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STREAM: A THREE-DIMