAT('$','  YAXIS MIN and MAX [0-9999] : ')
C     READ (6,*) YMIN,YMAX
C     IF (YMIN.GE.YMAX) THEN
C         WRITE(5,35)
35  FORMAT(' *** ILLEGAL ENTRY - MIN > or = MAX ***')
C         GOTO 25
C     ENDIF
40  WRITE(5,45)
45  FORMAT('$','  ZAXIS MIN and MAX [0-9999] : ')
C     READ (6,*) ZMIN,ZMAX
C     IF (ZMIN.GE.ZMAX) THEN
C         WRITE(5,35)
C         GOTO 40
C     ENDIF
C
C     YAXIS(1)=YMIN
C     ZAXIS(1)=ZMIN
C     SMAX=AMAX1(YMAX-YMIN,ZMAX-ZMIN)
C     YAXIS(2)=YMIN+(2.*SMAX)

```

```

YMX=YMIN+SMAX
ZAXIS(2)=ZMIN+(1.538*SMAX)
ZMX=ZMIN+SMAX
C
C          SCALE FACTOR BETWEEN TEKTRONIX WINDOW AND AED DISPLAY
C
FACTOR=512./SMAX
C
C          DRAW FRAME AROUND WORKING AREA ON AED767 MONITOR
C
WRITE(5,*) FFD,ESC,'SEN3DDDNERSSEC1.OPT3.1.XXX'
WRITE(5,*) ESC,'MOV0.0.DVA640.0.DVA640.512.DVA0.512.DVA0.0.XXX'
WRITE(5,*) ESC,'MOV1.1.DVA639.1.DVA639.511.DVA1.511.DVA1.1.XXX'
WRITE(5,*) ESC,'MOV512.0.DVA512.512.XXX'
C
C          TEKTRONIX INITIALIZATION
C
CALL GRSTRT(4014,1)
CALL NEWPAG
CALL WINDOW(0.,1024.,0.,787.)
CALL VWPORT(0.,640.,0.,492.)
C
C          WRITE HEADER TO DISPLAY
C
CALL MOVE(520.,490.)
CALL TEXT(1,' ')
CALL MOVE(516.,470.)
CALL TEXT(10,' PERCS')
CALL MOVE(516.,450.)
CALL TEXT(15,'GRAPHIC DISPLAY')
CALL MOVE(512.,430.)
CALL DRAW(640.,430.)
C
C          SETUP TEKTRONIX WINDOW
C
CALL WINDOW(YAXIS(1),YAXIS(2),ZAXIS(1),ZAXIS(2))
CALL VWPORT(0.,260.,0.,200.)
C
CALL EDGE(0.,65.5,0.,65.5)
C
C          DRAW SHIELDS AND FILL WITH COLOR
C
DO 50 J=1,ISHLD
C
C          DETERMINE 4 CORNERS OF RECTANGLE IN XY PLANE
C
RL=SQRT((SH(J,3)-SH(J,1))**2+(SH(J,4)-SH(J,2))**2)
XX(1)=SH(J,1)+(SH(J,7)*(SH(J,4)-SH(J,2))/RL)
XX(2)=SH(J,1)-(SH(J,7)*(SH(J,4)-SH(J,2))/RL)

```

```

XX(3)=SH(J,3)+(SH(J,7)*(SH(J,4)-SH(J,2))/RL)
XX(4)=SH(J,3)-(SH(J,7)*(SH(J,4)-SH(J,2))/RL)
XX(5)=XX(1)
C
YY(1)=SH(J,2)+(SH(J,7)*(SH(J,3)-SH(J,1))/RL)
YY(2)=SH(J,2)-(SH(J,7)*(SH(J,3)-SH(J,1))/RL)
YY(3)=SH(J,4)+(SH(J,7)*(SH(J,3)-SH(J,1))/RL)
YY(4)=SH(J,4)-(SH(J,7)*(SH(J,3)-SH(J,1))/RL)
YY(5)=YY(1)
C
C          CHECK TO SEE IF X PLANE INTERSECTS RECTANGLE
C
NI=0
DO 48 K=1,4
  IF ((XX(K)-XC)*(XX(K+1)-XC).LE.0.0) THEN
C          CALCULATE Y VALUE AT POINT OF INTERSECTION
NI=NI+1
C          CHECK TO SEE IF DENOMINATOR IS ZERO
    IF ((XX(K+1)-XX(K)).LT.1.0E-4) THEN
      YR(NI)=YY(K)
      GOTO 48
    ENDIF
    YR(NI)=YY(K)+((YY(K+1)-YY(K))*(XC-XX(K))/(XX(K+1)-XX(K)))
    ENDIF
48  CONTINUE
C
  IF (NI.EQ.0) GOTO 50
C
C          DRAW SHIELD USING COLOR CODE FOUND IN SH(J,8)
C
C          CHANGE COLOR AND TURN ON ANTI-ALIASING
C
CALL CMCLOS
JJ=IFIX(SH(J,8))
WRITE(5,*) ESC, 'SEC', ICOL(JJ), '.AAV2.XXX'
CALL CMOPEN
C
CALL MOVE(YR(1),SH(J,5))
CALL DRAW(YR(2),SH(J,5))
CALL DRAW(YR(2),SH(J,6))
CALL DRAW(YR(1),SH(J,6))
CALL DRAW(YR(1),SH(J,5))
C          FILL WITH COLOR
IYM=IFIX((((YR(1)+YR(2))/2.)-YAXIS(1))*FACTOR)
IZM=IFIX((((SH(J,5)+SH(J,6))/2.)-ZAXIS(1))*FACTOR)
ENCODE(4,60,JX1) IYM
ENCODE(4,60,JX2) IZM
C
C          DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE

```

```

YC=(YR(1)+YR(2))/2.
ZC=(SH(J, 5)+SH(J, 6))/2.
  IF (YC. LT. YAXIS(1). OR. YC. GT. YMX) GOTO 50
  IF (ZC. LT. ZAXIS(1). OR. ZC. GT. ZMX) GOTO 50
C
C      FILL AND TURN OFF ANTI-ALIASING
CALL CMCLOS
WRITE(5, *) ESC, 'MOV', JX1, ' ', JX2, ' ', IFLAAVO, XXX'
CALL CMOPEN
C
50 CONTINUE

C
C      DRAW PIPES IN SPECIFIED X COORDINATE
C      (PLANES PARALLEL TO YZ PLANE)
C
DO 100 M=1, NPIPES
C
C      IS THERE A XY PROJECTION OR IS IT PARALLEL TO Y AXIS ?
C
IF(SQRT((X(M, 4)-X(M, 1))**2+(X(M, 5)-X(M, 2))**2). LE. 1. E-4)GOTO 80
IF(ABS(X(M, 4)-X(M, 1)). LE. 1. E-4)GO TO 70
C
YC=X(M, 2)+(X(M, 5)-X(M, 2))*(XC-X(M, 1))/(X(M, 4)-X(M, 1))
C
C      YC IS THE INTERSECTION OF THE PIPE WITH THE X=XC PLANE
C      IF Y1<YC<Y2 OR IF Y1>YC>Y2 THEN PIPE IS CUT BY PLANE
C
IF((X(M, 2)-YC)*(X(M, 5)-YC). GT. 0. 0)GO TO 100
C
C      WE HAVE AN INTERSECTION
C
ZC=X(M, 3)+(XC-X(M, 1))*(X(M, 6)-X(M, 3))/(X(M, 4)-X(M, 1))
C
C
C      DRAW THE OUTSIDE OF THE PIPE
C
C      CHANGE COLOR FIRST AND TURN ON ANTI-ALIASING
C
CALL CMCLOS
JJ=IFIX(X(M, 10))
WRITE(5, *) ESC, 'SEC', ICOL(JJ), ' ', AAV2, XXX'
CALL CMOPEN
C
A=X(M, 7)+X(M, 8)
PHI=(X(M, 4)-X(M, 1))/SQRT((X(M, 5)-X(M, 2))**2+(X(M, 6)-
&X(M, 3))**2+(X(M, 4)-X(M, 1))**2)
B=(X(M, 7)+X(M, 8))/PHI

```

```

C      YZRHO=SQRT((X(M,5)-X(M,2))**2+(X(M,6)-X(M,3))**2)
      IF(YZRHO.LE.1.E-4)THEN
      THETA=0.
      ELSE
      THETA=ASIN((X(M,5)-X(M,2))/YZRHO)
      END IF

C      CALL MOVE(YC+A*COS(THETA),ZC-A*SIN(THETA))

C      DRAW ELLIPSE
C
C      DO 55 I=1,51
      PHE=0.04*FLOAT(I)*PI
      XP=A*COS(PHE)*COS(THETA)+B*SIN(PHE)*SIN(THETA)
      YP=B*COS(THETA)*SIN(PHE)-A*SIN(THETA)*COS(PHE)
      CALL DRAW(YC+XP , ZC+YP)
55 CONTINUE

C      FILL OUTSIDE PIPE WITH COLOR, OFF ANTI-ALIASING
C
C      IX1=IFIX((YC-YAXIS(1))*FACTOR)
      IX2=IFIX((ZC-ZAXIS(1))*FACTOR)

C      ENCODE(4,60,JX1)IX1
      ENCODE(4,60,JX2)IX2
60 FORMAT(I4)

C      DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
C      IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO 61
      IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO 61
C      FILL AND TURN OFF ANTI-ALIASING
      CALL CMCLOSE
      WRITE(5,*) ESC, 'MOV', JX1, ', ', JX2, ', IFLAARO. XXX'
      CALL CMOPEN

C      DRAW INNER PIPE
C
C      61 A=X(M,7)
      PHI=(X(M,4)-X(M,1))/SQRT((X(M,5)-X(M,2))**2+(X(M,6)-
      &X(M,3))**2+(X(M,4)-X(M,1))**2)
      B=X(M,7)/PHI

C      YZRHO=SQRT((X(M,5)-X(M,2))**2+(X(M,6)-X(M,3))**2)
      IF(YZRHO.LE.1.E-4)THEN
      THETA=0.
      ELSE
      THETA=ASIN((X(M,5)-X(M,2))/YZRHO)
      END IF

```

```

C      CALL MOVE(YC+A*COS(THETA), ZC-A*SIN(THETA))
C
C      DRAW ELLIPSE
C
C      CHANGE COLOR
C
C      CALL CMCLOS
C      JJ=IFIX(X(M,9))
C      WRITE(5,*) ESC, 'SEC', ICOL(JJ), '. XXX'
C      CALL CMOPEN
C
C      DO 65 I=1,51
C      PHE=0.04*FLOAT(I)*PI
C      XP=A*COS(PHE)*COS(THETA)+B*SIN(PHE)*SIN(THETA)
C      YP=B*COS(THETA)*SIN(PHE)-A*SIN(THETA)*COS(PHE)
C      CALL DRAW(YC+XP, ZC+YP)
65  CONTINUE
C
C      DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
C      IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO 100
C      IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO 100
C
C      CALL CMCLOS
C      WRITE(5,*)ESC, 'MOV', JX1, '. ', JX2, '. IFLXXX'
C      CALL CMOPEN
C
C      GO TO 100
C
C      70 IF (ABS(XC-X(M,1)).GE.X(M,7)+X(M,8))GO TO 100
C
C      THE PIPE IS CUT LENGTHWISE BY YZPLANE
C
C      YZRHO=SQRT((X(M,5)-X(M,2))**2+(X(M,6)-X(M,3))**2)
C      DRAW OUTSIDE OF PIPE
C      H=SQRT((X(M,7)+X(M,8))**2-(XC-X(M,1))**2)
C      XINC=H*(X(M,6)-X(M,3))/YZRHO
C      YINC=H*(X(M,5)-X(M,2))/YZRHO
C      CHANGE COLOR AND TURN ON ANTI-ALIASING
C      CALL CMCLOS
C      JJ=IFIX(X(M,10))
C      WRITE(5,*) ESC, 'SEC', ICOL(JJ), '. AAV2. XXX'
C      CALL CMOPEN
C
C      CALL MOVE(X(M,2)-XINC, X(M,3)+YINC)
C      CALL DRAW(X(M,5)-XINC, X(M,6)+YINC)
C      CALL DRAW(X(M,5)+XINC, X(M,6)-YINC)
C      CALL DRAW(X(M,2)+XINC, X(M,3)-YINC)
C      CALL DRAW(X(M,2)-XINC, X(M,3)+YINC)

```

```

C          COLOR FILL ORIGIN
IX1=IFIX((((X(M,2)+X(M,5))/2. )-YAXIS(1))*FACTOR)
IX2=IFIX((((X(M,3)+X(M,6))/2. )-ZAXIS(1))*FACTOR)
C
YC=(X(M,2)+X(M,5))/2.
ZC=(X(M,3)+X(M,6))/2.
ENCODE(4,60,JX1)IX1
ENCODE(4,60,JX2)IX2
C
C          DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO 71
IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO 71
C
C          FILL WITH COLOR AND TURN OFF ANTI-ALIASING
CALL CMCLOS
WRITE(5,*)ESC, 'MOV', JX1, ' ', JX2, ' ', IFLAAV0. XXX'
CALL CMOPEN
C
C          INSIDE OF PIPE
C
71 IF (ABS(XC-X(M,1)).GE.X(M,7))GOTO 100
C
H=SQRT(X(M,7)*X(M,7)-(XC-X(M,1))**2)
XINC=H*(X(M,6)-X(M,3))/YZRHO
YINC=H*(X(M,5)-X(M,2))/YZRHO
C          CHANGE COLOR
CALL CMCLOS
JJ=IFIX(X(M,9))
WRITE(5,*) ESC, 'SEC', ICOL(JJ), ' ', XXX'
CALL CMOPEN
C
CALL MOVE(X(M,2)-XINC,X(M,3)+YINC)
CALL DRAW(X(M,5)-XINC,X(M,6)+YINC)
CALL DRAW(X(M,5)+XINC,X(M,6)-YINC)
CALL DRAW(X(M,2)+XINC,X(M,3)-YINC)
CALL DRAW(X(M,2)-XINC,X(M,3)+YINC)
C
C          DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO 100
IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO 100
C
C          FILL WITH COLOR
CALL CMCLOS
WRITE(5,*)ESC, 'MOV', JX1, ' ', JX2, ' ', IFLXXX'
CALL CMOPEN
C
GOTO 100
C
80 IF (ABS(XC-X(M,1)).GE.X(M,7)+X(M,8)) GOTO 100

```

```

C
C          CUT THROUGH PIPE BY PLANE
C
C          DRAW OUTSIDE, CHANGE COLOR, ANTI-ALIASING ON
C
CALL CMCLOS
JJ=IFIX(X(M,10))
WRITE(5,*) ESC, 'SEC', ICOL(JJ), '. AAV2. XXX'
CALL CMOPEN

C
H=SQRT((X(M,7)+X(M,8))**2-(XC-X(M,1))**2)
CALL MOVE(X(M,2)+H, X(M,3))
CALL DRAW(X(M,2)+H, X(M,6))
CALL DRAW(X(M,5)-H, X(M,6))
CALL DRAW(X(M,5)-H, X(M,3))
CALL DRAW(X(M,2)+H, X(M,3))

C          FILL WITH COLOR
IX1=IFIX(((X(M,2)+X(M,5))/2. )-YAXIS(1))*FACTOR)
IX2=IFIX(((X(M,3)+X(M,6))/2. )-ZAXIS(1))*FACTOR)
ENCODE(4,60,JX1)IX1
ENCODE(4,60,JX2)IX2

C
C          DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
C
YC=(X(M,2)+X(M,5))/2.
ZC=(X(M,3)+X(M,6))/2.
IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO B1
IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO B1

C
C          FILL AND TURN ANTI-ALIASING OFF
C
CALL CMCLOS
WRITE(5,*) ESC, 'MDV', JX1, ', ', JX2, ', . IFLAAVO. XXX'
CALL CMOPEN

C
B1      IF (ABS(XC-X(M,1)).GE.X(M,7))GOTO 100
C
C          DRAW INSIDE OF PIPE
C
C          CHANGE COLOR
C
CALL CMCLOS
JJ=IFIX(X(M,9))
WRITE(5,*) ESC, 'SEC', ICOL(JJ), '. XXX'
CALL CMOPEN

C
H=SQRT(X(M,7)*X(M,7)-(XC-X(M,1))**2)
CALL MOVE(X(M,2)+H, X(M,3))
CALL DRAW(X(M,2)+H, X(M,6))
CALL DRAW(X(M,5)-H, X(M,6))
CALL DRAW(X(M,5)-H, X(M,3))

```



```

      CALL DRAW(X(M,2)+H,X(M,3))
C
C      DON'T FILL IF CENTER OUTSIDE DRAWING SURFACE
      IF (YC.LT.YAXIS(1).OR.YC.GT.YMX) GOTO 100
      IF (ZC.LT.ZAXIS(1).OR.ZC.GT.ZMX) GOTO 100
C
C      FILL WITH COLOR
      CALL CMCLOS
      WRITE(5,*) ESC, 'MOV', JX1, ' ', JX2, ' IFLXXX'
      CALL CMOPEN
C
100 CONTINUE
      CALL MOVE(YAXIS(1),ZAXIS(1))
C
C      DISPLAY PIPE COLOR KEY AND MENU IN RIGHTHAND BOX
C
      WRITE(5,*) ESC, 'SEC2.XXX'
      CALL WINDOW(0.,1024.,0.,787.)
      CALL VWPORT(0.,640.,0.,492.)
C
C      DUMMY WRITE TO GET THIS TO WORK
C
      CALL MOVE(525.,420.)
      CALL TEXT(1,' ')
      CALL EDGE(0.,130.,0.,100.)
C
C      KEY TO PIPE MATERIALS
C
      CALL MOVE(525.,400.)
      CALL TEXT(11,' COLOR KEY')
      CALL MOVE(520.,390.)
      CALL DRAW(632.,390.)
C
C      WRITE UP TO 6 MATERIALS FOR COLOR KEY
C
      IF (NSH.GE.6) NSH=6
      DO 110 I=1,NSH
C
        IX1=390-(I*20)+1
        ENCODE(4,60,JX1)IX1
        RSW=390.-I*20.
C
        CALL CMCLOS
        WRITE(5,*) ESC, 'SEC', ICOL(I), ' MOV522. ', JX1, ' DCL7. IFLXXX'
        CALL CMOPEN
        CALL MOVE(540.,RSW)
        CALL TEXT(12,TITLE2(I))
110 CONTINUE
C      CHANGE COLOR BACK TO GREEN

```

```

      CALL CMCLOS
      WRITE(5,*) ESC, 'SEC2. XXX'
      CALL CMOPEN
C
C           MENU QUESTION
C
      IFLAG=0
160 CALL MOVE(520.,200.)
      CALL TEXT(14, ' ENTER CHOICE ')
      CALL MOVE(520.,180.)
      CALL TEXT(14, 'P = POINT DOSE')
      CALL MOVE(520.,160.)
      CALL TEXT(14, 'C = CONTINUE ')
      CALL MOVE(520.,140.)
      CALL TEXT(7, 'E = END')
      IF (IFLAG.NE.0) GOTO 170
C
C           CHANGE AED FORMAT AND WAIT FOR ANSWER
C
      CALL CMCLOS
      WRITE(5,*) ESC, 'SEN1888N', CR
      CALL CMOPEN
      CALL LOCATE(1,YDUM,ZDUM,IDAT,IGOT)
C
C           ERASE MENU QUESTION (WRITE OVER IN BLACK)
C
      CALL CMCLOS
      WRITE(5,*) ESC, 'SEN3DDDNSECO. XXX'
      CALL CMOPEN
      IFLAG=1
      GOTO 160
C
C           CHANGE COLOR BACK TO GREEN
C
170 CALL CMCLOS
      WRITE(5,*) ESC, 'SEC2. XXX'
      CALL CMOPEN
C
      RETURN
      END

```

6.0 SUBROUTINE PICKPT

The subroutine PICKPT allows the user to specify the point at which a dose is calculated either by entering the Y and Z coordinates directly or by joystick positioning of the cursor. The Y and Z values are passed to the calculation procedures of PERCS.

This routine begins by asking which point dose option the user wants; specifying Y and Z numerically or with the cursor. The user should respond with a single letter "S" or "C," the default being "C" or cursor controlled. If the user specifies "S," the proceeding question is erased (written over in black) and he is prompted for a Y value. This must be an integer and should be within the range of legal values (greater than or equal to YMIN but less than or equal to YMAX). Once the number is typed in, a carriage return must be entered. This is repeated for the Z value.

If "C" or a cursor specified point is chosen, the user positions the green X on the display screen with the joystick to the desired location and then presses a single alpha-numeric key (carriage return will cause problems). In both cases, the interactive questions/commands are erased and the message 'DOSE RATE AT' followed by the 3 coordinates of the point (X, Y, and Z) are displayed, along with 'IS EQUAL TO.' This lets the user know that the information has been passed to the computational phase and an answer is being calculated.

```

C PICKPT SUBROUTINE
C          SUBROUTINE TO SPECIFY POINT FOR DOSE CALCULATIONS
C
C          SUBROUTINE PICKPT(YAXIS,ZAXIS,XC,Y,Z)
C
C          CHARACTER*1 ESC,CR,HOME
C          CHARACTER*4 IX,IY,IZ
C          DIMENSION YAXIS(2),ZAXIS(2)
C          DATA      ESC/27/,CR/13/,ISPEC/83/,HOME/95/
C
C          WRITE MESSAGE TO SCREEN
C
C          IFLAG=0
10  CALL MOVE(517.,220.)
    CALL TEXT(1,' ')
    CALL MOVE(517.,200.)
    CALL TEXT(15,'PT DOSE OPTIONS')
    CALL MOVE(517.,180.)
    CALL TEXT(15,' S= SPECIFY Y,Z')
    CALL MOVE(517.,160.)
    CALL TEXT(15,' C= CURSOR Y,Z ')
    CALL MOVE(517.,140.)
    CALL TEXT(15,' ENTER S OR C ')
    IF (IFLAG.NE.0) GOTO 20
C          SET TERMINAL TO RECEIVE SINGLE LETTER
    CALL CMCLOS
    WRITE(5,*) ESC,'SEN1888N',CR
    CALL CMOPEN
C          RECEIVE LETTER INPUT (CR WILL NOT WORK)
    CALL LOCATE(1,YDUM,ZDUM,IDAT,IGOT)
C
C          ERASE LAST MENU (OVERWRITE WITH BLACK)
C
    CALL CMCLOS
    WRITE(5,*) ESC,'SEN3DDDNSECO.XXX'
    CALL CMOPEN
    IFLAG=1
    GOTO 10
C
20  CALL CMCLOS
    WRITE(5,*) ESC,'SEC2.SEN1888N',CR
    CALL CMOPEN
C          CHOOSE BETWEEN CURSOR OR USER SPECIFIED POINT
    IF (IDAT.NE.ISPEC) GOTO 50
C
C          USER ENTERS SPECIFICATIONS
C
    IFLAG=-1
25  IFLAG=IFLAG+1

```

```

      CALL CMCLOSE
      WRITE(5,*) ESC, 'SEN3DDDNSEC2. SEN1888N', CR
C      DUMMY ALIGNMENT CALL
      CALL CMOPEN
      CALL MARKER(0,492,0)
      CALL CMCLOSE
C
      WRITE(5,26)
26  FORMAT(30(/))
      WRITE(5,27)
27  FORMAT('$',T67,'ENTER Y  ')
      READ (6,30) KY
30  FORMAT(I4)
C
      Y= FLOAT(KY)
      ENCODE(4,30,IY) KY
C
      WRITE(5,32)
32  FORMAT('$',T67,'ENTER Z  ')
      READ (6,30) KZ
C
      Z= FLOAT(KZ)
      ENCODE(4,30,IZ) KZ
C
      CALL CMOPEN
C
C      CHECK TO SEE IF POINT IS WITHIN WINDOW
C
      IF (Y.LT.YAXIS(1).OR.Y.GT.((YAXIS(2)+YAXIS(1))/2.)) GOTO 35
      IF (Z.LT.ZAXIS(1)) GOTO 35
      IF (Z.GT.((ZAXIS(2)+.538*ZAXIS(1))/1.538)) GOTO 35
      GOTO 40
C
C      USER POINT OUTSIDE OF WINDOW
C
35  IFLAG=1
      CALL MOVE(525.,150.)
      CALL TEXT(11,'*** ILLEGAL')
      CALL MOVE(525.,130.)
      CALL TEXT(10,' VALUE ***')
      CALL MOVE(525.,110.)
      CALL TEXT(10,' TRY AGAIN')
      GOTO 45
C
40  CALL WINDOW(YAXIS(1),YAXIS(2),ZAXIS(1),ZAXIS(2))
      CALL VWPORT(0.,260.,0.,200.)
C      CHANGE COLOR TO RED FOR MARKER
      CALL CMCLOSE
      WRITE(5,*) ESC, 'SEN3DDDNSEC1. XXX'

```

```

      CALL CMOPEN
C      MARK A RED X IN APPROPRIATE POSITION
      CALL MARKER(Y,Z,13)
C
C      ERASE WITH BLACK WRITING
C
      CALL WINDOW(0.,1024.,0.,787.)
      CALL VWPORT(0.,640.,0.,492.)
C
45 CALL CMCLOSE
   WRITE(5,*) ESC, 'SEN3DDDNSEC1.XXX'
C
C      ERASE Y AND Z VALUES ENTERED- DUMMY MARKER
C
      CALL CMOPEN
      CALL MARKER(0,492,0)
      CALL CMCLOSE
C
      WRITE(5,*) ESC, 'SECO.SEN1888N', CR
      WRITE(5,46)
46  FORMAT(29(/))
      IF (KY.LT.10.) WRITE(5,471) KY
      IF (KY.GE.10. .AND. KY.LT.100.) WRITE(5,472) KY
      IF (KY.GE.100. .AND. KY.LT.1000.) WRITE(5,473) KY
      IF (KY.GE.1000.) WRITE(5,474) KY
C
471 FORMAT(T67, 'ENTER Y ', I1)
472 FORMAT(T67, 'ENTER Y ', I2)
473 FORMAT(T67, 'ENTER Y ', I3)
474 FORMAT(T67, 'ENTER Y ', I4)
C
      IF (KZ.LT.10.) WRITE(5,481) KZ
      IF (KZ.GE.10. .AND. KZ.LT.100.) WRITE(5,482) KZ
      IF (KZ.GE.100. .AND. KZ.LT.1000.) WRITE(5,483) KZ
      IF (KZ.GE.1000.) WRITE(5,484) KZ
C
481 FORMAT(T67, 'ENTER Z ', I1)
482 FORMAT(T67, 'ENTER Z ', I2)
483 FORMAT(T67, 'ENTER Z ', I3)
484 FORMAT(T67, 'ENTER Z ', I4)
C
      CALL CMOPEN
C
C      IF IFLAG=0, GOTO WRITE COORDINATE
C      =1, WRITE ENTER MESSAGE AGAIN
C      =2, ERASE ENTER MESSAGE THEN CONT.
C
      IF (IFLAG-1) 80,25,49
C

```

```

C          ERASE ERROR MESSAGE
49 CALL MOVE(525.,150.)
   CALL TEXT(11,'*** ILLEGAL')
   CALL MOVE(525.,130.)
   CALL TEXT(10,' VALUE ***')
   CALL MOVE(525.,110.)
   CALL TEXT(10,' TRY AGAIN')
   GOTO 80

C
C          USE CURSOR TO INDICATE POSITION
C
50 IFLAG=0
60 CALL MOVE(517.,220.)
   CALL TEXT(1,' ')
   CALL MOVE(517.,200.)
   CALL TEXT(15,'POSITION CURSOR')
   CALL MOVE(517.,180.)
   CALL TEXT(15,'& STRIKE A KEY ')
   IF (IFLAG.NE.0) GOTO 80
C          SET TEKTRONIX WINDOW
CALL WINDOW(YAXIS(1),YAXIS(2),ZAXIS(1),ZAXIS(2))
CALL VWPOR(0.,260.,0.,200.)
C          GET POSITION OF CURSOR WITH LETTER INPUT
CALL LOCATE(1,YP,ZP,IDAT,IGOT)
Y=YAXIS(1)+(YP-YAXIS(1))/2.
Z=ZAXIS(1)+(ZP-ZAXIS(1))/2.
C
JY=IFIX(Y)
JZ=IFIX(Z)
ENCODE(4,30,IY) JY
ENCODE(4,30,IZ) JZ
C          CHANGE COLOR TO RED
CALL CMCLOS
WRITE(5,*) ESC,'SEN3DDDNSEC1.XXX'
CALL CMOPEN
C          MARK POSITION WITH A X
CALL MARKER(Y,Z,13)
C
C          ERASE QUESTION
C
CALL WINDOW(0.,1024.,0.,787.)
CALL VWPOR(0.,640.,0.,492.)
C
CALL CMCLOS
WRITE(5,*) ESC,'SEC0.SEN188BN',CR
CALL CMOPEN
C
IFLAG=1
GOTO 60

```

```

C
C          WRITE X,Y,Z COORDINATES TO SCREEN
C
      80 CALL CMCLOSE
        WRITE(5,*) ESC, 'SEN3DDDNSEC2. XXX'
        CALL CMOPEN
C
      CALL MOVE(525.,220.)
      CALL TEXT(1,' ')
      CALL MOVE(525.,200.)
      CALL TEXT(12,'DOSE RATE AT')
C
      JX=IFIX(XC+.5)
      ENCODE(4,30,IX) JX
      CALL MOVE(525.,180.)
      CALL TEXT(3,'X =')
      CALL MOVE(560.,180.)
      CALL TEXT(4,IX)
C
      CALL MOVE(525.,160.)
      CALL TEXT(3,'Y =')
      CALL MOVE(560.,160.)
      CALL TEXT(4,IY)
C
      CALL MOVE(525.,140.)
      CALL TEXT(3,'Z =')
      CALL MOVE(560.,140.)
      CALL TEXT(4,IZ)
C
      CALL MOVE(525.,120.)
      CALL TEXT(12,' IS EQUAL TO')
C
C          DUMMY ROUTINE TO GET IT TO WRITE BEFORE CALCULATING
C
      DO 90 II=1,25
        CALL MOVE(525.,10.)
        CALL TEXT(1,' ')
      90 CONTINUE
C
      RETURN
      END

```


7.0 SUBROUTINE WRITPT

The WRITPT subroutine displays the dose rate at the chosen point and asks the user what to do next. The dose rate will be an integer of up to 4 digits. If the dose rate is less than 10,000 mrem/hr, it will be expressed in units of mrem/hr. If greater, it will appear in units of rem/hr. The user is then asked if another point is desired. The code expects a single character response of 'Y' (yes) or 'N' (no) with 'N' being the default. If 'Y' is pressed, the current information is erased (although the red X marking the previous chosen location on the working surface remains) and the code goes back to the PICKPT subroutine. If 'N' is pressed, the user is asked if he would like to specify a new X coordinate plane. Again the response should be a single character 'Y' or 'N' with 'N' the default. If this is no, the program is terminated. For a yes response, the screen is completely erased and the user is returned to the beginning of PGRAF.

```

C WRITPT SUBROUTINE
C          SUBROUTINE TO DISPLAY RESULTS OF POINT DOSE CALCULATION
C
C          SUBROUTINE WRITPT(ANSWER, LOG, XC, Y, Z)
C
C          CHARACTER*1 ESC, CR
C          CHARACTER*4 IDOSE, IX, IY, IZ
C          DATA          ESC/27/, IYES/89/, CR/13/
C
C          JX=IFIX(XC+.5)
C          JY=IFIX(Y)
C          JZ=IFIX(Z)
C          ENCODE(4, 30, IX) JX
C          ENCODE(4, 30, IY) JY
C          ENCODE(4, 30, IZ) JZ
C
C          JDOSE=IFIX(ANSWER)
C          IF (JDOSE.GE.10000) GOTO 50
C
C          ENCODE(4, 30, IDOSE)JDOSE
30  FORMAT(I4)
C
C          DOSE IN MREM
C
C          CALL MOVE(520., 100.)
C          CALL TEXT(4, IDOSE)
C          CALL MOVE(556., 100.)
C          CALL TEXT(8, ' MREM/HR')
C          GOTO 60
C
C          DOSE IN REM
C
C          50 JDOSE=IFIX(ANSWER/1000.)
C          ENCODE(4, 30, IDOSE)JDOSE
C          CALL MOVE(520., 100.)
C          CALL TEXT(4, IDOSE)
C          CALL MOVE(556., 100.)
C          CALL TEXT(7, ' REM/HR')
C
C          ANOTHER POINT ?
C
C          60 CALL MOVE(516., 60.)
C          CALL TEXT(15, 'NEW POINT?[Y/N]')
C
C          CALL CMCLOS
C          WRITE(5, *) ESC, 'SEN1888N', CR
C          CALL CMOPEN
C

```

```

        CALL LOCATE(1,YDUM,ZDUM,IAN,IGOT)
C
        IF (IAN.NE.IYES) GOTO 90
            LOG=0
C
C   ERASE DOSE RATE ON SCREEN
C
65 CALL CMCLOSE
   WRITE(5,*) ESC, 'SEN3DDDNSECO. XXX'
   CALL CMOPEN
C
   CALL MOVE(525.,220.)
   CALL TEXT(1,' ')
   CALL MOVE(525.,200.)
   CALL TEXT(12,'DOSE RATE AT')
C
   CALL MOVE(525.,180.)
   CALL TEXT(3,'X =')
   CALL MOVE(560.,180.)
   CALL TEXT(4,IX)
C
   CALL MOVE(525.,160.)
   CALL TEXT(3,'Y =')
   CALL MOVE(560.,160.)
   CALL TEXT(4,IY)
C
   CALL MOVE(525.,140.)
   CALL TEXT(3,'Z =')
   CALL MOVE(560.,140.)
   CALL TEXT(4,IZ)
C
   CALL MOVE(525.,120.)
   CALL TEXT(12,' IS EQUAL TO')
C
   CALL MOVE(520.,100.)
   CALL TEXT(4,IDOSE)
   CALL MOVE(556.,100.)
C
   JDOSE=IFIX(ANSWER)
   IF (JDOSE.GE.10000) GOTO 70
   CALL TEXT(8,' MREM/HR')
   GOTO 80
70 CALL TEXT(7,' REM/HR')
C
80      CALL MOVE(516.,60.)
   CALL TEXT(15,'NEW POINT?[Y/N]')
   CALL CMCLOSE
   WRITE(5,*) ESC, 'SEC2. XXX'
   CALL CMOPEN

```

```

C      RETURN
C
C      ANOTHER COORDINATE ON X PLANE ?
C
90 CALL MOVE(516.,30.)
   CALL TEXT(13,'NEW X PLANE ?')
C
   CALL LOCATE(1,YDUM,XDUM,IAN,IGOT)
C
      IF (IAN.NE.IYES) GOTO 100
      LOG=-1
C
C      ERASE EVERYTHING
C
      CALL CMCLOS
      WRITE(5,*) ESC, 'SEN3DDDNSECO.XXX'
      CALL CMOPEN
      CALL MOVE(516.,30.)
      CALL TEXT(13,'NEW X PLANE ?')
      GOTO 65
C
C      BOTH ANSWERS ARE NO - STOP
C
100 LOG=1
   CALL GRSTOP
   RETURN
   END

```

8.0 SUBROUTINES QUAD1 AND QUAD2

QUAD1 and QUAD2 are the two subroutines which numerically evaluate the double integral of the point kernel through length along a source pipe and through all angles around the pipe, respectively. The main routine of PERCS evaluates the upper and lower limit of integration along a given pipe and then calls upon QUAD1 to numerically evaluate the integral. QUAD1 in turn calls upon QUAD2 to evaluate the integral of the point kernel through all angles about the particular point along the source pipe.

Many classes of physical and mathematical problems, including the evaluation of the point kernel, present integrals for which there is no analytical solution. Some of the best mathematical minds have studied this problem and the literature abounds with various numerical methods to evaluate integrals. Because many of the methods were developed long before the advent of computers, many routines in use today are based on early "hand" methods. Computers, however, are notably short on good judgment, so the challenge has been to build algorithms which would evaluate the error in the calculation as the algorithm proceeded and use this information to control the calculation.

All quadrature routines calculate the value of the integrand at discrete points along the range of integration and use these values to estimate the integral. Many general types of quadrature routines have been developed, each with its own merits and disadvantages. Many of the routines are keyed to repeat the calculations with more and more discrete points along the range of integration until the estimated error is below some value. Much theoretical work has been done to provide a basis for estimating the error between what the routine has calculated and the true integral. A "brute force" method for error control is to repeatedly double the number of points along the range until two consecutive results agree to within a specified error allowance. Other methods make use of some theory of error and perform extra calculations to estimate the error and to make some correction for it.

Because the evaluation of the point kernel (i.e., the integrand) in PERCS is costly in terms of computation time, it is advantageous to use the more sophisticated routines rather than "brute force" methods. The extra time spent in calculation of error correcting terms is more than saved by not calling for the calculation of more data points. The two quadrature routines chosen for use in PERCS are an eight-panel Newton-Coates method and spline quadrature. Both of these methods make efficient use of the data points and quickly converge to a correct answer.

The Newton-Coates formulas are a family of integration formulas based on passing polynomials of various degree through equally spaced data points and evaluating the integral of the interpolating polynomial. The rectangular rule, the trapezoidal rule, and Simpson's Rule are the first three members of the Newton-Coates family, representing interpolating polynomials of degree zero, one, and two, respectively. Spline formulas are usually used to interpolate values between discrete data points. Cubic splines are widely used for this type of interpolation. Cubic polynomials are evaluated by

restricting the cubic equation to be continuous at each node (data point), to have continuous first and second derivatives at each node, and to satisfy an imposed end condition. The extension of this technique to integration is straightforward, but the evaluation of the various coefficients in each sub-interval is usually too costly in terms of computational time to allow general use of this technique. As discussed above, however, in PERCS this extra time is amply repaid. The reader is directed to texts on numerical analysis for further discussions of quadrature methods and Forsythe et al. (1977) for more specific discussions: the two methods used here are adapted from examples given in their book.

If the dose point lies within the ends of the pipe, and is twenty pipe radii or closer, the spline quadrature method is used in QUAD1, otherwise the eight-panel Newton-Coates method is used. This division is arbitrary and based on empirical tests of which routine would converge faster for given geometries. The eight-panel Newton-Coates method is used exclusively in QUAD2 because it was inevitably the faster routine.

For cylindrical sources as considered in PERCS, the point kernel integral takes the form:

$$\text{Dose} = \frac{1}{4\pi} \int_{\text{ALOW}}^{\text{AHIGH}} \int_0^{2\pi} \frac{\sum_{i=1}^{20} \left\{ S_A \sum_{\gamma=1}^{10} [\text{BLDUP} * E * \text{YIELD} * k(e) * e^{-BSUM}] \right\} R \, d\text{ALPHA} \, dA}{\text{RHO}^2}$$

where:

- RHO is the distance between the differential source point and the dose point
- $\sum_{\gamma=1}^{10}$ is the summation of up to ten different gamma-ray emissions from a given isotope
- BLDUP is the ratio of the dose from the total flux to the dose from the uncollided flux
- E is the energy of a particular gamma-ray emitted during an isotope decay process
- YIELD is the probability of a particular gamma-ray being emitted during an isotope decay process
- k(E) is a factor which converts MeV/cm²/sec to mrem/hr for a given gamma-ray energy

- BSUM is the sum of all the optical thicknesses along a source-dose line. Note that for a fixed geometry, BSUM is a function of gamma-ray energy
- S_A is the differential source strength in $\mu\text{Ci}/\text{cm}^2$ at a given distance and length along a source pipe
- $\sum_{i=1}^{20}$ is the summation of up to twenty isotopes in a given source pipe
- R is the inside radius of the source pipe
- ALPHA is the running variable of integration about all angles
- A is the running variable of integration of length along a source pipe

QUAD1 numerically integrates this kernel about all angles for a given length along a source pipe. QUAD2, using the results from QUAD1 for chosen points along the source pipe, performs the numerical integration along the length of the pipe. This result is passed back to the main routine and the integration of the next source pipe is initiated by the main routine.

```

SUBROUTINE QUAD1(RESULT)
  DIMENSION F(33),H(33),B(33)
  DIMENSION C(33),D(33),G(33),HI(17)
  COMMON R,DD,A,T
  COMMON/QUAD/W0,W1,W2,W3,W4
  COMMON/DAN/ALOW,AHIGH
  COMMON/DAN2/AOLD
C
C DETERMINE WHETHER NEWTON-COTES OR SPLINE METHOD WILL BE USED
C
  IF((DD.LT.(20.0*R)).AND.((AHIGH*ALOW).LT.0.0)) GOTO 100
C
C PIPE IS DIVIDED INTO 32 PARTS
C
  PANEL=(AHIGH-ALOW)*0.03125
C
C CALCULATE F ARRAY FOR INTEGRATION ... VALUES WILL BE
C TESTED FOR CONVERGENCE
C
  DO 5 I=1,33,2
    Q=I-1
    X=Q*PANEL+ALOW
    A=X
    AOLD=X-1.
    CALL QUAD2(RESLT)
    F(I)=RESLT
5    CONTINUE
C
C START INTEGRATION USING NEWTON-COTES FOR EACH TIME
C
  IJ=0
C
  Q1=(W0*(F( 1)+F(33))+
1    W1*(F( 5)+F(29))+
2    W2*(F( 9)+F(25))+
3    W3*(F(13)+F(21))+
4    W4* F(17))*4.0*PANEL
C
  Q2=(W0*(F( 1)+F(17)+F(17)+F(33))+
1    W1*(F( 3)+F(15)+F(19)+F(31))+
2    W2*(F( 5)+F(13)+F(21)+F(29))+
3    W3*(F( 7)+F(11)+F(23)+F(27))+
4    W4*(F( 9)+F(25)))*2.0*PANEL
C
  DIFF=(Q2-Q1)/1023.0
  RESULT=Q2+DIFF
  IF(RESULT.LT.1.E-7) GO TO 50
  ERREST=ABS(DIFF)/RESULT
  IF(ERREST.GT.0.0001) IJ=1

```



```

50  CONTINUE
    IF(IJ.EQ.1) GOTO 55
    RETURN
55  DO 75 I=2,32,2
    Q=I-1
    X=Q*PANEL+ALOW
    A=X
    AOLD=X-1.
    CALL QUAD2(RESLT)
    F(I)=RESLT
75  CONTINUE
C
    Q3=(W0*(F( 1)+F( 9)+F( 9)+F(17)+
1      F(17)+F(25)+F(25)+F(33))+
2      W1*(F( 2)+F( 8)+F(10)+F(16)+
3      F(18)+F(24)+F(26)+F(32))+
4      W2*(F( 3)+F( 7)+F(11)+F(15)+
5      F(19)+F(23)+F(27)+F(31))+
6      W3*(F( 4)+F( 6)+F(12)+F(14)+
7      F(20)+F(22)+F(28)+F(30))+
8      W4*(F( 5)+F(13)+F(21)+F(29)))*PANEL
C
    DIFF=(Q3-Q2)/1023.0
    RESULT=Q3+DIFF
    IF(RESULT.LT.1.E-7) GO TO 80
    ERREST=ABS(DIFF)/RESULT
    IF(ERREST.LT.0.0002) GOTO 80
C
C  TRY SPLINE METHOD OF QUADRATURE
C
    DO 76 I=1,33
    G(I)=(I-1)*PANEL+ALOW
    H(I)=F(I)
76  CONTINUE
    CALL SPLINE(33,G,H,B,C,D)
    WRITE(6,99)
    WRITE(6,98)0.25*R*RESULT,0.25*R*Q2
    RESULT=0.0
    DO 77 K=1,32
    RESULT=RESULT+PANEL*0.5*(H(K)+H(K+1))-
    &((C(K)+C(K+1))/12.)*PANEL**3
77  CONTINUE
C
80  CONTINUE
    RETURN
98  FORMAT(2X,'Q3=',1PE12.3,5X,'Q2=',1PE12.3)
99  FORMAT(2X,'ERROR .GT. 20% AFTER 32 PANELS IN QUAD1')
C
C  SPLINE METHOD OF INTEGRATION

```

```

C
100  AOLD=ALOW-1.
      DO 209 I=1,17
      JJ=17-I
      A=0.0625*ALOW*FLOAT(JJ)
      CALL QUAD2(RESLT)
      F(I)=RESLT
      H(I)=A
209  CONTINUE
      DO 226 I=1,16
      A=0.0625*FLOAT(I)*AHIGH
      CALL QUAD2(RESLT)
      H(17+I)=A
      F(17+I)=RESLT
226  CONTINUE
      IG=33
      RESULT=0.0
      DO 275 I=1,17
      G(I)=F(I)
275  CONTINUE
      CALL SPLINE(17,H,G,B,C,D)
C    CALL DRAWIT(17,H,G,B,C,D)
      DO 300 K=1,16
      DIFF=H(K+1)-H(K)
      RESULT=RESULT+DIFF*0.5*(G(K)+G(K+1))
      &      -((C(K)+C(K+1))/12.)*DIFF**3
300  CONTINUE
      DO 305 I=1,17
      G(I)=F(I+16)
      HI(I)=H(I+16)
305  CONTINUE
      CALL SPLINE(17,HI,G,B,C,D)
C    CALL DRAWIT(17,HI,G,B,C,D)
      DIFF=HI(2)-HI(1)
      DO 319 K=1,16
      RESULT=RESULT+DIFF*0.5*(G(K)+G(K+1))
      &      -((C(K)+C(K+1))/12.)*DIFF**3
319  CONTINUE
      RETURN
      END

```

```

C *****
C THIS SUBROUTINE PERFORMS THE INTEGRATION WITH RESPECT TO ANGLE
C ABOUT PIPE USING A NEWTON-COTES 8-PANEL INTEGRATION SCHEME
C THE ERROR IS ESTIMATED BY SUBDIVIDING THE PANELS (SEE TEXT)
C *****
C
      SUBROUTINE QUAD2(RESULT)
      DIMENSION NMEV(10), ENERGY(10, 5, 2)
      DIMENSION ANGLE(33), ISOTP(20), IIP(20, 10)
      DIMENSION SHLD(30, 3), F(33)
      COMMON/QUAD/W0, W1, W2, W3, W4, NLIB, ANGLE, NSI
      COMMON/LIB2/NMEV, ENERGY, ISOTP, IIP
C
      CONV(EN)=37.0*(1.986-0.5162*ALOG(EN))*EN
C
      DO 30 NA=1, 33, 2
      CALL GEO(ANGLE(NA), NSHLD, SHLD, RHOSQR)
C
          F(NA)=0.0
C
          DO 25 L=1, ISOTP(NSI)
C
              J = IIP(NSI, L)
              DO 15 I=1, NMEV(J)
              E=ENERGY(J, I, 1)
              CALL BUILDUP(NSHLD, SHLD, E, BLDUP, BSUM)
C
                  F(NA)=F(NA)+BLDUP*CONV(E)*EXP(-BSUM)*
1                      ENERGY(J, I, 2)*SA(J)
10                  CONTINUE
15                  CONTINUE
C
25                  CONTINUE
                  F(NA)=F(NA)/RHOSQR
30      CONTINUE
C
C START INTEGRATION USING NEWTON-COTES FOR EACH TIME
C
      JFLAG=0.0
C
      Q1=(W0*(F( 1)+F(33))+
1          W1*(F( 5)+F(29))+
2          W2*(F( 9)+F(25))+
3          W3*(F(13)+F(21))+
4          W4* F(17))*0.25
C
      Q2=(W0*(F( 1)+F(17)+F(17)+F(33))+
1          W1*(F( 3)+F(15)+F(19)+F(31))+
2          W2*(F( 5)+F(13)+F(21)+F(29))+

```

```

3      W3*(F( 7)+F(11)+F(23)+F(27))+
4      W4*(F( 9)+F(25)))*0.125
C
      DIFF=(Q2-Q1)/1023.
      RESULT=Q2+DIFF
      IF(RESULT.LT.1.E-7) GO TO 50
      ERREST=ABS(DIFF)/RESULT
      IF(ERREST.GT.0.0001) JFLAG=1
50     IF(JFLAG.EQ.1) GO TO 55
      RETURN
55     DO 60 NA=2,32,2
      CALL GEO(ANGLE(NA),NSHLD,SHLD,RHOSQR)
C
      F(NA)=0.0
C
      DO 625 L=1,ISOTP(NSI)
C
      J = IIP(NSI,L)
      DO 615 I=1,NMEV(J)
      E=ENERGY(J,I,1)
      CALL BUILDUP(NSHLD,SHLD,E,BLDUP,BSUM)
C
      F(NA)=F(NA)+BLDUP*CONV(E)*EXP(-BSUM)*
1      ENERGY(J,I,2)*SA(J)
615    CONTINUE
C
625    CONTINUE
      F(NA)=F(NA)/RHOSQR
60 CONTINUE
C
      Q3=(W0*(F( 1)+F( 9)+F( 9)+F(17)+
1      F(17)+F(25)+F(25)+F(33))+
2      W1*(F( 2)+F( 8)+F(10)+F(16)+
3      F(18)+F(24)+F(26)+F(32))+
4      W2*(F( 3)+F( 7)+F(11)+F(15)+
5      F(19)+F(23)+F(27)+F(31))+
6      W3*(F( 4)+F( 6)+F(12)+F(14)+
7      F(20)+F(22)+F(28)+F(30))+
8      W4*(F( 5)+F(13)+F(21)+F(29)))*0.0625
C
      DIFF=(Q3-Q2)/1023.0
      RESULT=Q3+DIFF
70     CONTINUE
      RETURN
      END

```

9.0 SUBROUTINE SPLINE

A spline fit is an algorithm which is used to estimate a function between data points. A cubic spline fits a cubic polynomial between each point with continuous first and second derivatives. The cubic spline is often used in curve fitting and interpolation routines and can also be used as a quadrature routine in numerical integration.

The subroutine SPLINE is called from QUAD1 for the integration of the point kernel equation. SPLINE calculates the parameters of a cubic spline function and passes these in arrays back to QUAD1. The program used in SPLINE is taken from Forsythe (1977). A brief summary of the calculational method follows.

The input to SPLINE includes the number of data points or nodes and the x and y coordinates of the points. The coordinates are used in the following equation to calculate the coefficients B, C, and D.

$$S(X) = Y(I) + B(I) * (X - X(1)) + C(I) * (X - X(1)) ** 2 + D(I) * (X - X(1)) ** 3$$

Matrix computations are used to solve a system of N-2 simultaneous linear equations with N unknowns where N is the total number of points. Two end conditions must also be specified and the method used here is to fit the third derivatives of the cubics with S(X). A complete explanation of the spline function is contained in Forsythe (1977).

```

      SUBROUTINE SPLINE (N,X,Y,B,C,D)
      INTEGER N
      REAL X(N),Y(N),B(N),C(N),D(N)
C
C   THE COEFFICIENTS B(I), C(I), AND D(I), I=1,2...N ARE COMPUTED
C   FOR A CUBIC INTERPOLATING SPLINE
C
C    $S(X)=Y(I)+B(I)*(X-X(I))+C(I)*(X-X(I))**2+D(I)*(X-X(I))**3$ 
C
C   FOR  $X(I) \leq X \leq X(I+1)$ 
C
C   INPUT..
C
C   N= NUMBER OF DATA POINTS OF KNOTS (N.GE.2)
C   X= THE ABSCISSAS OF THE KNOTS IN STRICTLY INCREASING ORDER
C   Y= THE ORDINATES OF THE KNOTS
C
C   OUTPUT..
C
C   B,C,D = ARRAYS OF SPLINE COEFFICIENTS AS DEFINED ABOVE
C
C   USING P TO DENOTE DIFFERENTIATION
C
C    $Y(I) = S(X(I))$ 
C    $B(I) = SP(X(I))$ 
C    $C(I) = SPP(X(I))/2$ 
C    $D(I) = SPPP(X(I))/6$  (DERIVATIVE FROM THE RIGHT)
C
C   FUNCTION SEVAL CAN BE USED TO EVALUATE THE SPLINE
C
      INTEGER NM1, IB, I
      REAL T
C
      NM1=N-1
      IF(N.LT.2) RETURN
      IF(N.LT.3) GO TO 50
C
C   SET TRIDIAGONAL SYSTEM
C
C   B=DIAGONAL, D=OFFDIAGONAL, C=RIGHT HAND SIDE
C
      D(1)=X(2)-X(1)
      C(2)=(Y(2)-Y(1))/D(1)
      DO 10 I=2,NM1
          D(I)=X(I+1)-X(I)
          B(I)=2. *(D(I-1)+D(I))
          C(I+1)=(Y(I+1)-Y(I))/D(I)
          C(I)=C(I+1)-C(I)
10  CONTINUE

```

```

C
C END CONDITIONS. THIRD DERIVATIVES AT X(1) AND X(N)
C OBTAINED FROM DIVIDED DIFFERENCES
C
      B(1)=-D(1)
      B(N)=-D(N-1)
      C(1)= 0.
      C(N)= 0.
      IF (N.EQ.3) GO TO 15
      C(1)=C(3)/(X(4)-X(2)) - C(2)/(X(3)-X(1))
      C(N)=C(N-1)/(X(N)-X(N-2)) - C(N-2)/(X(N-1)-X(N-3))
      C(1)=C(1)*D(1)**2/(X(4)-X(1))
      C(N)=-C(N)*D(N-1)**2/(X(N)-X(N-3))
C
C FORWARD ELIMINATION
C
15 DO 20 I=2,N
      T=D(I-1)/B(I-1)
      B(I)=B(I)-T*D(I-1)
      C(I)=C(I)-T*C(I-1)
20 CONTINUE
C
C BACK SUBSTITUTION
C
      C(N)=C(N)/B(N)
      DO 30 IB=1,NM1
          I=N-IB
          C(I)=(C(I)-D(I)*C(I+1))/B(I)
30 CONTINUE
C
C C(I) IS NOW THE SIGMA(I) OF TEXT
C
C COMPUTE POLYNOMIAL COEFFICIENTS
C
      B(N)=(Y(N)-Y(NM1))/D(NM1)+D(NM1)*(C(NM1)+2.*C(N))
      DO 40 I=1,NM1
          B(I)=(Y(I+1)-Y(I))/D(I)-D(I)*(C(I+1)+2.*C(I))
          D(I)=(C(I+1)-C(I))/D(I)
          C(I)=3.*C(I)
40 CONTINUE
      C(N)=3.*C(N)
      D(N)=D(N-1)
      RETURN
C
50 B(1)=(Y(2)-Y(1))/(X(2)-X(1))
   C(1)=0.
   D(1)=0.
   B(2)=B(1)
   C(2)=0.
   D(2)=0.
   RETURN
END

```


10.0 SUBROUTINE GEO

The subroutine GEO is called by the routine QUAD2 after the integration variable A has been fixed along the length of the source pipe by QUAD1 and ALPHA, the angular variable of integration, has been fixed in QUAD2. GEO locates all of the shielding materials along the source-dose line and their position and length along the line is stored in the array SHLD. GEO first calculates the shielding provided by the source pipe itself, then loops throughout all other pipes to see if they lie between the differential source point and the dose point, and, if there are any auxiliary shields, calls the subroutine SHIELD which checks each of the shields to determine if they are between the source and dose points.

Figure 10.1 shows the main variables which will be used throughout the subroutine. R is the inside radius of the source pipe, T the thickness of the wall of the source pipe, A is the running integration variable along the length of the pipe, RHO is the length of the source-dose line, D is the right angle distance between the centerline of the pipe and the dose point, and z is the xy projection of RHO. ALPHA, the other running variable of integration, is the angle of the source point from D. The centerline of the source pipe and the dose point define a unique plane, and no matter what the angle or relation in absolute coordinates, relative coordinates as shown in this figure are always defined.

If only the xy projection (in relative coordinates) is considered for a moment, one notes that as the integration of the angle ALPHA starts, at first there will only be shielding from the pipe wall (see Figure 10.2). As the angle increases, however, there reaches a point where the source-dose line will transverse the fill material of the pipe (see Figure 10.3). The formulas needed to calculate the various distances are shown along with the figures. Once the two-dimensional distances are known, the three-dimensional distances are easily calculated because the distance (A) along the pipe is known.

In general, the dose point will lie between the ends of the source pipe or will lie in a plane above or below the pipe. The special case where the dose point lies exactly on one end of pipe is included as lying between the ends of the pipe. If the dose point lies between the ends of the pipe, the calculated three-dimensional distances are the true distances throughout the shielding materials of the source pipe. If, however, the dose point is above or below the ends of the source pipe, the calculated distance might not be correct. If the source-dose line exits through the bottom or top of the pipe, the calculated distance will be too large since the distances were calculated using the two-dimensional projections of the pipe walls (see Figure 10.4). The correct distance through the shielding materials is simple to calculate using similar triangles as shown in Figure 10.4 since the vertical directions (in relative coordinates) is known.

If the dose point lies inside the pipe or within the pipe walls, the algorithms throughout the rest of the code will still work. Therefore, these dose locations are allowed and treated as special cases at the start of GEO. The only case explicitly forbidden is when the dose point resides exactly on the source, i.e., where the dose point is distance R away from the centerline of the pipe and is within the ends of the pipe. The formulas and graphical description of these special cases is shown in Figures 10.5 through 10.7. As discussed in the paragraph above, if the dose point is above or below the pipe, allowance must be made for the difference between the distance calculated from the two-dimensional projections and the actual three-dimensional distances.

The next step, now that the shielding from the source pipe itself is calculated, is to check all other pipes to see if the source-dose line passes through them. The absolute coordinates for the differential source point are obtained from the subroutine SCOORD, whose algorithms are discussed elsewhere in this report. Having the absolute coordinates for the source-dose line, each pipe other than the source pipe is chosen in turn and the distance of closest approach between the centerline of the chosen pipe and the source-dose line (or their extensions) is calculated. This minimum distance is straightforward to derive and is presented in many texts or handbooks on analytical geometry (e.g., CRC Handbook of Mathematics 1967):

Distance between line through P_1 in direction (a_1, b_1, c_1) and line through P_2 in direction (a_2, b_2, c_2) :

$$\text{Distance} = \pm \frac{\begin{vmatrix} x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ a_1 & b_1 & c_1 \\ a_1 & b_2 & c_2 \end{vmatrix}}{\sqrt{\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}^2 + \begin{vmatrix} c_1 & a_1 \\ c_2 & a_2 \end{vmatrix}^2 + \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}^2}}$$

If the minimum approach distance is greater than the sum of the radius and the wall thickness of the chosen pipe, the source-dose line cannot pass through it and it is excluded from consideration with a single test. The magnitude of the distance being less than the radius plus the wall thickness is a sufficient but not a necessary condition of passage of the source-dose line through the chosen pipe. To understand this, consider Figure 10.8. Since the extensions of the lines are used to calculate the distance of closest approach, the source-dose line might pass "over" or "under" the pipe and never hit it, even though the distance of closest approach is less than the radius of the chosen pipe (line 3 in Figure 10.8). As annoying as it is to have to test twice to assure a "hit" of the chosen pipe, the use of the

projections also has beneficial properties. Use of the projections will also return a positive test on lines which pass through the end of the pipe and exit through a side of the pipe (line 2 in Figure 10.8), or indeed, lines which pass from end to end through the pipe and never touch the walls will test positive.

To calculate in a single algorithm the true three-dimensional distances through the chosen pipe (if, indeed, there is any) in general coordinates, allowing for any orientation of the source-dose line and the chosen pipe, and allowing for entrance or exit of the source-dose line through the ends of the pipes is an awesome task that does not allow for clarity of programming. A less heroic approach was taken: the chosen pipe was moved into a standard configuration which would then allow the calculation of the distances of the source-dose line through the pipe to be done on a case by case basis.

If the centerline of the chosen pipe has a projection on the xy plane, as shown in Figure 10.9, the origin of the coordinate system can be translated so that it coincides with the beginning of the centerline of the chosen pipe.

The coordinate system is now rotated in two steps so that the centerline of the chosen pipe coincides with the z-axis. The formulas relating coordinates in a rotated system to coordinates before the system was rotated can be easily derived and are presented in many texts (e.g., Protter and Morrey 1970).

$$x' = x \cos \theta + y \sin \theta$$

$$y' = -x \sin \theta + y \cos \theta$$

where the primed quantities are in the new coordinate system rotated angle θ about the origin from the old coordinate system. As shown in Figure 10.10, the first step is to rotate the coordinate system about the z-axis until the projection of the centerline of the chosen pipe is coincident with the x-axis. Using the formulas given above, the new coordinate can be related to the old coordinates by:

$$x' = x \cos \theta + y \sin \theta$$

$$y' = -x \sin \theta + y \cos \theta$$

For the particular case of rotation to the x-axis

$$\cos \theta = \frac{x_2}{\sqrt{x_2^2 + x_1^2}}$$

and

$$\sin\theta = \frac{y_2}{\sqrt{x_2^2 + x_1^2}}$$

where x_2 and y_2 are the coordinates of the endpoint of the centerline of the pipe in the translated (but unrotated) coordinate system.

The second and final step is to rotate the coordinate system about the y axis by the angle ϕ . As above

$$z'' = z\cos\phi + x' \sin\phi$$

$$x'' = -z\sin\phi + x' \cos\phi$$

where x'' and z'' are the coordinates in the twice rotated system. Using the same arguments as in the xy plane:

$$\cos\theta = \frac{z_2}{\sqrt{z_2^2 + (x'_2)^2}}$$

$$\sin\theta = \frac{x'_2}{\sqrt{z_2^2 + (x'_2)^2}}$$

After some algebra

$$x_{NEW} = x'' = \frac{-z\sqrt{x_2^2 + y_2^2} + \frac{z}{\sqrt{x_2^2 + y_2^2}}(xx_2 + yy_2)}{PRHO}$$

$$y_{NEW} = y'' = \frac{-xy_2 + zx_2}{\sqrt{x_2^2 + y_2^2}}$$

$$z_{NEW} = \frac{xx_2 + yy_2 + zz_2}{PRHO}$$

$$PRHO = \sqrt{x_2^2 + y_2^2 + z_2^2}$$

where x, y, z are the coordinates of any point in the original translated, but unrotated, coordinate system; $x_{NEW}, y_{NEW}, z_{NEW}$ are the corresponding coordinates in the twice rotated system; and $PRHO$ is the length of the chosen pipe. If, for a particular case, there is no xy projection, a different calculational path must be taken, but, in general, all source-dose, centerline configurations will now appear as shown in Figure 10.11.

Now a final rotation about the z -axis is performed to bring the source-dose line parallel to the xz -plane. In this particular coordinate system the calculation of the distance the source-dose line travels through the chosen pipe is considerably simplified. Since the points along the source-dose line all have the same x coordinates, the true three-dimensional distances can be calculated using only the new y and z coordinates.

Again, since projections are used, various tests must be applied to assure the correct distance through the pipe is calculated. All of the possibilities shown in Figure 10.12 are considered on a case by case basis in $GE0$ and the correct distances through pipe wall and pipe fill material are calculated and stored in the array $SHLD$.

After all pipes have been checked, and the distances from the start of the shielding material from the source, and the attendant shield thickness for each shielding material from interviewing pipes has been stored in $SHLD$, a simple sorting routine is invoked to arrange the contents of $SHLD$ in increasing order from the dose point.

If there are any auxiliary shields present, the subroutine $SHIELD$ is called which will add the contributions, if any, of the auxiliary shields to the array $SHLD$. The completed array is passed back to the calling routine $QUAD2$ and geometrical considerations are now complete for a single source-dose line.

FIGURE 10.1. Variables in Relative Coordinate System

FIGURE 10.2. For Angles Below a Critical Value, The Source-Dose Line Crosses Only the Wall

FORMULAS:

$$\frac{\sin \alpha}{z} = \frac{\sin \beta}{D} = \frac{\sin \alpha}{\sqrt{D^2 + R^2 - 2DR \cos \alpha}}$$

but $(R + T)^2 = R^2 + x^2 - 2Rx \cos \beta$

or $x^2 - 2Rx \cos \beta - 2RT - T^2 = D$

Therefore: $x = R \cos \beta + \sqrt{R^2 \cos^2 \beta + T^2 + 2RT}$

FIGURE 10.3. For Angles Above a Critical Value, The Source-Dose Line Crosses Two Materials

FORMULAS:

$$\frac{\sin \gamma}{D} = \frac{\sin \alpha}{z} ; \frac{\sin (\pi - 2\gamma)}{y} = \frac{\sin \gamma}{R} = \frac{\sin 2\gamma}{y}$$

$$y = \frac{\sin 2\gamma}{\sin \gamma} R = 2 R \cos \gamma$$

x as in Figure 10.2 using β for angle

y^* (actual distance)

$$\frac{y^*}{\rho} = \frac{A - \text{ALLOW}}{A}$$

FIGURE 10.4. Three Dimensional Consideration for Source-Dose Lines Which Exit Through End of Pipe

Two Dimensional Distance = z
 Three Dimensional Distance = ρ

FIGURE 10.5. For Angles Below Critical Value and Dose Point Within Wall

FIGURE 10.6. For Angles Above Critical Value and Dose Point Within Wall

FORMULAS:

$$\frac{\sin \gamma}{D} = \frac{\sin \alpha}{z} ; \frac{\sin (\pi - 2\gamma)}{y} = \frac{\sin \gamma}{R} = \frac{\sin 2\gamma}{y}$$

$$y = \frac{\sin 2\gamma}{\sin \gamma} R = 2 R \cos \gamma$$

x as in Figure 10.5 using β for angle

Two Dimensional Distance = z
 Three Dimensional Distance = D

FIGURE 10.7. Dose Point Within Pipe (D Cannot Equal 0 or R)

FIGURE 10.8. Examples of Three Dimensional Considerations

FIGURE 10.9. Translation of Coordinate System

FIGURE 10.10. Coordinate System Rotations

FIGURE 10.11. Twice-Rotated Coordinate System

FIGURE 10.12. Example of Special Cases for Distance Calculation

```

C *****
C THE SUBROUTINE GEO DETERMINES THE NUMBER OF SHIELDS INTERSECTED
C BY THE SOURCE-DOSE LINE AND LOADS THEIR POSITION AND LENGTH ALONG
C THE SOURCE-DOSE LINE IN ARRAY 'SHLD'.
C *****
C
C     SUBROUTINE GEO(ALPHA, NSHLD, SHLD, RHOSQR )
C     DIMENSION SHLD(30,3), X(50,11), P(3), SH(10,8)
C     COMMON R, D, A, T, P, NPIPES, X
C     COMMON/THREE/ISHLD, SH, XS, YS, ZS
C     COMMON/DAN/ALOW, AHIGH, M
C     PARAMETER PI=3.14159265, PIBY2=1.5707963
C
C     NSHLD=0
C     YSTAR=0.0
C
C     SIMILAR TRIANGLES WILL BE USED TO DETERMINE THE POSITION
C     OF THE DOSE POINT WITH RESPECT TO A GIVEN PIPE
C
C     Z=SQRT(D*D+R*R-2.0*R*D*COS(ALPHA))
C
C     RHO=SQRT(Z*Z+A*A)
C     RHOSQR=RHO*RHO
C
C     TEST TO SEE IF DOSE POINT IS OUTSIDE PIPE
C
C     IF(D.GE.(R+T))GOTO 4
C
C     IF(ALOW*AHIGH)1,1,2
C
C     DOSE POINT LIES BETWEEN OR ON ENDS OF PIPE
C
C     1 IF(D-R)7,8,9
C
C     7 SHLD(1,1)=RHO
C     SHLD(1,2)=0.0
C     SHLD(1,3)=X(M,9)
C
C     NSHLD=1
C     GOTO 90
C
C     8 WRITE(5,*)' ERROR IN GEO... D.EQ.R ...EXITING'
C     STOP
C
C     9 SHLD(1,1)=RHO*R/D
C     SHLD(1,2)=0.0
C     SHLD(1,3)=X(M,9)
C
C     SHLD(2,1)=RHO-SHLD(1,2)

```

```

        SHLD(2,2)=SHLD(1,2)
        SHLD(2,3)=X(M,10)
C
        NSHLD=2
        GOTO 90
C
C DOSE POINT LIES ABOVE OR BELOW PIPE ENDS
C
        2 END=AHIGH
        IF(AHIGH.GE.0.0)END=ALOW
C
        IF(D-R)11,12,12
C
C
11 SHLD(1,1)=RHO*(A-END)/A
   SHLD(1,2)=0.0
   SHLD(1,3)=X(M,9)
C
        NSHLD=1
        GOTO 15
C
12 IF(D*D-R*R-Z*Z.GE.0.0)THEN
   SHLD(1,1)=RHO*(A-END)/A
   SHLD(1,2)=0.0
   SHLD(1,3)=X(M,10)
C
        NSHLD=1
        GOTO 15
C
        ELSE
        SINGAM=SIN(ALPHA)*D/Z
        Y=2.0*R*SQRT(1.0-SINGAM*SINGAM)
C
        TEST=RHO*(A-END)/A
        IF(RHO*Y/Z.GE.TEST)THEN
        SHLD(1,1)=TEST
        SHLD(1,2)=0.0
        SHLD(1,3)=X(M,9)
C
        NSHLD=1
        GOTO 15
C
        ELSE
        SHLD(1,1)=RHO*Y/Z
        SHLD(1,2)=0.0
        SHLD(1,3)=X(M,9)
C
        SHLD(2,1)=TEST-SHLD(1,2)
        SHLD(2,2)=SHLD(1,2)

```

```

      SHLD(2,3)=X(M,10)
C
      NSHLD=2
      GOTO 15
C
      ENDIF
      ENDIF
C
4 F=RHO/Z
  IF((R*R+Z*Z-D*D).LE.0) GOTO 221
C
  SINGAM=SIN(ALPHA)*D/Z
  COSGAM=SQRT(1.0-SINGAM*SINGAM)
  Y=2.0*COSGAM*R
  YSTAR=Y*F
C
  NSHLD=NSHLD+1
  IF(NSHLD.GT.30) GOTO 80
  SHLD(NSHLD,1)=YSTAR
  SHLD(NSHLD,2)=0.0
  SHLD(NSHLD,3)=X(M,9)
C
  COSB=-COSGAM
  GO TO 222
221 SINB=D*SIN(ALPHA)/Z
  COSB=-SQRT(1.0-SINB*SINB)
222 W=R*COSB+SQRT(R*R*COSB*COSB+T*T+2.0*R*T)
  TSTAR=W*F
C
  NSHLD=NSHLD+1
  IF(NSHLD.GT.30) GOTO 80
  SHLD(NSHLD,1)=TSTAR
  SHLD(NSHLD,2)=YSTAR
  SHLD(NSHLD,3)=X(M,10)
C
  IF((AHIGH*ALOW).LE.0.0) GOTO 15
  END=AHIGH
  IF(AHIGH.GT.0.0) END=ALOW
  TEST=RHO*(A-END)/A
  IF(TEST.GE.(YSTAR+TSTAR)) GOTO 15
  IF(NSHLD.EQ.2) GOTO 5
  SHLD(1,1)=TEST
  GOTO 15
5  IF(TEST.GT.YSTAR) GO TO 6
  SHLD(1,1)=TEST
  NSHLD=NSHLD-1
  GOTO 15
6  SHLD(2,1)=TEST-YSTAR
  GO TO 15

```

```

C
C  GET SURFACE COORDINATES XS,YS,ZS FROM SUBROUTINE
C
15  CALL SCOORD(ALPHA,XS,YS,ZS)
C
C  CALCULATE SOURCE DOSE DIRECTION NUMBERS
C
      A1=XS-P(1)
      B1=YS-P(2)
      C1=ZS-P(3)
C
C  START THROUGH PIPES TO CHECK FOR SHIELDING
C
      DO 39 IP=1,NPIPES
      IF(IP.EQ.M) GO TO 39
C
      A2=X(IP,4)-X(IP,1)
      B2=X(IP,5)-X(IP,2)
      C2=X(IP,6)-X(IP,3)
C
C  CALCULATE DISTANCE BETWEEN SOURCE-DOSE LINE AND PIPE CENTERLINE
C
      TOP=(X(IP,1)-P(1))*(B1*C2-B2*C1)+(P(2)-X(IP,2))*(A1*C2-A2*C1)
      &+(X(IP,3)-P(3))*(A1*B2-B1*A2)
      DIST=ABS(TOP)/SQRT((B1*C2-B2*C1)**2+(C1*A2-A1*C2)**2
      &+(A1*B2-A2*B1)**2)
C
C  IF DIST IS GREATER THAN RADIUS OF PIPE + PIPE THICKNESS, SKIP
C
      IF(DIST.GE.(X(IP,7)+X(IP,8))) GO TO 39
C
      PRHO=SQRT(A2*A2+B2*B2+C2*C2)
      XYRHO=SQRT(A2*A2+B2*B2)
      IF(XYRHO.LE.0.0001)GOTO 18
C
C  CALCULATE THE NEW COORDINATES SO THAT PIPE LIES ON Z AXIS
C
      C4=C2/XYRHO
      XDNEW=((X(IP,3)-P(3))*XYRHO+C4*(A2*(P(1)-X(IP,1))
      &+B2*(P(2)-X(IP,2))))/PRHO
      XSNEW=((X(IP,3)-ZS)* XYRHO+C4*(A2*(XS -X(IP,1))
      &+B2*(YS -X(IP,2))))/PRHO
C
      YDNEW=((P(2)-X(IP,2))*A2+B2*(X(IP,1)-P(1)))/XYRHO
      YSNEW=((YS -X(IP,2))*A2+B2*(X(IP,1)-XS ))/XYRHO
C
C  ROTATE SYSTEM SO SOURCE-DOSE LINE PROJECTION IS PARALLEL TO X AXIS
C
16  XDS=XDNEW-XSNEW

```

```

YDS=YDNEW-YSNEW
XYNEW=SQRT(XDS*XDS+YDS*YDS)
IF(XYNEW.LE.0.0001)GO TO 19
C
XDL=(XDNEW*XDS+YDNEW*YDS)/XYNEW
YDL=(YDNEW*XDS-XDNEW*YDS)/XYNEW
XSL=(XSNEW*XDS+YSNEW*YDS)/XYNEW
C
X2=SQRT((X(IP,7)+X(IP,8))**2-DIST*DIST)
X1=-X2
C
IF(XDL.LT.X1.AND.XSL.LT.X1.OR.XDL.GT.X2.AND.XSL.GT.X2)GOTO 39
C
IF(XSL.GT.XDL)THEN
XSL=-XSL
XDL=-XDL
ENDIF
C
ZDL=(A2*(P(1)-X(IP,1))+B2*(P(2)-X(IP,2))+C2*(P(3)-X(IP,3)))/PRHO
ZSL=(A2*(XS-X(IP,1))+B2*(YS-X(IP,2))+C2*(ZS-X(IP,3)))/PRHO
C
C USING X COORDINATES OF S-D INTERSECTION WITH PIPE, FIND PROJECTED Z
C
ZF=(ZDL-ZSL)/(XDL-XSL)
Z1=ZSL+ZF*(X1-XSL)
Z2=ZSL+ZF*(X2-XSL)
C
C CHECK TO SEE IF SOURCE-DOSE LINE MISSES PIPE
C
IF(Z1.GE.PRHO.AND.Z2.GE.PRHO.OR.Z1.LE.0.0.AND.Z2.LE.0.0)GOTO 39
C
C CHECK TO SEE IF EACH END OF SOURCE-DOSE LINE ACTUALLY GOES THRU PIPE
C
IF(DIST.GE.X(IP,7))GOTO 36
XIN=SQRT(X(IP,7)*X(IP,7)-DIST*DIST)
ITEST=1
IF(Z1.LE.PRHO.AND.Z1.GE.0.0)ITEST=2
IF(Z2.LE.PRHO.AND.Z2.GE.0.0)ITEST=ITEST+2
GO TO(20,26,30,35)ITEST
20 IF(Z1.GT.PRHO)Z1=PRHO
IF(Z1.LT.0.0)Z1=0.0
X1=XSL+(Z1-ZSL)/ZF
IF(Z2.GT.PRHO)Z2=PRHO
IF(Z2.LT.0.0)Z2=0.0
X2=XSL+(Z2-ZSL)/ZF
C
IF(XDL.LT.X2)THEN
X2=XDL
Z2=ZDL

```

```

ENDIF
C
IF(X1.GT.-XIN)GOTO 23
IF(X2.GT.-XIN)GOTO 21
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
SHLD(NSHLD,3)=X(IP,10)
GO TO 39
C
21 ZIN1=ZSL+ZF*(-XIN-XSL)
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((X1+XIN)**2+(ZIN1-Z1)**2)
SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
SHLD(NSHLD,3)=X(IP,10)
C
IF(X2.GT.XIN)GO TO 22
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((XIN+X2)**2+(Z2-ZIN1)**2)
SHLD(NSHLD,2)=SHLD(NSHLD-1,1)+SHLD(NSHLD-1,2)
SHLD(NSHLD,3)=X(IP,9)
GO TO 39
C
22 ZIN2=ZSL+ZF*(XIN-XSL)
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((ZIN2-ZIN1)**2+4.0*XIN*XIN)
SHLD(NSHLD,2)=SHLD(NSHLD-1,1)+SHLD(NSHLD-1,2)
SHLD(NSHLD,3)=X(IP,9)
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((X2-XIN)**2+(Z2-ZIN2)**2)
SHLD(NSHLD,2)=SHLD(NSHLD-1,1)+SHLD(NSHLD-1,2)
SHLD(NSHLD,3)=X(IP,10)
GO TO 39
C
23 IF(X1.GT.XIN) GOTO 25
IF(X2.GT.XIN) GOTO 24
C
NSHLD=NSHLD+1
SHLD(NSHLD,1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
SHLD(NSHLD,3)=X(IP,9)
GO TO 39
C
24 ZIN2=ZSL+ZF*(XIN-XSL)

```

```

      NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((XIN-X1)**2+(ZIN2-Z1)**2)
      SHLD(NSHLD, 2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
      SHLD(NSHLD, 3)=X(IP, 9)
C
      NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((X2-XIN)**2+(Z2-ZIN2)**2)
      SHLD(NSHLD, 2)=SHLD(NSHLD-1, 1)+SHLD(NSHLD-1, 2)
      SHLD(NSHLD, 3)=X(IP, 10)
      GO TO 39
C
25  NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
      SHLD(NSHLD, 2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
      SHLD(NSHLD, 3)=X(IP, 10)
      GO TO 39
C
26  IF(Z2.GT.PRHO)Z2=PRHO
      IF(Z2.LT.0.0) Z2=0.0
      X2=XSL+(Z2-ZSL)/ZF
C
265  IF(XDL.LT.X2)THEN
      X2=XDL
      Z2=ZDL
      ENDIF
C
      IF(X2.GT.-XIN)GO TO 27
C
      NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
      SHLD(NSHLD, 2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
      SHLD(NSHLD, 3)=X(IP, 10)
      GO TO 39
C
27  ZIN1=ZSL+ZF*(-XIN-XSL)
C
      NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((XIN+X1)**2+(Z1-ZIN1)**2)
      SHLD(NSHLD, 2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
      SHLD(NSHLD, 3)=X(IP, 10)
C
      IF(X2.GT.XIN) GOTO 28
C
      NSHLD=NSHLD+1
      SHLD(NSHLD, 1)=SQRT((XIN+X2)**2+(Z2-ZIN1)**2)
      SHLD(NSHLD, 2)=SHLD(NSHLD-1, 1)+SHLD(NSHLD-1, 2)
      SHLD(NSHLD, 3)=X(IP, 9)
      GO TO 39
C

```



```

28 NSHLD=NSHLD+1
   IF(NSHLD.GT.30) GOTO 80
   ZIN2=ZSL+ZF*(XIN-XSL)
   SHLD(NSHLD,1)=SQRT((ZIN2-ZIN1)**2+4.0*XIN*XIN)
   SHLD(NSHLD,2)=SHLD(NSHLD-1,1)+SHLD(NSHLD-1,2)
   SHLD(NSHLD,3)=X(IP,9)
C
29 NSHLD=NSHLD+1
   IF(NSHLD.GT.30) GOTO 80
   SHLD(NSHLD,1)=SQRT((X2-XIN)**2+(Z2-ZIN2)**2)
   SHLD(NSHLD,2)=SHLD(NSHLD-1,1)+SHLD(NSHLD-1,2)
   SHLD(NSHLD,3)=X(IP,10)
   GO TO 39
C
30 IF(XDL.LT.X2)GOTO 20
C
   IF(Z1.GT.PRHO)Z1=PRHO
   IF(Z1.LT.0.0) Z1=0.0
C
   X1=XSL+(Z1-ZSL)/ZF
   IF(X1.LT.-XIN) GOTO 35
   IF(X1.GE.XIN) GOTO 31
   ZIN2=ZSL+ZF*(XIN-XSL)
C
   NSHLD=NSHLD+1
   SHLD(NSHLD,1)=SQRT((XIN+X1)**2+(ZIN2-Z1)**2)
   SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
   SHLD(NSHLD,3)=X(IP,9)
   GO TO 29
C
31 NSHLD=NSHLD+1 ,
   SHLD(NSHLD,1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
   SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
   SHLD(NSHLD,3)=X(IP,10)
   GO TO 39
C
35 IF(XDL.LT.X2)GOTO 265
C
   ZIN1=ZSL+ZF*(-XIN-XSL)
C
   NSHLD=NSHLD+1
   SHLD(NSHLD,1)=SQRT((XIN+X1)**2+(Z1-ZIN1)**2)
   SHLD(NSHLD,2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
   SHLD(NSHLD,3)=X(IP,10)
C
   NSHLD=NSHLD+1
   IF(NSHLD.GT.30) GOTO 80
   ZIN2=ZSL+ZF*(XIN-XSL)
   SHLD(NSHLD,1)=SQRT((ZIN2-ZIN1)**2+4.0*XIN*XIN)

```

```

      SHLD(NSHLD, 2)=SHLD(NSHLD-1, 1)+SHLD(NSHLD-1, 2)
      SHLD(NSHLD, 3)=X(IP, 9)
C
      NSHLD=NSHLD+1
      IF(NSHLD.GT. 30) GOTO 80
      SHLD(NSHLD, 1)=SHLD(NSHLD-2, 1)
      SHLD(NSHLD, 2)=SHLD(NSHLD-1, 1)+SHLD(NSHLD-1, 2)
      SHLD(NSHLD, 3)=X(IP, 10)
C
      GO TO 39
C
C THE SOURCE DOSE LINE GOES THROUGH THE PIPE WALL ONLY
C
36   IF(ZF.LT. 1. E-7) THEN
      X2=XDL
      Z2=ZDL
      GOTO 365
      ENDIF
C
      IF(Z1.LE. PRHO. AND. Z1.GE. 0. ) THEN
      Z1=AMIN1(Z1, PRHO)
      Z1=AMAX1(Z1, 0. )
      X1=XSL+(Z1-ZSL)/ZF
      END IF
C
      IF(Z2.LE. PRHO. AND. Z2.GE. 0. ) THEN
      Z2=AMIN1(Z2, PRHO)
      Z2=AMAX1(Z2, 0. )
      X2=XSL+(Z2-ZSL)/ZF
      END IF
C
      IF(XDL.LT. X2) THEN
      X2=XDL
      Z2=ZDL
      ENDIF
C
365  NSHLD=NSHLD+1
      IF(NSHLD.GT. 30) GOTO 80
      SHLD(NSHLD, 1)=SQRT((X2-X1)**2+(Z2-Z1)**2)
      SHLD(NSHLD, 2)=SQRT((X1-XSL)**2+(Z1-ZSL)**2)
      SHLD(NSHLD, 3)=X(IP, 10)
      GO TO 39
C
18   XSNEW=XS
      YSNEW=YS
      XDNEW=P(1)
      YDNEW=P(2)
      GO TO 16
19   ZDL=(A2*(P(1)-X(IP, 1))+B2*(P(2)-X(IP, 2))+C2*(P(3)-X(IP, 3)))/PRHO

```

```

      ZSL=(A2*(XS  -X(IP,1))+B2*(YS  -X(IP,2))+C2*(ZS  -X(IP,3)))/PRHO
C
      IF(ZDL.GE.PRHO.AND.ZSL.GE.PRHO.OR.ZDL.LE.0.0.AND.ZSL.LE.0.0)
      1GOTO 39
C
      NSHLD=NSHLD+1
      IF(NSHLD.GT.30) GOTO 80
C
      IF(ZSL.GT.0.0)THEN
      SHLD(NSHLD,2)=ZSL-PRHO
C
      IF(ZDL.LE.0.0)THEN
      SHLD(NSHLD,1)=PRHO
      ELSE
      SHLD(NSHLD,1)=PRHO-ZDL
      ENDIF
C
      ELSE
      SHLD(NSHLD,2)=0.0
C
      IF(ZDL.GE.PRHO)THEN
      SHLD(NSHLD,1)=PRHO
      ELSE
      SHLD(NSHLD,1)=ZDL
      ENDIF
      ENDIF
C
      IF(DIST.LE.X(IP,7))THEN
      SHLD(NSHLD,3)=X(IP,9)
      ELSE
      SHLD(NSHLD,3)=X(IP,10)
      ENDIF
C
      39 CONTINUE
C
C SORT ROUTINE TO ORDER SHIELDS BY DISTANCE FROM SOURCE POINT
C
      90 NFLAG=0
      IFLAG=0
      DO 99 N=1,NSHLD-1
      IF(SHLD(N,2).LT.SHLD(N+1,2))IFLAG=1
      IF(IFLAG.EQ.0)GO TO 99
      DO 95 MM=1,3
      TEMP=SHLD(N+1,MM)
      SHLD(N+1,MM)=SHLD(N,MM)
      SHLD(N,MM)=TEMP
      95 CONTINUE
      NFLAG=1
      IFLAG=0

```

```

99 CONTINUE
   IF(NFLAG.EQ.1)GO TO 90
C
   IF(ISHLD.GE.1) CALL SHIELD(NSHLD,SHLD,RHO)
C
   RETURN
80 WRITE(6,*)' **ERROR NUMBER OF SHIELDS IN ARRAY EXCEEDED',NSHLD
   STOP
   END

```

11.0 SUBROUTINE SC00R

The subroutine SC00R is called from routine GEO. SC00R's function is to calculate the absolute coordinates of the source point given A, the value of the variable of integration along the length of a given pipe, and ALPHA, the value of the angle of integration around the pipe at the given distance A.

To accomplish this task, several steps are required. First, the coordinate system is translated so that the beginning of the centerline of the source pipe is coincident with the origin of the coordinate system. The coordinates of the centerline (xpc, ypc, zpc) of the pipe in the translated coordinate system at distance A from the beginning of the pipe are found by use of similar triangles. Namely:

$$xpc = (A-ALOW)xp/PRHO$$

$$ypc = (A-ALOW)yp/PRHO$$

$$zpc = (A-ALOW)zp/PRHO$$

where xp, yp, zp are the coordinates of the end of the pipe in the translated coordinate system and PRHO is the length of the pipe (see Figures 11.1 and 11.2).

If a line going through the dose point is constructed parallel to the centerline of the pipe (see Figure 11.2), for a given distance A along the pipe, the corresponding point on the parallel line has the coordinates:

$$xpa = xd + A*xp/PRHO$$

$$ypa = yd + A*yp/PRHO$$

$$zpa = zd + A*zp/PRHO$$

Knowing this point, the point on the surface source where ALPHA is equal to zero is calculated using similar triangles to be:

$$xsx = xpc + (xpc-xpa)(R/D)$$

$$ysy = ypc + (ypc-ypa)(R/D)$$

$$zsz = zpc + (zpc-zpa)(R/D)$$

For a given distance A along the source pipe, as the angular integration proceeds, the source point would move in a circle in three space along the inside of the pipe. In general, the projection onto the xy plane of the locus of all these points would be an ellipse (see Figure 11.1). The equation for an ellipse centered on the origin is:

$$x = a \sin \beta$$

$$y = b \cos \beta$$

where a is the minor axis and b is the major axis. For the general case, the ellipse must be translated down the x axis and then rotated by angle - ZETA. The distance that the coordinate system must be translated is:

$$TRANS = \sqrt{xpc^2 + ypc^2}$$

The equations relating coordinates in a coordinate system rotated angle - ZETA about the origin from the starting coordinate system is:

$$\begin{aligned}x' &= x \cos \xi - y \sin \xi \\y' &= y \cos \xi + x \sin \xi\end{aligned}$$

Furthermore, the major axis of the ellipse is R, the radius of the source pipe, the minor axis is $R \sin \phi$, where ϕ is the complement of the azimuthal angle (the three-dimensional angle measured from the xy plane to the centerline of the pipe). Combining these relationships

$$\begin{aligned}xs &= (\sqrt{xpc^2 + ypc^2} + R \sin \phi \sin \beta) \cos \xi - R \cos \beta \sin \xi \\ys &= R \cos \beta \cos \xi + (\sqrt{xpc^2 + ypc^2} + R \sin \phi \sin \beta) \sin \xi\end{aligned}$$

From Figure 11.3 the z-coordinate can be calculated by

$$zs = zpc + R \cos \phi \sin \beta$$

To find what angle β is when ALPHA equals zero consider the last formula. If $GAMMA = \beta - ALPHA$ then;

$$\sin \gamma = \frac{zs - zpc}{R \cos \phi}$$

or

$$GAMMA = \arcsin \left(\frac{zs - zpc}{R \cos \phi} \right)$$

Now, knowing GAMMA, β is easily calculated by

$$\beta = GAMMA + ALPHA$$

For each value of A, all these calculations must be performed. For all of the values of ALPHA, however, xs, ys, and zs are calculated with only three FORTRAN lines, at great savings in execution time.

FIGURE 11.1. Translated Coordinate System Showing Projection of Surface Points Onto xy Plane

FIGURE 11.2. Calculation of Surface Coordinates When ALPHA Equal Zero

FORMULAS:

$$\frac{x_p}{PRHO} = \frac{x_{pa} - x_d}{A}$$

or $x_{pa} = x_d + A * x_p / PRHO$

Also $\frac{x_{sx} - x_{pc}}{R} = \frac{x_{pa} - x_{pc}}{D}$

or $x_{sx} = x_{pc} + (x_{pc} - x_{pa}) (R/D)$

FIGURE 11.3. Calculation of Z Component of Surface Point

```

C *****
C THE SUBROUTINE SCOORD FINDS THE ABSOLUTE
C COORDINATES OF THE SOURCE POINT
C *****
C
C SUBROUTINE SCOORD(ALPHA, XS, YS, ZS)
C DIMENSION X(50,11), P(3)
C COMMON R, D, A, T, P, NPIPES, X
C COMMON/DAN/ALOW, AHIGH, M, X9, X10, X11
C COMMON/DAN2/AOLD, IFLAG, XPC, YPC, ZPC, COSPHI, SINPHI,
C &COSA, SINA, GAMMA, PRHO
C PARAMETER PI=3.14159265358, PIBY2=1.570796326
C
C TEST TO SEE IF A HAS CHANGED; RESET FLAG
C
C IF(A.EQ.AOLD) GO TO 10
C IFLAG=0
C
C TRANSFORM COORDINATES SO PIPE VECTOR STARTS FROM ORIGIN
C AND CALCULATE ANGLE QUANTITIES
C
C XP=X(M,4)-X(M,1)
C YP=X(M,5)-X(M,2)
C ZP=X(M,6)-X(M,3)
C
C PRHO=AHIGH-ALOW
C COSPHI=SQRT(XP*XP+YP*YP)
C IF(COSPHI.LE.Q.0001) GO TO 20
C SINPHI=ZP/PRHO
C COSA=XP/COSPHI
C SINA=YP/COSPHI
C
C CALCULATING COORDINATES OF CENTER OF PIPE
C
C XPC=(A-ALOW)*XP/PRHO
C YPC=(A-ALOW)*YP/PRHO
C ZPC=(A-ALOW)*ZP/PRHO
C
C
C CALCULATING COORDIANATES OF INSIDE SURFACE OF PIPE
C BETWEEN CENTER OF PIPE AND DOSE POINT
C
C XSX=XPC-(XPC-(XP*A/PRHO)-P(1)+X(M,1))*R/D
C YSY=YP-(YP-(YP*A/PRHO)-P(2)+X(M,2))*R/D
C ZSZ=ZPC-(ZPC-(ZP*A/PRHO)-P(3)+X(M,3))*R/D
C
C DETERMINING ANGLE BETWEEN STARTING OF ALPHA RELATIVE
C TO XY PLANE (SEE FIGURE)
C

```

```

SINGAM=(ZPC-ZSZ)*PRHO/(R*COSPHI)
IF(ABS(SINGAM).GT.1.)GO TO 18
4  GAMMA=ASIN(SINGAM)
   TCOS=XSX/SQRT(XSX*XSX+YSY*YSY)
   IF(TCOS.GE.COSA) GO TO 10
   IF(GAMMA.GE.0.0.AND.GAMMA.LE.PIBY2) GO TO 5
   GAMMA=-PI-GAMMA
   GO TO 10
5  GAMMA=PI-GAMMA
C
C  CALCULATE COORDINATES
C
10  IF(IFLAG.EQ.1) GO TO 25
   B=ALPHA+GAMMA
   AOLD=A
C
   XS=(SQRT(XPC*XPC+YPC*YPC)+R*SINPHI*SIN(B))*COSA
   &-R*SINA*COS(B)+X(M,1)
C
   YS=R*COSA*COS(B)+(SQRT(XPC*XPC+YPC*YPC)
   &+R*SINPHI*SIN(B))*SINA+X(M,2)
C
   ZS=ZPC+R*(COSPHI/PRHO)*SIN(B)+X(M,3)
C
   RETURN
18  IF((ABS(SINGAM)-1.).LE.0.002)GO TO 19
   WRITE(6,30)
   STOP
19  SINGAM=SIGN(1.,SINGAM)
   GO TO 4
C
C  PIPE VECTOR LIES ALONG THE Z-AXIS
C
20  IFLAG=1
   SINGAM=(P(1)-X(M,1))/D
   IF(ABS(SINGAM).GE.1.) GOTO 38
21  GAMMA=ASIN(SINGAM)
   IF((P(2)-X(M,2)).GE.0.0) GO TO 25
   IF(GAMMA.GE.0.0.AND.GAMMA.LE.PIBY2) GO TO 24
   GAMMA=-PI-GAMMA
   GO TO 25
24  GAMMA=PI-GAMMA
25  B=ALPHA+GAMMA
   XS=R*SIN(B)+X(M,1)
   YS=R*COS(B)+X(M,2)
   ZS=A+P(3)
   RETURN
38  IF((ABS(SINGAM)-1.).LE.0.002)GO TO 39
   WRITE(6,30)

```

```
      STOP
39    SINGAM=SIGN(1.,SINGAM)
      GO TO 21
30    FORMAT(2X,'ERROR IN SCOOD -- SINGAM.GT.1.002')
      END
```

12.0 SUBROUTINE SHIELD

The subroutine SHIELD checks each auxiliary shield to determine if it is between the source and dose points. SHIELD also calculates the distance to the start of the auxiliary shield and the distance through it. These distances are stored in the array SHLD along with the material type of the shield. When the subroutine GEO calls SHIELD, the new value of NSHLD (the total number of shields between the source and dose points) and the array SHLD are returned.

First, SHIELD finds the projection of the source-dose line in the xy-plane. This simplifies the calculations since the auxiliary shields are always perpendicular to the xy-plane. The xy coordinate system is then translated and rotated so that the source-dose line is coincident with the x-axis, with the source point at the origin. This allows straightforward calculation of the distance from the source point to the start of the shield and the straight line distance through the shield.

The main loop in SHIELD goes through each auxiliary shield serially, first checking whether the shield is above or below the source-dose line by comparing z-coordinates of the source and dose points against the top and bottom of the shield. If this test is negative, there is no possibility of the shield being between the source and dose points and the program goes to the end of the loop and starts checking the next auxiliary shield. If the test is positive, the x- and y-coordinates of the shield must be tested for intersection.

To test for intersection of the x-axis with the auxiliary shield, SHIELD finds the coordinates of the four corners of the shield in the rotated, translated coordinate system. If the y coordinates of the corners are all positive or all negative, the source-dose line cannot go through the shield, and the program passes to the end of the loop. If some of the y coordinates are positive and some are negative, the product of pairs of coordinates can be tested and when the product is negative, the line between those two coordinates has intersected the source-dose line (see Figure 12.1). If the source-dose line crosses between one such coordinate pair, it must cross another to exit. When both of these intersection points have been found, the one closest to the source point (having the smallest x value) is designated XSTART, the other coordinate as XEND.

The dose point is now tested to determine if it falls inside or outside the shield. This is easily done since the x-coordinate of the dose point is now just the xy-distance between the source point and dose point. In the case where the x-coordinate of the dose point is less than XSTART, the shield does not come between the source point and dose point and the program goes to the end of the main loop. If the dose point falls between XSTART and XEND, only the part of the shield before the dose point is of any concern and XEND is set to equal to the dose point. One last test is made to see if the source point

(0,0) is inside the shield and if this is true, XSTART is set at zero since there would be no distance between the source point and the start of the shield.

When the source-dose line is parallel to the z-axis, there is no projection in the xy-plane. A series of tests checks to see if the source-dose line falls within the auxiliary shield by comparing the x-y distances from the source-dose line to the shield centerlines with the half-thickness and the half-length. XSTART and XEND are then functions of the differences in z-coordinates. These tests make it possible to bypass the source dose line rotation and coordinate transformations.

Once it is known that all or part of the auxiliary shield lies between the source point and dose point, the distance from the source point to the shield, XSTART, is compared to the distance from the source of the other shields. When a shield is found that has a distance from the source greater than XSTART, that shield and all the other shields after it are bumped up by one shield number using the subroutine BUMP. BUMP also moves the distances up in the array SHLD to correspond with the newly assigned shield numbers. Now the auxiliary shield is assigned the previous number of the other shield and the SHLD array is expanded to include the auxiliary shield, its distance from the source point, and the distance through the shield. The subroutine BUMP also multiplies the distances in the xy-plane by the ratio of the distance between the source and dose points in real space to the distance of the xy projection so SHLD array contains the real distances.

After placing the auxiliary shield in the correct position with respect to the other shields, another loop tests all the shields following the auxiliary shield to see if they start after the end of the auxiliary shield or if some may be inside the auxiliary shield. If one or more shields are inside the auxiliary shield, the distances between shields or between XEND and the last internal shield are determined. The subroutine BUMP is then called to assign the right progression of numbers and distances to the areas of auxiliary shield between and after the internal shields. The last thing that the code does is modify the thickness of the auxiliary shield in front of the first internal shield to be the difference of the start of the internal shield and the start of the auxiliary shield.

The special case where another shield overlaps the start or end of the auxiliary shield is also tested for. If the other shield overlaps the start, XSTART is reset to equal the end of the other shield. If the shield overlaps the end, XEND is reset to equal the start of the overlapping shield. Each time XEND and XSTART are changed, the corresponding values in the array SHLD are changed.

FIGURE 12.1. Intersection of Source-Dose Line with Auxiliary Shield

```

C *****
C THE SUBROUTINE SHIELD CALCULATES THE INTERSECTION
C OF THE SOURCE-DOSE LINE AND FILLS THE SHLD ARRAY
C WITH VALUES FOR THE THICKNESS, DISTANCE, AND TYPE
C OF SHIELD
C *****
C
      SUBROUTINE SHIELD(NSHLD,SHLD,RHO)
      DIMENSION SHLD(30,3),P(3),SH(10,8),S(4)
      COMMON/THREE/ISHLD,SH,XS,YS,ZS,TEMP
      COMMON R,D,A,T,P
C
C   DEFINE FUNCTIONS
C
      XROT(X,Y,J)=((X-XS)*DX+(Y-YS)*DY)/SDD
      YROT(X,Y,J)=((Y-YS)*DX-(X-XS)*DY)/SDD
      DX=P(1)-XS
      DY=P(2)-YS
      DZ=P(3)-ZS
      SDD=SQRT((DX)**2+(DY)**2)
      IF(SDD.EQ.0.0)ANGC=1.0
      IF(SDD.EQ.0.0)GO TO 20
      ANGC=RHO/SDD
C
C   STARTING LOOP TO CHECK SHIELD PLANES FOR INTERSECTION BY SOURCE-
C   DOSE LINE
C
      20 DO 25 J=1,ISHLD
C
C   CHECK TO SEE IF SHIELD IS ABOVE OR BELOW SOURCE-DOSE LINE
C
      IF(SH(J,5).GE.ZS.AND.SH(J,5).GE.P(3))GO TO 25
      IF(SH(J,6).LE.ZS.AND.SH(J,6).LE.P(3))GO TO 25
C
      XD=SH(J,3)-SH(J,1)
      YD=SH(J,4)-SH(J,2)
      SHLTH=SQRT((XD)**2+(YD)**2)
C
C   SPECIAL CASE WHERE S-D LINE IS PARALLEL TO Z-AXIS
C
      IF(SDD.NE.0.)GO TO 40
      SL1=YD/XD
      SL2=-1/SL1
      XI=(YS-SH(J,4)+(SL1*SH(J,3))-(SL2*XS))/(SL1-SL2)
      YI=SL2*(XI-XS)+YS
      D1=SQRT((YI-YS)**2.+(XI-XS)**2.)
      IF(D1.GT.SH(J,7))GO TO 25
      CX=SH(J,1)+XD/2.
      CY=SH(J,2)+YD/2.

```



```

XK=(CY-YS+(SL1*XS)-(SL2*CX))/(SL1-SL2)
YK=SL1*(XK-XS)+YS
D2=SQRT((YK-YS)**2.+(XK-XS)**2.)
IF(D2.GT.SHLTH/2.)GO TO 25
XSTART=SH(J,5)-ZS
XEND=SH(J,6)-ZS
IF(P(3).LT.ZS)XSTART=ZS-SH(J,6)
IF(P(3).LT.ZS)XEND=ZS-SH(J,5)
IF(ZS.GT.SH(J,5).AND.ZS.LT.SH(J,6))XSTART=0.0
IF(P(3).LT.SH(J,6).AND.P(3).GT.SH(J,5))XEND=ABS(RHO)
GO TO 30

```

C

C FIND COORDINATES OF CORNERS OF AUXILIARY SHIELD

C

```

40 X3=SH(J,1)-SH(J,7)*YD/SHLTH
Y3=SH(J,2)+SH(J,7)*XD/SHLTH
X4=SH(J,1)+SH(J,7)*YD/SHLTH
Y4=SH(J,2)-SH(J,7)*XD/SHLTH
X5=SH(J,3)-SH(J,7)*YD/SHLTH
Y5=SH(J,4)+SH(J,7)*XD/SHLTH
X6=SH(J,3)+SH(J,7)*YD/SHLTH
Y6=SH(J,4)-SH(J,7)*XD/SHLTH

```

C

C ROTATE COORDINATES SO S-D LINE IS POSITIVE X-AXIS (0 TO DX)

C

```

XP3=XROT(X3,Y3,J)
XP4=XROT(X4,Y4,J)
XP5=XROT(X5,Y5,J)
XP6=XROT(X6,Y6,J)
YP3=YROT(X3,Y3,J)
YP4=YROT(X4,Y4,J)
YP5=YROT(X5,Y5,J)
YP6=YROT(X6,Y6,J)

```

C

C CHECK FOR S-D LINE XY-PROJECTION AND SHIELD INTERSECTION

C

```

DO 10 K=1,4
S(K)=0.
10 CONTINUE
IF(YP3*YP4.GT.0.)GO TO 100
S(1)=XP3-(XP4-XP3)*YP3/(YP4-YP3)
100 IF(YP3*YP5.GT.0.)GO TO 110
S(2)=XP3-(XP5-XP3)*YP3/(YP5-YP4)
110 IF(YP3*YP6.GT.0.)GO TO 120
S(3)=XP3-(XP6-XP3)*YP3/(YP6-YP5)
120 IF(YP4*YP6.GT.0.)GO TO 130
S(4)=XP4-(XP6-XP4)*YP4/(YP6-YP4)

```

C

C FIND INTERSECTION OF SHIELD WITH X-AXIS

```

C
130  XEND=0.
      DO 70 K=1,4
      IF(S(K).GT.XEND)XEND=S(K)
70   CONTINUE
      XSTART=0.
      DO 80 K=1,4
      IF(S(K).NE.0.0.AND.S(K).LT.XEND)XSTART=S(K)
80   CONTINUE
C
      IF(XSTART.EQ.0.0.AND.XEND.EQ.0.0)GO TO 25
C
C TEST TO SEE IF DOSE POINT IS INSIDE OF AUXILIARY SHIELD
C
      IF(XEND.GT.SDD)XEND=SDD
C
C CHECK TO SEE IF DOSE POINT IS IN FRONT OF AUXILIARY SHIELD
C
      IF(XSTART.GE.SDD)GO TO 25
C
C FIND WHERE THE START OF THE SHIELD IS WITH RESPECT TO OTHER SHIELDS
C
30   DO 60 NTEST=1,NSHLD
      IF(SHLD(NTEST,2)/ANGC.LE.XSTART)GO TO 59
      CALL BUMP(NSHLD,ANGC,NTEST,SHLD,XEND-XSTART,XSTART,SH(J,B))
C
C CHECK FOR ANY PIPES OR SHIELDS WITHIN THE AUXILIARY SHIELD
C
      NN=NTEST
99   NN=NN+1
      IF(SHLD(NN,2)/ANGC.GE.XEND)GO TO 25
C
C IF MORE THAN ONE INTERNAL PIPE, FILL INBETWEEN WITH AUXILIARY SHIELD
C
      XELS=(SHLD(NN,2)+SHLD(NN,1))/ANGC
      IF(XELS.GE.XEND)GO TO 62
      TSH=SHLD(NN+1,2)-XELS
      IF(SHLD(NN+1,2).GT.XEND)TSH=XEND-XELS
      IF(NN.EQ.NSHLD)TSH=0.0
      IF(TSH.LT.0.001)GO TO 98
      CALL BUMP(NSHLD,ANGC,NN+1,SHLD,TSH,XELS,SH(J,B))
98   IF(NN.LT.NSHLD)GO TO 99
C
C ADD SHIELDING BEFORE FIRST INTERNAL PIPE
C
62   SHLD(NTEST,1)=SHLD(NTEST+1,2)-(XSTART*ANGC)
      GO TO 25
59   XTEST=(SHLD(NTEST,2)+SHLD(NTEST,1))/ANGC
      IF(XTEST.GT.XEND)GO TO 25

```

```

        IF(XTEST.GT.XSTART)XSTART=XTEST
60    CONTINUE
        NSHLD=NSHLD+1
        SHLD(NSHLD,1)=(XEND-XSTART)*ANGC
        SHLD(NSHLD,2)=XSTART*ANGC
        SHLD(NSHLD,3)=SH(J,8)
25    CONTINUE
        RETURN
        END
C *****
        SUBROUTINE BUMP(NSHLD,ANGC,NS,SHLD,A1,A2,A3)
        DIMENSION SHLD(30,3),P(3)
        COMMON R,D,A,T,P
        IF(NSHLD.GE.30)GO TO 13
C
        DO 5 I=NSHLD,NS,-1
            IP1=I+1
            SHLD(IP1,1)=SHLD(I,1)
            SHLD(IP1,2)=SHLD(I,2)
            SHLD(IP1,3)=SHLD(I,3)
5        CONTINUE
        NSHLD=NSHLD+1
        SHLD(NS,1)=A1*ANGC
        SHLD(NS,2)=A2*ANGC
        SHLD(NS,3)=A3
        RETURN
13    WRITE(6,*)'ERROR IN BUMP; NSHLD = 30'
        END

```


13.0 SUBROUTINE BUILDUP

The subroutine BUILDUP is called by the routine QUAD2 after GEO has been called. A loop within QUAD2 picks each isotope in turn from the isotopes within the source pipe. Then each gamma ray energy from the chosen isotope is called. For each gamma ray energy, BUILDUP is called.

The buildup factor is the ratio of the dose from the uncollided flux (which is what the point kernel calculates) to the dose from the total flux which includes not only the uncollided flux, but also gamma rays which have scattered into the dose point.

Fortunately, the buildup factor can be estimated by knowing the energy of the gamma ray, the total number of relaxation lengths through all the shielding along the straight line path, and the equivalent atomic number (Z) of the shield. For shields which consist of layers of materials of differing atomic number, there is not agreement among authorities on how best to calculate the effective atomic number.

From the physics of gamma-ray interaction, it can be reasoned that a thick final shield (the shield closest to the dose point) will "screen out" the effects of earlier shields, since the scattered radiation will have lower energies and, in general, larger interaction cross sections.

In BUILDUP, if the last shield is two relaxation lengths thick or thicker (i.e., at least 86% of the gamma rays are absorbed), the atomic number of the final shield is used to calculate the buildup factor. If the final shield is less than two relaxation lengths thick, the next outermost shield is added to the outer shield and the effective Z is found by taking the cube root of the sum of the cubes of the atomic number weighted with the relaxation lengths of the shields. If the two outermost shields together are not two relaxation lengths thick, the third outermost shield is added in using the same weighting procedure. This continues until the sum of the relaxation lengths is two or greater or until all the shields are summed.

The sum of the relaxation lengths for all the shields along the source-dose line is calculated and passed back as BSUM to QUAD2.

Now that the total optical thickness (sum of relaxation lengths) is known, the effective atomic number calculated and the energy of the gamma-ray is known, the buildup factor is found by doing a triple interpolation through Z , optical thickness, and energy from tables of buildup factors measured by Goldstein (1954). The buildup factor is passed to QUAD2 and the operations of the subroutine are complete for this one gamma-ray energy, from one isotope, for a given source-dose line.

```

C *****
C THE SUBROUTINE BUILDUP CALCULATES THE EXPOSURE BUILDUP
C BY INTERPOLATION THRU Z, ENERGY, AND OPTICAL THICKNESS
C *****
C
C SUBROUTINE BUILDUP(NSHLD, SHLD, E, BLDUP, BSUM)
C DIMENSION SHLD(30,3), BLDZ(6), BLDMUR(9), BLD(6,3,8)
C DIMENSION ZLIST(10)
C COMMON/LIB1/ZLIST, DMULB, ELIST, Z
C DATA BLD/1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
C & 2.52, 2.37, 1.98, 1.56, 1.24, 1.17, 2.13, 2.02, 1.87, 1.64, 1.37,
C &1.31, 1.83, 1.75, 1.76, 1.57, 1.39, 1.33, 5.14, 4.24, 3.09, 2.08, 1.42, 1.30,
C &3.71, 3.31, 2.89, 2.30, 1.69, 1.56, 2.77, 2.61, 2.43, 2.17, 1.76, 1.64, 14.30,
C &9.47, 5.98, 3.09, 1.69, 1.48, 7.68, 6.57, 5.39, 3.74, 2.26, 1.98, 4.88, 4.62,
C &4.13, 3.53, 2.51, 2.23, 38.80, 21.50, 11.70, 4.57, 2.00, 1.67, 16.20, 13.10,
C &10.20, 6.17, 3.02, 2.50, 8.46, 8.05, 7.25, 5.87, 3.66, 3.09, 77.60, 38.90,
C &19.20, 6.04, 2.27, 1.85, 27.10, 21.20, 16.20, 8.85, 3.74, 2.97, 12.40, 11.90,
C &10.90, 8.53, 4.84, 3.95, 178., 80.8, 35.4, 8.64, 2.65, 2.08, 50.4, 37.9, 28.3,
C &13.70, 4.81, 3.67, 19.5, 18.7, 17.6, 13.6, 6.87, 5.36, 334., 141., 55.6, 17.8,
C &2.73, 3.0, 82.2, 58.5, 42.7, 18.8, 5.86, 4.0, 27.7, 26.3, 25.1, 19.3, 9., 6.48/
C DATA BLDMUR/0., 1., 2., 4., 7., 10., 15., 20., 40./
C DATA BLDZ/7.5, 13., 26., 50., 82., 92./
C
C IF( (SHLD(1,1)*DMU(SHLD(1,3),E)) .GE.2. ) GO TO 31
C
C CALCULATE BSUM
C
C SUM3=0.0
C BSUM=0.0
C
C IF(NSHLD.EQ.0)THEN
C BSUM=0.
C BLDUP=0.
C RETURN
C ENDIF
C
C DO 15 K=1, NSHLD
C BC=SHLD(K,1)*DMU(SHLD(K,3),E)
C IF(BSUM.LT.2.)DIV=BSUM+BC
C IF(BSUM.LT.2.)SUM3=SUM3+BC*(ZLIST(SHLD(K,3))**3)
C BSUM=BSUM+BC
15 CONTINUE
C
C IF(DIV.EQ.0.0.AND.BSUM.EQ.0.0)GO TO 40
C
C CALCULATE AN AVERAGE Z FOR SHIELD REGIONS NEEDED TO MAKE MU*R.GE.2.
C
C Z=(SUM3/DIV)**0.3333333333

```

```

C
C INTERPOLATE TO FIND BUILDUP FACTOR USING BSUM AND LAST SHIELD
C MATERIAL EQUIVALENT Z
C
16 DO 20 L=1,6
   IF(Z.LT.BLDZ(L)) GO TO 21
20 CONTINUE
   GO TO 90
21 IF(L.EQ.1) GO TO 91
   DO 25 M=2,8
   IF(BSUM.LE.BLDMUR(M)) GO TO 26
25 CONTINUE.
   M=8
26 IF(E.GT.1.) GO TO 30
   RZ=(Z-BLDZ(L-1))/(BLDZ(L)-BLDZ(L-1))
   RE=2.0*E-1.0
   RMUR=(BSUM-BLDMUR(M-1))/(BLDMUR(M)-BLDMUR(M-1))
C
   BLDUP=((1.-RE)*((1.-RMUR)*BLD(L-1,1,M-1)+RMUR*BLD(L-1,1,M))
&      +RE*((1.-RMUR)*BLD(L-1,2,M-1)+RMUR*BLD(L-1,2,M)))
&      *(1.-RZ)
&      + ((1.-RE)*((1.-RMUR)*BLD(L,1,M-1)+RMUR*BLD(L,1,M))
&      +RE*((1.-RMUR)*BLD(L,2,M-1)+RMUR*BLD(L,2,M)))
&      * RZ
C
RETURN
C
30 RZ=(Z-BLDZ(L-1))/(BLDZ(L)-BLDZ(L-1))
   RE=E-1.0
   RMUR=(BSUM-BLDMUR(M-1))/(BLDMUR(M)-BLDMUR(M-1))
C
   BLDUP=((1.-RE)*((1.-RMUR)*BLD(L-1,2,M-1)+RMUR*BLD(L-1,2,M))
&      +RE*((1.-RMUR)*BLD(L-1,3,M-1)+RMUR*BLD(L-1,3,M)))
&      *(1.-RZ)
&      + ((1.-RE)*((1.-RMUR)*BLD(L,2,M-1)+RMUR*BLD(L,2,M))
&      +RE*((1.-RMUR)*BLD(L,3,M-1)+RMUR*BLD(L,3,M)))
&      * RZ
C
RETURN
31 Z=ZLIST(SHLD(1,3))
   BSUM=0.0
   DO 35 K=1,NSHLD
   BSUM=BSUM+SHLD(K,1)*DMU(SHLD(K,3),E)
35 CONTINUE
   GO TO 16
40 BLDUP=1.0
   RETURN
90 WRITE(6,98)
   STOP

```

```

91  WRITE(6,99)
    STOP
98  FORMAT(2X,'Z IS GREATER THAN 92--ERROR')
99  FORMAT(2X,'Z IS LESS THAN 7.5--ERROR')
    END
C *****
C FUNCTION TO INTERPOLATE THROUGH ENERGY
C *****
C
    REAL FUNCTION DMU(SHNUM,E)
    DIMENSION ZLIST(10),DMULB(10,8),ELIST(8)
    COMMON/LIB1/ZLIST,DMULB,ELIST
C
C  TEST FOR ERROR
C
    IF(E.LE.0.)GO TO 20
    I=SHNUM
    DO 5 N=1,8
    IF(E.LT.ELIST(N))GO TO 6
5   CONTINUE
    N=8
6   IF(N.EQ.1)N=2
    RE=(E-ELIST(N-1))/(ELIST(N)-ELIST(N-1))
    DMU=(1.-RE)*DMULB(I,N-1)+RE*DMULB(I,N)
    EOLD=E
    RETURN
20  WRITE(6,21)
21  FORMAT(2X,'ENERGY .LE. ZERO IN DMU')
    END

```


14.0 FUNCTION SA

The program function SA determines which geometry was specified in the source library to describe the distribution of activity for a given isotope in a pipe. The function returns the activity of the isotope (in units of microcuries/cm²) at the location specified in subroutine QUAD2.

Currently only two geometries are available to describe the isotopic distribution in a pipe. The first geometry assumes a constant distribution along the pipe's inner surface. The second geometry considers a linear distribution of the activity. Function SA is written to simplify the insertion of future distribution models.

```

C *****
C THIS FUNCTION DETERMINES WHICH MODEL IS SPECIFIED
C IN SOURCE LIBRARY
C *****
C
  REAL FUNCTION SA(II)
  DIMENSION SRC(20,10,6)
  COMMON/LIB3/SRC
  COMMON/DAN/ALOW,AHIGH,M,X9,X10,X11
  COMMON R,D,A
C
  IS=X11
  INDEX=SRC(IS,II,1)
  GO TO (10,20)INDEX
10  SA=SRC(IS,II,2)
  RETURN
20  RA=(A-ALOW)/(AHIGH-ALOW)
  SA=SRC(IS,II,3)*RA+(1.-RA)*SRC(IS,II,2)
  RETURN
  END

```

15.0 TESTS AND EXAMPLES

The following examples illustrate the use of PERCSLIB to create and edit input files for the program PERCS. The underlined sections in the examples are the user's responses. Example 1 demonstrates the procedure used to create a shield library, an isotope library, a program input library, and a source library. In the example, the shield library consists of four shielding materials. The isotope library contains three isotopes. The program input and source libraries consider six pipes (each containing one of four different sources) and a single shield as illustrated in Figures 15.1. Example 2 illustrates the execution procedure of PERCS, using the data entered in Example 1. The graphics portion of the program described in Example 2 is illustrated in Figures 15.1 through 15.6.

The simple procedure for editing the shield library and adding a fifth shield material is illustrated in Example 3. Example 4 shows the procedure for editing the current isotope library and adding two isotopes. Example 5 demonstrates the method of changing the parameters in the program input library and source libraries. These changes, which are illustrated in Figure 15.7, include altering the radius, material, and source of the second pipe and adding a seventh pipe and corresponding source. Example 6 illustrates the execution of PERCS, using the data edited in the previous examples. The graphics portion of the program described in the Example 6 is illustrated in Figures 15.7 through 15.10.

EXAMPLE 1

PERCSLIB Input Session

-Creating a shield library, isotope library, program input library and source library.

RUN PERCSLIB

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

1

IS THERE AN OLD SHIELD FILE ON THE SYSTEM? (TYPE Y OR N)

N

NUMBER OF SHIELD MATERIALS?

4

NAME OF MATERIAL 1? WATER

FOR THIS MATERIAL ATOMIC NUMBER Z IS...?	<u>7.55</u>
FOR MATERIAL 1, AND ENERGY 0.5 MU=?	<u>0.097</u>
FOR MATERIAL 1, AND ENERGY 0.6 MU=?	<u>0.090</u>
FOR MATERIAL 1, AND ENERGY 0.7 MU=?	<u>0.083</u>
FOR MATERIAL 1, AND ENERGY 0.8 MU=?	<u>0.079</u>
FOR MATERIAL 1, AND ENERGY 0.9 MU=?	<u>0.074</u>
FOR MATERIAL 1, AND ENERGY 1.0 MU=?	<u>0.071</u>
FOR MATERIAL 1, AND ENERGY 1.2 MU=?	<u>0.064</u>
FOR MATERIAL 1, AND ENERGY 1.4 MU=?	<u>0.059</u>

NAME OF MATERIAL 2? IRON

FOR THIS MATERIAL ATOMIC NUMBER Z IS...?	<u>26.0</u>
FOR MATERIAL 2, AND ENERGY 0.5 MU=?	<u>0.652</u>
FOR MATERIAL 2, AND ENERGY 0.6 MU=?	<u>0.599</u>
FOR MATERIAL 2, AND ENERGY 0.7 MU=?	<u>0.577</u>
FOR MATERIAL 2, AND ENERGY 0.8 MU=?	<u>0.523</u>
FOR MATERIAL 2, AND ENERGY 0.9 MU=?	<u>0.493</u>
FOR MATERIAL 2, AND ENERGY 1.0 MU=?	<u>0.468</u>
FOR MATERIAL 2, AND ENERGY 1.2 MU=?	<u>0.428</u>
FOR MATERIAL 2, AND ENERGY 1.4 MU=?	<u>0.397</u>

NAME OF MATERIAL 3? AIR

FOR THIS MATERIAL ATOMIC NUMBER Z IS...?	<u>8.0</u>
FOR MATERIAL 3, AND ENERGY 0.5 MU=?	<u>0.000038</u>
FOR MATERIAL 3, AND ENERGY 0.6 MU=?	<u>0.000038</u>
FOR MATERIAL 3, AND ENERGY 0.7 MU=?	<u>0.000037</u>
FOR MATERIAL 3, AND ENERGY 0.8 MU=?	<u>0.000037</u>
FOR MATERIAL 3, AND ENERGY 0.9 MU=?	<u>0.000036</u>
FOR MATERIAL 3, AND ENERGY 1.0 MU=?	<u>0.000036</u>
FOR MATERIAL 3, AND ENERGY 1.2 MU=?	<u>0.000034</u>
FOR MATERIAL 3, AND ENERGY 1.4 MU=?	<u>0.000033</u>

NAME OF MATERIAL 4? CONCRETE

FOR THIS MATERIAL ATOMIC NUMBER Z IS...?	<u>11.0</u>
FOR MATERIAL 4, AND ENERGY 0.5 MU=?	<u>0.204</u>
FOR MATERIAL 4, AND ENERGY 0.6 MU=?	<u>0.188</u>
FOR MATERIAL 4, AND ENERGY 0.7 MU=?	<u>0.175</u>
FOR MATERIAL 4, AND ENERGY 0.8 MU=?	<u>0.165</u>
FOR MATERIAL 4, AND ENERGY 0.9 MU=?	<u>0.156</u>
FOR MATERIAL 4, AND ENERGY 1.0 MU=?	<u>0.149</u>
FOR MATERIAL 4, AND ENERGY 1.2 MU=?	<u>0.136</u>
FOR MATERIAL 4, AND ENERGY 1.4 MU=?	<u>0.126</u>

CURRENT DATA IS THE FOLLOWING:

SHIELDING LIBRARY

FOR MATERIAL 1--WATER
ATOMIC NUMBER (Z) IS 7.550E+00
FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
MU (IN CM(-1)) IS 0.097 0.090 0.083 0.079 0.074 0.071 0.064 0.059

FOR MATERIAL 2--IRON
ATOMIC NUMBER (Z) IS 2.600E+01
FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
MU (IN CM(-1)) IS 0.652 0.599 0.577 0.523 0.493 0.468 0.428 0.397

FOR MATERIAL 3--AIR
ATOMIC NUMBER (Z) IS 8.000E+00
FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
MU (IN CM(-1)) IS 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

FOR MATERIAL 4--CONCRETE
ATOMIC NUMBER (Z) IS 1.100E+01
FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
MU (IN CM(-1)) IS 0.204 0.188 0.175 0.165 0.156 0.149 0.136 0.126

OPTIONS:

- 1--ADD
- 2--DELETE
- 3--CHANGE
- 4--TO EXIT

4

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

2

IS THERE AN OLD ISOTOPE FILE ON THE SYSTEM? (TYPE Y OR N)

N

ENTER NUMBER OF ISOTOPES 3

ENTER TITLE FOR ISOTOPE 1 CS-137
ENTER NUMBER OF GAMMAS/DISINTEGRATION 1
ENTER ENERGY(MEV) FOR GAMMA 1 0.662
YIELD FOR THIS ENERGY? 0.85

ENTER TITLE FOR ISOTOPE 2 CO-60
ENTER NUMBER OF GAMMAS/DISINTEGRATION 2
ENTER ENERGY(MEV) FOR GAMMA 1 1.173
YIELD FOR THIS ENERGY? 1.0
ENTER ENERGY(MEV) FOR GAMMA 2 1.332
YIELD FOR THIS ENERGY? 1.0

ENTER TITLE FOR ISOTOPE 3 CO-58
ENTER NUMBER OF GAMMAS/DISINTEGRATION 4
ENTER ENERGY(MEV) FOR GAMMA 1 0.511
YIELD FOR THIS ENERGY? 0.30
ENTER ENERGY(MEV) FOR GAMMA 2 0.810
YIELD FOR THIS ENERGY? 0.99
ENTER ENERGY(MEV) FOR GAMMA 3 0.865
YIELD FOR THIS ENERGY? 0.014
ENTER ENERGY(MEV) FOR GAMMA 4 1.67
YIELD FOR THIS ENERGY? 0.006

CURRENT DATA IS THE FOLLOWING:

ISOTOPE LIBRARY

1 CS-137

FOR GAMMA 1 ENERGY IS 6.620E-01 YIELD IS 8.500E-01

2 CO-60

FOR GAMMA 1 ENERGY IS 1.173E+00 YIELD IS 1.000E+00
FOR GAMMA 2 ENERGY IS 1.332E+00 YIELD IS 1.000E+00

3 CO-58

FOR GAMMA 1 ENERGY IS 5.110E-01 YIELD IS 3.000E-01
FOR GAMMA 2 ENERGY IS 8.100E-01 YIELD IS 9.900E-01
FOR GAMMA 3 ENERGY IS 8.650E-01 YIELD IS 1.400E-02
FOR GAMMA 4 ENERGY IS 1.670E+00 YIELD IS 6.000E-03

OPTIONS:

- 1--ADD
- 2--DELETE
- 3--CHANGE
- 4--TO EXIT

4

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

3

IS THERE A CURRENT FILE ON THE SYSTEM? (Y OR N)

N

ENTER A NEW TITLE

PERCS RUN #1

ENTER NUMBER OF PIPES

6

FOR PIPE NUMBER 1
INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0 0.10 0.0 0
 0.0 40.0 0.0 0

0 0.200 0.0 0
800 0.200 0.800 0

ENTER RADIUS (IN CM)

20.0

ENTER THICKNESS (IN CM)

4.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE

1

ENTER NUMBER FOR WALL MATERIAL

2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

ENTER NUMBER OF ISOTOPES IN THE SOURCE

1

SPECIFY THE 1 ISOTOPES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1,2,3

CHOICES ARE -

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58

2

FOR SOURCE MODEL NUMBER 1

FOR CO-60

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C

WHAT IS THE CONCENTRATION OF CO-60 IN
MICROCURIES/SQUARE CM? 8.0

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CO-60 HAS A CONSTANT CONCENTRATION
OF 8.000E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

FOR PIPE NUMBER 2

INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END

MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0,10.0,0.0

0.0,40.0,0.0

0.0,500.0,0.0

800.0,500.0,1000.0

ENTER RADIUS (IN CM)

20.0

ENTER THICKNESS (IN CM)

4.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE

1

ENTER NUMBER FOR WALL MATERIAL

2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)

N

ENTER NUMBER OF ISOTOPES IN THE SOURCE

3

SPECIFY THE 3 ISOTOPES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1,2,3

CHOICES ARE -

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58

1,2,3

FOR SOURCE MODEL NUMBER 2

FOR CS-137
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CS-137 IN
MICROCURIES/SQUARE CM? 8.5

FOR CO-60
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CO-60 IN
MICROCURIES/SQUARE CM? 5.0

FOR CO-58
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CO-58 IN
MICROCURIES/SQUARE CM? 5.4

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A CONSTANT CONCENTRATION
OF 8.500E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-60 HAS A CONSTANT CONCENTRATION
OF 5.000E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-58 HAS A CONSTANT CONCENTRATION
OF 5.400E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

FOR PIPE NUMBER 3
INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0,10.0,0.0
 0.0,40.0,0.0

0.0,800.0,0.0
800.0,800.0,800.0

ENTER RADIUS (IN CM)
20.0

ENTER THICKNESS (IN CM)
4.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

1 -- WATER
2 -- IRON
3 -- AIR
4 -- CONCRETE
1

ENTER NUMBER FOR WALL MATERIAL
2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)
Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)
N

ENTER NUMBER OF ISOTOPES IN THE SOURCE
2

SPECIFY THE 2 ISOTOPES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1,2,3

CHOICES ARE -
1 - CS-137
2 - CO-60
3 - CO-58
1,3

FOR SOURCE MODEL NUMBER 3

FOR CS-137
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CS-137 IN
MICROCURIES/SQUARE CM? 8.8

FOR CO-58
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CO-58 IN
MICROCURIES/SQUARE CM? 9.2

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A CONSTANT CONCENTRATION
OF 8.800E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-58 HAS A CONSTANT CONCENTRATION
OF 9.200E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

FOR PIPE NUMBER 4

INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0,10.0,0.0
 0.0,40.0,0.0

300.0,300.0,0.0
200.0,300.0,1000.0

ENTER RADIUS (IN CM)

25.0

ENTER THICKNESS (IN CM)

5.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE

3

ENTER NUMBER FOR WALL MATERIAL

2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)

Y

WHICH ONE?

2

FOR PIPE NUMBER 5

INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0,10.0,0.0
 0.0,40.0,0.0

300.0,600.0,0.0
200.0,600.0,1000.0

ENTER RADIUS (IN CM)

25.0

ENTER THICKNESS (IN CM)

5.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE

3

ENTER NUMBER FOR WALL MATERIAL

2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)

N

ENTER NUMBER OF ISOTOPIES IN THE SOURCE

1

SPECIFY THE 1 ISOTOPIES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1,2,3

CHOICES ARE -

1 - CS-137

2 - CO-60

3 - CO-58

3

FOR SOURCE MODEL NUMBER 4

FOR CO-58

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR

LINEAR ALONG THE PIPE? (C OR L) C
WHAT IS THE CONCENTRATION OF CO-58 IN
MICROCURIES/SQUARE CM? 5.4

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CO-58 HAS A CONSTANT CONCENTRATION
OF 5.400E+00 MICROCURIES/SQUARE CM

OPTIONS:

1--ADD AN ISOTOPE

2--DELETE AN ISOTOPE

3--CHANGE AN ISOTOPE

4--CONTINUE

4

FOR PIPE NUMBER 6

INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0,10.0,0.0

0.0,40.0,0.0

0.0,753 0,100.0

500.0,200 0,100.0

ENTER RADIUS (IN CM)

30.0

ENTER THICKNESS (IN CM)

10.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH

CHOICES ARE -

1 -- WATER

2 -- IRON

3 -- AIR

4 -- CONCRETE

1

ENTER NUMBER FOR WALL MATERIAL
2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)
Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)
Y

WHICH ONE?
3

DID YOU MAKE A MISTAKE ON A PIPE? (Y OR N)
N

DO YOU WANT THE INPUT DATA TO PRINT OUT? (Y/N) Y

ENTER NUMBER OF EXTERNAL SHIELDS
1

ENTER INPUT IN E12.3 FORMAT
 ALL MEASUREMENTS IN CENTIMETERS

ENTER COORDINATES FOR THE CENTERLINE OF THE
 LOWER SURFACE OF THE SHIELD
 ENTER X1, Y1
 EXAMPLE - 20.0, 80.0
100.0, 100.0

ENTER X2, Y2
 EXAMPLE - 0.0, 80.0
700.0, 100.0

ENTER LOWER Z-AXIS COORDINATE
 EXAMPLE - 0.0
0.0

ENTER UPPER Z-AXIS COORDINATE
 EXAMPLE - 70.0
400.0

ENTER HALF THICKNESS (IN CM)
40.0

ENTER NUMBER TO SPECIFY SHIELD TYPE
 1 -- WATER
 2 -- IRON
 3 -- AIR
 4 -- CONCRETE
4

DID YOU MAKE A MISTAKE ON A SHIELD? (Y OR N)
N

WHICH ITEM WOULD YOU LIKE TO CHANGE?
 1--TITLE
 2--PIPES
 3--ADD ANOTHER PIPE
 4--PRINT OUT
 5--SOURCE CONTENT
 6--SHIELD
 7--NO MORE CHANGES
7

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)
 1--SHIELD
 2--ISOTOPE
 3--PROGRAM INPUT DATA
 4--TO EXIT
4

EXAMPLE 2

RUN PERCS

** WELCOME TO PERCS **
WRITTEN AND TESTED BY WD REECE LAST ON 18 SEP 1983

```
PERCS RUN #1
FOR PIPE 1
(X1,Y1,Z1)= 0.000E+00 2.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 2.000E+02 8.000E+02
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 1.

FOR PIPE 2
(X1,Y1,Z1)= 0.000E+00 5.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 5.000E+02 1.000E+03
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2
SOURCE INDEX IS 2.

FOR PIPE 3
(X1,Y1,Z1)= 0.000E+00 8.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 8.000E+02 8.000E+02
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2
SOURCE INDEX IS 3.

FOR PIPE 4
(X1,Y1,Z1)= 3.000E+02 3.000E+02 0.000E+00
(X2,Y2,Z2)= 2.000E+02 3.000E+02 1.000E+03
RADIUS IS 2.500E+01 PIPE THICKNESS IS 5.000E+00
FILLED WITH MATERIAL 3. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 2.

FOR PIPE 5
(X1,Y1,Z1)= 3.000E+02 6.000E+02 0.000E+00
(X2,Y2,Z2)= 2.000E+02 6.000E+02 1.000E+03
RADIUS IS 2.500E+01 PIPE THICKNESS IS 5.000E+00
FILLED WITH MATERIAL 3. WALLS ARE MATERIAL 2
SOURCE INDEX IS 4.

FOR PIPE 6
(X1,Y1,Z1)= 0.000E+00 7.530E+02 1.000E+02
(X2,Y2,Z2)= 5.000E+02 2.000E+02 1.000E+02
RADIUS IS 3.000E+01 PIPE THICKNESS IS 1.000E+01
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2
SOURCE INDEX IS 3.
```

FOR SHIELD 1
 XY COORDINATES FOR SHIELD CENTERLINE
 1.000E+02 1.000E+02
 7.000E+02 1.000E+02
 ZHIGH= 0.000E+00 ZLOW= 4.000E+02
 HALF THICKNESS= 4.000E+01 SHIELD INDEX=4

ISOTOPE LIBRARY

CS-137

6.620E-01 8.500E-01

CO-60

1.173E+00 1.000E+00
 1.332E+00 1.000E+00

CO-58

5.110E-01 3.000E-01
 8.100E-01 9.900E-01
 8.650E-01 1.400E-02
 1.670E+00 6.000E-03

SHIELDING MATERIALS LIBRARY

FOR MATERIAL 1 --WATER
 ATOMIC NUMBER (Z) IS 7.550E+00
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.097 0.090 0.083 0.079 0.074 0.071 0.064 0.059
 FOR MATERIAL 2 --IRON
 ATOMIC NUMBER (Z) IS 2.600E+01
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.652 0.599 0.577 0.523 0.493 0.463 0.428 0.397
 FOR MATERIAL 3 --AIR
 ATOMIC NUMBER (Z) IS 8.000E+00
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 FOR MATERIAL 4 --CONCRETE
 ATOMIC NUMBER (Z) IS 1.100E+01
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.204 0.180 0.175 0.165 0.156 0.149 0.136 0.126

PERCS - GRAPHICS DISPLAY

ENTER X-PLANE COORDINATE FOR Y-Z DISPLAY : 250

TO DEFINE DISPLAY WINDOW ENTER THE FOLLOWING

YAXIS MIN and MAX [0-9999] : 0.1000

ZAXIS MIN and MAX [0-9999] : 0.1000

The terminal switches to graphics mode and draws the pipes shown in Figure 15.1. The option of running a point dose calculation (P) requesting a new x-plane coordinate (C) or terminating the program (E) is given. If the user requests a point dose calculation (Figure 15.2), PERCS presents the option of specifying the point by placement of the cursor or by numerically entered y,z-coordinates. To specify the point with the cursor, the user positions the cursor and strikes a key (Figure 15.3). Figure 15.4 illustrates the graphics display during the calculational phase of PERCS. After the dose has been calculated and displayed, the user has the option of specifying a new dose point (Figure 15.5). If a new point is not desired, a new x-plane may be requested (Figure 15.6). If a new x-plane is declined, the program ends.

FIGURE 15.1. Graphics Display for Example 2. User may request a point dose calculation, a new x-plane, or termination of the program.

FIGURE 15.2. Graphics Display for Example 2. User may use cursor to specify dose point or may numerically enter y,z-coordinates.

FIGURE 15.3. Graphics Display for Example 2. Specifying dose point by cursor position.

FIGURE 15.4. Graphics Display for Example 2.
 Calculational phase of PERCS.

FIGURE 15.5. Graphics Display for Example 2.
Calculated dose rate.

FIGURE 15.6. Graphics Display for Example 2. User may choose a new x-plane or terminate the program.

EXAMPLE 3

Editing the Shield Library

RUN PERCLIB

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

1

IS THERE AN OLD SHIELD FILE ON THE SYSTEM? (TYPE Y OR N)

Y

CURRENT DATA IS THE FOLLOWING:

SHIELDING LIBRARY

FOR MATERIAL 1--WATER

ATOMIC NUMBER (Z) IS 7.550E+00

FOR ENERGY (IN MEV)	0.500	0.600	0.700	0.800	0.900	1.000	1.200	1.400
MU (IN CM(-1)) IS	0.097	0.090	0.083	0.079	0.074	0.071	0.064	0.059

FOR MATERIAL 2--IRON

ATOMIC NUMBER (Z) IS 2.600E+01

FOR ENERGY (IN MEV)	0.500	0.600	0.700	0.800	0.900	1.000	1.200	1.400
MU (IN CM(-1)) IS	0.652	0.599	0.577	0.523	0.493	0.468	0.428	0.397

FOR MATERIAL 3--AIR

ATOMIC NUMBER (Z) IS 8.000E+00

FOR ENERGY (IN MEV)	0.500	0.600	0.700	0.800	0.900	1.000	1.200	1.400
MU (IN CM(-1)) IS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FOR MATERIAL 4--CONCRETE

ATOMIC NUMBER (Z) IS 1.100E+01

FOR ENERGY (IN MEV)	0.500	0.600	0.700	0.800	0.900	1.000	1.200	1.400
MU (IN CM(-1)) IS	0.204	0.188	0.175	0.165	0.156	0.149	0.136	0.126

OPTIONS:

- 1--ADD
- 2--DELETE
- 3--CHANGE
- 4--TO EXIT

1

ENTER NUMBER OF SHIELDS TO BE ADDED

1

NAME OF MATERIAL 5? LEAD

FOR THIS MATERIAL ATOMIC NUMBER Z IS...? 82.0

FOR MATERIAL 5, AND ENERGY 0.5 MU=?	<u>1.746</u>
FOR MATERIAL 5, AND ENERGY 0.6 MU=?	<u>1.361</u>
FOR MATERIAL 5, AND ENERGY 0.7 MU=?	<u>1.136</u>
FOR MATERIAL 5, AND ENERGY 0.8 MU=?	<u>0.971</u>
FOR MATERIAL 5, AND ENERGY 0.9 MU=?	<u>0.866</u>
FOR MATERIAL 5, AND ENERGY 1.0 MU=?	<u>0.782</u>
FOR MATERIAL 5, AND ENERGY 1.2 MU=?	<u>0.699</u>
FOR MATERIAL 5, AND ENERGY 1.4 MU=?	<u>0.635</u>

CURRENT DATA IS THE FOLLOWING:

SHIELDING LIBRARY

FOR MATERIAL 1--WATER
 ATOMIC NUMBER (Z) IS 7.550E+00
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.097 0.090 0.083 0.079 0.074 0.071 0.064 0.059

FOR MATERIAL 2--IRON
 ATOMIC NUMBER (Z) IS 2.600E+01
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.652 0.599 0.577 0.523 0.493 0.468 0.428 0.397

FOR MATERIAL 3--AIR
 ATOMIC NUMBER (Z) IS 8.000E+00
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

FOR MATERIAL 4--CONCRETE
 ATOMIC NUMBER (Z) IS 1.100E+01
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 0.204 0.188 0.175 0.165 0.156 0.149 0.136 0.126

FOR MATERIAL 5--LEAD
 ATOMIC NUMBER (Z) IS 8.200E+01
 FOR ENERGY (IN MEV) 0.500 0.600 0.700 0.800 0.900 1.000 1.200 1.400
 MU (IN CM(-1)) IS 1.746 1.361 1.136 0.971 0.866 0.782 0.699 0.635

OPTIONS:
 1--ADD
 2--DELETE
 3--CHANGE
 4--TO EXIT
4

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)
 1--SHIELD
 2--ISOTOPE
 3--PROGRAM INPUT DATA
 4--TO EXIT
4

EXAMPLE 4

Editing the Isotope Library

RUN PERCSLIB

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

2

IS THERE AN OLD ISOTOPE FILE ON THE SYSTEM? (TYPE Y OR N)

Y

CURRENT DATA IS THE FOLLOWING:

ISOTOPE LIBRARY

1 CS-137

FOR GAMMA 1 ENERGY IS 6.620E-01 YIELD IS 8.500E-01

2 CO-60

FOR GAMMA 1 ENERGY IS 1.173E+00 YIELD IS 1.000E+00
FOR GAMMA 2 ENERGY IS 1.332E+00 YIELD IS 1.000E+00

3 CO-58

FOR GAMMA 1 ENERGY IS 5.110E-01 YIELD IS 3.000E-01
FOR GAMMA 2 ENERGY IS 8.100E-01 YIELD IS 9.900E-01
FOR GAMMA 3 ENERGY IS 8.650E-01 YIELD IS 1.400E-02
FOR GAMMA 4 ENERGY IS 1.670E+00 YIELD IS 6.000E-03

OPTIONS:

- 1--ADD
- 2--DELETE
- 3--CHANGE
- 4--TO EXIT

1

ENTER NUMBER OF ISOTOPES TO BE ADDED

2

ENTER TITLE FOR ISOTOPE 4 CR-51

ENTER NUMBER OF GAMMAS/DISINTEGRATION 1
ENTER ENERGY(MEV) FOR GAMMA 1 0.320
YIELD FOR THIS ENERGY? 0.09

ENTER TITLE FOR ISOTOPE 5 CE-141
ENTER NUMBER OF GAMMAS/DISINTEGRATION 1
ENTER ENERGY(MEV) FOR GAMMA 1 0.145
YIELD FOR THIS ENERGY? 0.48

CURRENT DATA IS THE FOLLOWING:

ISOTOPE LIBRARY

1 CS-137

FOR GAMMA 1 ENERGY IS 6.620E-01 YIELD IS 8.500E-01

2 CO-60

FOR GAMMA 1 ENERGY IS 1.173E+00 YIELD IS 1.000E+00
FOR GAMMA 2 ENERGY IS 1.332E+00 YIELD IS 1.000E+00

3 CO-58

FOR GAMMA 1 ENERGY IS 5.110E-01 YIELD IS 3.000E-01
FOR GAMMA 2 ENERGY IS 8.100E-01 YIELD IS 9.900E-01
FOR GAMMA 3 ENERGY IS 8.650E-01 YIELD IS 1.400E-02
FOR GAMMA 4 ENERGY IS 1.670E+00 YIELD IS 6.000E-03

4 CR-51

FOR GAMMA 1 ENERGY IS 3.200E-01 YIELD IS 9.000E-02

5 CE-141

FOR GAMMA 1 ENERGY IS 1.450E-01 YIELD IS 4.800E-01

OPTIONS:

- 1--ADD
- 2--DELETE
- 3--CHANGE
- 4--TO EXIT

4

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

4

EXAMPLE 5

Editing the Program Input and Source Libraries

RUN PERCSLIB

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

3

IS THERE A CURRENT FILE ON THE SYSTEM? (Y OR N)

Y

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

1

CURRENT TITLE IS.....

PERCS RUN #1

ENTER A NEW TITLE

PERCS RUN #2

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

2

PIPE #

1

PIPE COORDINATES

	START OF CENTERLINE			END OF CENTERLINE		
	X1	Y1	Z1	X2	Y2	Z2
	0.000E+00	2.000E+02	0.000E+00	8.000E+02	2.000E+02	8.000E+02
	2.000E+01	4.000E+00	1.000E+00	2.000E+00	1.000E+00	
	RADIUS	WALL THICKNESS	MATERIAL IN PIPE	PIPE WALL MATERIAL	SOURCE INDEX NUMBER	
PIPE #	2					
	0.000E+00	5.000E+02	0.000E+00	8.000E+02	5.000E+02	1.000E+03
	2.000E+01	4.000E+00	1.000E+00	2.000E+00	2.000E+00	
PIPE #	3					
	0.000E+00	8.000E+02	0.000E+00	8.000E+02	8.000E+02	8.000E+02
	2.000E+01	4.000E+00	1.000E+00	2.000E+00	3.000E+00	
PIPE #	4					
	3.000E+02	3.000E+02	0.000E+00	2.000E+02	3.000E+02	1.000E+03
	2.500E+01	5.000E+00	3.000E+00	2.000E+00	2.000E+00	
PIPE #	5					
	3.000E+02	6.000E+02	0.000E+00	2.000E+02	6.000E+02	1.000E+03
	2.500E+01	5.000E+00	3.000E+00	2.000E+00	4.000E+00	
PIPE #	6					
	0.000E+00	7.330E+02	1.000E+02	5.000E+02	2.000E+02	1.000E+02
	3.000E+01	1.000E+01	1.000E+00	2.000E+00	3.000E+00	

CHANGE: 1- ALL PIPES, 2 - A SPECIFIC ONE, OR 3 - NO CHANGES (CHOOSE NUMBER)

2

WHICH PIPE DO YOU WANT TO RE-DO? (ENTER PIPE #)

2

WHAT WOULD YOU LIKE TO CHANGE?

- 1) EVERYTHING
- 2) PIPE COORDINATES
- 3) RADIUS
- 4) THICKNESS
- 5) MATERIAL PIPE IS FILLED WITH
- 6) WALL MATERIAL
- 7) SOURCE
- 8) NOTHING

CHANGE RADIUS OF
PIPE #2

3

ENTER RADIUS

15.0

ANY MORE CHANGES TO THIS PIPE? (Y OR N)

Y

WHAT WOULD YOU LIKE TO CHANGE?

- 1) EVERYTHING
- 2) PIPE COORDINATES
- 3) RADIUS
- 4) THICKNESS
- 5) MATERIAL PIPE IS FILLED WITH
- 6) WALL MATERIAL
- 7) SOURCE
- 8) NOTHING

CHANGE MATERIAL
PIPE #2 IS FILLED
WITH

5

ENTER NUMBER OF MATERIAL PIPE IS FILLED WITH

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE
- 5 -- LEAD

3

ANY MORE CHANGES TO THIS PIPE? (Y OR N)

Y

WHAT WOULD YOU LIKE TO CHANGE?

- 1) EVERYTHING
- 2) PIPE COORDINATES
- 3) RADIUS
- 4) THICKNESS
- 5) MATERIAL PIPE IS FILLED WITH
- 6) WALL MATERIAL
- 7) SOURCE
- 8) NOTHING

7

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)

N

CHANGE SOURCE
FOR PIPE #2

ENTER NUMBER OF ISOTOPES IN THE SOURCE

2

SPECIFY THE 2 ISOTOPES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1,2,3

CHOICES ARE -

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58
- 4 - CR-51
- 5 - CE-141

4,5

FOR SOURCE MODEL NUMBER 5

FOR CR-51

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C

WHAT IS THE CONCENTRATION OF CR-51 IN
MICROCURIES/SQUARE CM? 8.6

FOR CE-141

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) C

WHAT IS THE CONCENTRATION OF CE-141 IN
MICROCURIES/SQUARE CM? 8.7

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CR-51 HAS A CONSTANT CONCENTRATION
OF 8.600E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A CONSTANT CONCENTRATION
OF 8.700E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

ANY MORE CHANGES TO THIS PIPE? (Y OR N)

N

DID YOU MAKE A MISTAKE ON A PIPE? (Y OR N)

N

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

2

PIPE #	1				
0.000E+00	2.000E+02	0.000E+00	8.000E+02	2.000E+02	8.000E+02
2.000E+01	4.000E+00	1.000E+00	2.000E+00	1.000E+00	
PIPE #	2				
0.000E+00	5.000E+02	0.000E+00	8.000E+02	5.000E+02	1.000E+03
1.500E+01	4.000E+00	3.000E+00	2.000E+00	5.000E+00	
NEW RADIUS		NEW WALL		PIPE #2 NOW	
		MATERIAL		CONTAINS	
PIPE #	3			SOURCE #5	
0.000E+00	8.000E+02	0.000E+00	8.000E+02	8.000E+02	8.000E+02
2.000E+01	4.000E+00	1.000E+00	2.000E+00	3.000E+00	
PIPE #	4				
3.000E+02	3.000E+02	0.000E+00	2.000E+02	3.000E+02	1.000E+03
2.500E+01	5.000E+00	3.000E+00	2.000E+00	2.000E+00	
PIPE #	5			PIPE #4 STILL CONTAINS	
3.000E+02	6.000E+02	0.000E+00	2.000E+02	6.000E+02	1.000E+03
2.500E+01	5.000E+00	3.000E+00	2.000E+00	4.000E+00	
PIPE #	6				
0.000E+00	7.530E+02	1.000E+02	5.000E+02	2.000E+02	1.000E+02
3.000E+01	1.000E+01	1.000E+00	2.000E+00	3.000E+00	

CHANGE: 1- ALL PIPES, 2 - A SPECIFIC ONE, OR 3 - NO CHANGES (CHOOSE NUMBER)

3

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

ADD A 7TH PIPE

3

FOR PIPE NUMBER 7

INPUT COORDINATES (2 SETS) - IN E12.3 FORMAT
ONE FOR START OF CENTERLINE, ONE SET FOR END
MEASUREMENTS ARE IN CENTIMETERS

EXAMPLE - 0.0, 10.0, 0.0
 0.0, 40.0, 0.0

300.0, 900.0, 0.0
200.0, 900.0, 1000.0

ENTER RADIUS (IN CM)

20.0

ENTER THICKNESS (IN CM)

4.0

ENTER NUMBER OF MATERIAL THE PIPE IS FILLED WITH
CHOICES ARE -

- 1 -- WATER
- 2 -- IRON
- 3 -- AIR
- 4 -- CONCRETE
- 5 -- LEAD

1

ENTER NUMBER FOR WALL MATERIAL

2

DOES THIS PIPE CONTAIN A SOURCE? (Y OR N)

Y

DO YOU WANT TO USE A PREVIOUS SOURCE? (Y OR N)

N

ENTER NUMBER OF ISOTOPES IN THE SOURCE

4

SPECIFY THE 4 ISOTOPES DESIRED BY ENTERING
THE CORRESPONDING NUMBER - SEPARATE BY COMMAS
EXAMPLE - 1, 2, 3

CHOICES ARE -

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58
- 4 - CR-51
- 5 - CE-141

1, 2, 3, 5

FOR SOURCE MODEL NUMBER 6

FOR CS-137
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L
AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:
3.000E+02 9.000E+02 0.000E+00
WHAT IS THE CONCENTRATION OF CS-137 IN
MICROCURIES/SQUARE CM? 6.7
AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:

2.000E+02 9.000E+02 1.000E+03
WHAT IS THE CONCENTRATION OF CS-137 IN
MICROCURIES/SQUARE CM? 8.2

FOR CO-60
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L
AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:
3.000E+02 9.000E+02 0.000E+00
WHAT IS THE CONCENTRATION OF CO-60 IN
MICROCURIES/SQUARE CM? 7.2
AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:
2.000E+02 9.000E+02 1.000E+03
WHAT IS THE CONCENTRATION OF CO-60 IN
MICROCURIES/SQUARE CM? 7.8

FOR CO-58
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L
AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:
3.000E+02 9.000E+02 0.000E+00
WHAT IS THE CONCENTRATION OF CO-58 IN
MICROCURIES/SQUARE CM? 6.1
AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:
2.000E+02 9.000E+02 1.000E+03
WHAT IS THE CONCENTRATION OF CO-58 IN
MICROCURIES/SQUARE CM? 6.5

FOR CE-141
IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L
AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:
3.000E+02 9.000E+02 0.000E+00
WHAT IS THE CONCENTRATION OF CE-141 IN
MICROCURIES/SQUARE CM? 6.7
AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:
2.000E+02 9.000E+02 1.000E+03
WHAT IS THE CONCENTRATION OF CE-141 IN
MICROCURIES/SQUARE CM? 7.2

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 8.200E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-60 HAS A LINEAR CONCENTRATION
RANGING FROM 7.200E+00 TO 7.800E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-58 HAS A LINEAR CONCENTRATION
RANGING FROM 6.100E+00 TO 6.500E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 7.200E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

DID YOU MAKE A MISTAKE ON A PIPE? (Y OR N)

N

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

CHECK PIPE
PARAMETERS

2

PIPE #	1	2	3	4	5	6
0.000E+00	2.000E+02	0.000E+00	8.000E+02	2.000E+02	8.000E+02	
2.000E+01	4.000E+00	1.000E+00	2.000E+00	1.000E+00		
PIPE #	2					
0.000E+00	5.000E+02	0.000E+00	8.000E+02	5.000E+02	1.000E+03	
1.500E+01	4.000E+00	3.000E+00	2.000E+00	5.000E+00		
PIPE #	3					
0.000E+00	8.000E+02	0.000E+00	8.000E+02	8.000E+02	8.000E+02	
2.000E+01	4.000E+00	1.000E+00	2.000E+00	3.000E+00		
PIPE #	4					
3.000E+02	3.000E+02	0.000E+00	2.000E+02	3.000E+02	1.000E+03	
2.500E+01	5.000E+00	3.000E+00	2.000E+00	2.000E+00		
PIPE #	5					
3.000E+02	6.000E+02	0.000E+00	2.000E+02	6.000E+02	1.000E+03	
2.500E+01	5.000E+00	3.000E+00	2.000E+00	4.000E+00		
PIPE #	6					
0.000E+00	7.530E+02	1.000E+02	5.000E+02	2.000E+02	1.000E+02	
3.000E+01	1.000E+01	1.000E+00	2.000E+00	3.000E+00		
PIPE #	7					
3.000E+02	9.000E+02	0.000E+00	2.000E+02	9.000E+02	1.000E+03	
2.000E+01	4.000E+00	1.000E+00	2.000E+00	6.000E+00		

CHANGE: 1- ALL PIPES, 2 - A SPECIFIC ONE, OR 3 - NO CHANGES (CHOOSE NUMBER)

3

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

5

ENTER NUMBER OF THE SOURCE YOU WISH TO CHANGE

6

CHANGE ISOTOPES
IN THE 6TH SOURCE

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 8.200E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-60 HAS A LINEAR CONCENTRATION
RANGING FROM 7.200E+00 TO 7.800E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-58 HAS A LINEAR CONCENTRATION
RANGING FROM 6.100E+00 TO 6.500E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 7.200E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

1

HOW MANY ISOTOPES ARE TO BE ADDED?

1

CURRENT ISOTOPES ARE -

ADD AN ISOTOPE

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58
- 4 - CE-141

SPECIFY THE NUMBER OF THE 1 ISOTOPES TO BE
ADDED TO SOURCE NUMBER 6 SEPARATE BY COMMAS

EXAMPLE: 1,2,3

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58
- 4 - CR-51
- 5 - CE-141

4

FOR CR-51

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L
AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:

3.000E+02 9.000E+02 0.000E+00

WHAT IS THE CONCENTRATION OF CR-51 IN
MICROCURIES/SQUARE CM? 8.3

AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:

2.000E+02 9.000E+02 1.000E+03

WHAT IS THE CONCENTRATION OF CR-51 IN
MICROCURIES/SQUARE CM? 8.6

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 8.200E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-60 HAS A LINEAR CONCENTRATION
RANGING FROM 7.200E+00 TO 7.800E+00 MICROCURIES/SQUARE CM

ISOTOPE CO-58 HAS A LINEAR CONCENTRATION
RANGING FROM 6.100E+00 TO 6.500E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 7.200E+00 MICROCURIES/SQUARE CM

ISOTOPE CR-51 HAS A LINEAR CONCENTRATION
RANGING FROM 8.300E+00 TO 8.600E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

2

HOW MANY ISOTOPES ARE TO BE DELETED?

3

SPECIFY THE NUMBER OF THE 3 ISOTOPES TO BE

DELETED FROM SOURCE NUMBER 6

- ONE PER LINE, <CR> IN BETWEEN

CURRENT ISOTOPES ARE -

- 1 - CS-137
- 2 - CO-60
- 3 - CO-58
- 4 - CE-141
- 5 - CR-51

DELETE 3 ISOTOPES

2
3
5

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 8.200E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 7.200E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

3

WHAT ISOTOPE DO YOU NEED TO CHANGE?

ENTER THE ISOTOPE TITLE (EXAMPLE - CR-51)

CS-137

CHANGE SURFACE
CONCENTRATION OF
Cs-137.

FOR CS-137

IS THE ISOTOPIC SURFACE CONCENTRATION CONSTANT OR
LINEAR ALONG THE PIPE? (C OR L) L

AT BEGINNING OF THE PIPE WHERE THE COORDINATES ARE:

3.000E+02 9.000E+02 0.000E+00

WHAT IS THE CONCENTRATION OF CS-137 IN

MICROCURIES/SQUARE CM? 7.9

AND AT THE END OF THE PIPE WHERE THE COORDINATES ARE:

2.000E+02 9.000E+02 1.000E+03

WHAT IS THE CONCENTRATION OF CS-137 IN

MICROCURIES/SQUARE CM? 8.3

CURRENT DATA IS THE FOLLOWING -

ISOTOPE CS-137 HAS A LINEAR CONCENTRATION
RANGING FROM 7.900E+00 TO 8.300E+00 MICROCURIES/SQUARE CM

ISOTOPE CE-141 HAS A LINEAR CONCENTRATION
RANGING FROM 6.700E+00 TO 7.200E+00 MICROCURIES/SQUARE CM

OPTIONS:

- 1--ADD AN ISOTOPE
- 2--DELETE AN ISOTOPE
- 3--CHANGE AN ISOTOPE
- 4--CONTINUE

4

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

DISPLAY SHIELD
COORDINATES

6

SHIELD #	1					
	X1	Y1	X2	Y2	ZLOW	ZHIGH
1.000E+02	1.000E+02	1.000E+00	7.000E+02	1.000E+02	0.000E+00	4.000E+02
4.000E+01	4.000E+00	4.000E+00				
HALF	SHIELD					
THICKNESS	MATERIAL					

CHANGE: 1 - ALL SHIELDS, 2 - A SPECIFIC ONE, OR 3 - NO CHANGES (CHOOSE NUMBER)

3

WHICH ITEM WOULD YOU LIKE TO CHANGE?

- 1--TITLE
- 2--PIPES
- 3--ADD ANOTHER PIPE
- 4--PRINT OUT
- 5--SOURCE CONTENT
- 6--SHIELD
- 7--NO MORE CHANGES

7

WHICH LIBRARY WOULD YOU LIKE TO EDIT? (ENTER #)

- 1--SHIELD
- 2--ISOTOPE
- 3--PROGRAM INPUT DATA
- 4--TO EXIT

4

EXAMPLE 6

RUN PERCS

** WELCOME TO PERCS **
WRITTEN AND TESTED BY WD REECE LAST ON 18 SEP 1983

```
PERCS RUN #2
FOR PIPE 1
(X1,Y1,Z1)= 0.000E+00 2.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 2.000E+02 8.000E+02
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 1.

FOR PIPE 2
(X1,Y1,Z1)= 0.000E+00 5.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 5.000E+02 1.000E+03
RADIUS IS 1.500E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 3. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 5.

FOR PIPE 3
(X1,Y1,Z1)= 0.000E+00 8.000E+02 0.000E+00
(X2,Y2,Z2)= 8.000E+02 8.000E+02 8.000E+02
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 3.

FOR PIPE 4
(X1,Y1,Z1)= 3.000E+02 3.000E+02 0.000E+00
(X2,Y2,Z2)= 2.000E+02 3.000E+02 1.000E+03
RADIUS IS 2.500E+01 PIPE THICKNESS IS 5.000E+00
FILLED WITH MATERIAL 3. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 2.

FOR PIPE 5
(X1,Y1,Z1)= 3.000E+02 6.000E+02 0.000E+00
(X2,Y2,Z2)= 2.000E+02 6.000E+02 1.000E+03
RADIUS IS 2.500E+01 PIPE THICKNESS IS 5.000E+00
FILLED WITH MATERIAL 3. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 4.

FOR PIPE 6
(X1,Y1,Z1)= 0.000E+00 7.530E+02 1.000E+02
(X2,Y2,Z2)= 5.000E+02 2.000E+02 1.000E+02
RADIUS IS 3.000E+01 PIPE THICKNESS IS 1.000E+01
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 3.

FOR PIPE 7
(X1,Y1,Z1)= 3.000E+02 9.000E+02 0.000E+00
(X2,Y2,Z2)= 2.000E+02 9.000E+02 1.000E+03
RADIUS IS 2.000E+01 PIPE THICKNESS IS 4.000E+00
FILLED WITH MATERIAL 1. WALLS ARE MATERIAL 2.
SOURCE INDEX IS 6.

FOR SHIELD 1
XY COORDINATES FOR SHIELD CENTERLINE
1.000E+02 1.000E+02
7.000E+02 1.000E+02
ZHIGH= 0.000E+00 ZLOW= 4.000E+02
HALF THICKNESS= 4.000E+01 SHIELD INDEX=4.
```

ISOTOPE LIBRARY

CS-137

6. 620E-01 8. 500E-01

CO-60

1. 173E+00 1. 000E+00
1. 332E+00 1. 000E+00

CO-58

5. 110E-01 3. 000E-01
8. 100E-01 9. 900E-01
8. 650E-01 1. 400E-02
1. 670E+00 6. 000E-03

CR-51

3. 200E-01 9. 000E-02

CE-141

1. 450E-01 4. 800E-01

SHIELDING MATERIALS LIBRARY

FOR MATERIAL 1 --WATER

ATOMIC NUMBER (Z) IS 7. 550E+00

FOR ENERGY (IN MEV) 0. 500 0. 600 0. 700 0. 800 0. 900 1. 000 1. 200 1. 400

MU (IN CM(-1)) IS 0. 097 0. 090 0. 083 0. 079 0. 074 0. 071 0. 064 0. 059

FOR MATERIAL 2 --IRON

ATOMIC NUMBER (Z) IS 2. 600E+01

FOR ENERGY (IN MEV) 0. 500 0. 600 0. 700 0. 800 0. 900 1. 000 1. 200 1. 400

MU (IN CM(-1)) IS 0. 652 0. 599 0. 577 0. 523 0. 493 0. 468 0. 428 0. 397

FOR MATERIAL 3 --AIR

ATOMIC NUMBER (Z) IS 8. 000E+00

FOR ENERGY (IN MEV) 0. 500 0. 600 0. 700 0. 800 0. 900 1. 000 1. 200 1. 400

MU (IN CM(-1)) IS 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000

FOR MATERIAL 4 --CONCRETE

ATOMIC NUMBER (Z) IS 1. 100E+01

FOR ENERGY (IN MEV) 0. 500 0. 600 0. 700 0. 800 0. 900 1. 000 1. 200 1. 400

MU (IN CM(-1)) IS 0. 204 0. 188 0. 175 0. 165 0. 156 0. 149 0. 136 0. 126

FOR MATERIAL 5 --LEAD

ATOMIC NUMBER (Z) IS 8. 200E+01

FOR ENERGY (IN MEV) 0. 500 0. 600 0. 700 0. 800 0. 900 1. 000 1. 200 1. 400

MU (IN CM(-1)) IS 1. 746 1. 361 1. 136 0. 971 0. 866 0. 782 0. 699 0. 635

PERCS - GRAPHICS DISPLAY

ENTER X-PLANE COORDINATE FOR Y-Z DISPLAY : 250

TO DEFINE DISPLAY WINDOW ENTER THE FOLLOWING

YAXIS MIN and MAX [0-9999] : 0,1000

ZAXIS MIN and MAX [0-9999] : 0,1000

The terminal switches to graphics mode and draws the pipes illustrated in Figure 15.7. A point dose calculation is requested and the user is asked whether the point will be specified by numerical coordinates (S) or cursor position (C) (Figure 15.8). Figure 15.9 illustrates the method of specifying a dose point with numerical coordinates. The dose rate is calculated (Figure 15.10). If the user opts to not specify another dose point or another x-axis, the program ends.

FIGURE 15.7. Graphics Display for Example 6. User may request a point dose calculation, a new x-plane, or termination of the program.

FIGURE 15.8. Graphics Display for Example 6. User may specify dose point with numerical coordinates or by cursor position.

FIGURE 15.9. Graphics Display for Example 6. Dose point is specified by numerical coordinates.

FIGURE 15.10. Graphics Display for Example 6.
Calculated dose rate.

16.0 CLOSING REMARKS

PERCS, in various stages of development, has been used for over six months at PNL to calculate doses for various configurations. Dose calculations have been performed for steam generator channel head work, for food irradiators, for prediction of radiation fields near activated piping, for the estimation of surface contamination on TMI lead screws, and many other tasks. The results have been uniformly gratifying.

There are limitations which PERCS shares with all other point kernel codes--streaming through ducts and voids is not handled well and albedo scattering is ignored. For example, during the measurement of the fields around a food irradiator, the irradiator and the lowest thermoluminescent dosimeters rested on a concrete floor. In the worst case, the albedo scatter from the concrete raised the measured dose to twice what PERCS had calculated. Likewise, massive shields behind a dose point will lead to under-prediction of the dose.

Finally, since PERCS is an interactive code, the quadrature routines are limited sharply as to how many points may be chosen in evaluating the integrals to keep the run time reasonable. Although some fairly severe cases have been tested and the quadrature routines have always converged to the correct answer within the allowed number of integration points, it should be possible to overwhelm the quadrature routines.

Many modifications and improvements to PERCS will be apparent to those interested in dose calculations and it is hoped that PERCS will continue to evolve. Dose calculations, because of the need to present complex geometrical relationships concisely, are particularly benefited by the addition of graphics. The continuing advances in computer graphics will offer new possibilities for years to come.

16.0 CLOSING REMARKS

PERC2, in various stages of development, has been used for over six months at PNL to calculate dose for various configurations. Dose calculations have been performed for steam generator channel head work, for food irradiators, for prediction of radiation fields near activated piping, for the estimation of surface contamination on IMI lead screws, and many other tasks. The results have been uniformly gratifying.

There are limitations which PERC2 shares with all other point kernel codes--streaming through ducts and voids is not handled well and shielded scattering is ignored. For example, during the measurement of the field around a food irradiator, the irradiator and the lowest fluorescent detectors rested on a concrete floor. In the worst case, the shielded scatter from the concrete raised the measured dose to twice what PERC2 had calculated. Likewise, massive shields behind a dose-point will lead to under-prediction of the dose.

Finally, since PERC2 is an interactive code, the quadrature routines are limited sharply as to how many points may be chosen in evaluating the integrals to keep the run time reasonable. Although some fairly severe cases have been tested and the quadrature routines have always converged to the correct answer within the allowed number of integration points, it should be possible to overweigh the quadrature routines.

Many modifications and improvements to PERC2 will be apparent to those interested in dose calculations and it is hoped that PERC2 will continue to evolve. Dose calculations, because of the need to present complex geometrical relationships concisely, are particularly benefited by the addition of graphics. The continuing advances in computer graphics will offer new possibilities for years to come.

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Publishing Coordinator (2)

NRC FORM 335 (11-81)		U.S. NUCLEAR REGULATORY COMMISSION BIBLIOGRAPHIC DATA SHEET		1. REPORT NUMBER (Assigned by DDC) NUREG/CR-3573 PNL-4923	
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) Personnel Exposure from Right Cylindrical Sources (PERCS): The Theory, The Code, and Examples				2. (Leave blank)	
				3. RECIPIENT'S ACCESSION NO.	
7. AUTHOR(S) W.D. Reece, R.T. Hadley, R. Harty, J. Glass, J.E. Tanner, L.F. Munson				5. DATE REPORT COMPLETED MONTH November YEAR 1983	
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352				DATE REPORT ISSUED MONTH January YEAR 1984	
				6. (Leave blank)	
				8. (Leave blank)	
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Division of Engineering Technology Office of Nuclear Regulatory Research U.S. Nuclear Regulatory Commission Washington, D.C. 20555				10. PROJECT/TASK/WORK UNIT NO.	
				11. FIN NO. B2412, B2429	
13. TYPE OF REPORT Technical			PERIOD COVERED (Inclusive dates)		
15. SUPPLEMENTARY NOTES				14. (Leave blank)	
16. ABSTRACT (200 words or less) A new interactive point kernel shielding code for gamma rays named PERCS (Personnel Exposure from Right Cylindrical Surfaces) is presented with theory, a listing and examples. PERCS calculates doses from more complicated geometries faster than other known shielding codes. The code is graphics-oriented, interactive, menu-driven and easy to use. PERCS is especially suited for calculation of dose arising from activated corrosion products plated on primary piping in commercial power plants.					
17. KEY WORDS AND DOCUMENT ANALYSIS PERCS, shielding, point kernel			17a. DESCRIPTORS activated corrosion products		
17b. IDENTIFIERS, OPEN-ENDED TERMS					
18. AVAILABILITY STATEMENT Unlimited			19. SECURITY CLASS (This report) Unclassified		21. NO. OF PAGES
			20. SECURITY CLASS (This page)		22. PRICE \$

1. TITLE AND SUBJECT PERSONNEL EXPOSURE FROM RIGHT CYLINDRICAL SOURCES (PERCS): THE THEORY, THE CODE, AND EXAMPLES		2. AUTHOR(S) W.T. RUSS, R.T. HADLEY, R. HARRY, J. GLASS, J.C. TANNER R.T. HADLEY Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352		3. REPORT NUMBER HUREG/CR-8573 PNL-8983		4. U.S. NUCLEAR REGULATORY COMMISSION BIBLIOGRAPHIC DATA SHEET	
5. DATE REPORT COMPLETED NOVEMBER 1983		6. DATE REPORT ISSUED NOVEMBER 1983		7. PERCENT COVERED BY THIS REPORT 100%		8. PROJECT TASKWORK UNIT NO. B6479, B6480	
9. PERCENT COVERED BY THIS REPORT 100%		10. PROJECT TASKWORK UNIT NO. B6479, B6480		11. FUNDING B6479, B6480		12. PERCENT COVERED BY THIS REPORT 100%	
13. ABSTRACT A new interactive point kernel (PERCS) calculating code for gamma rays from right cylindrical sources is presented with theory, a listing and examples. PERCS calculates doses from more complicated geometries (aster, driven and known shielding doses). The code is graphics-oriented, interactive, menu-driven and easy to use. PERCS is especially suited for calculation of dose arising from activated corrosion products plated on primary piping in commercial power plants.		14. KEY WORDS PERCS, shielding, point kernel, activated corrosion products		15. PERCENT COVERED BY THIS REPORT 100%		16. PERCENT COVERED BY THIS REPORT 100%	
17. PERCENT COVERED BY THIS REPORT 100%		18. PERCENT COVERED BY THIS REPORT 100%		19. PERCENT COVERED BY THIS REPORT 100%		20. PERCENT COVERED BY THIS REPORT 100%	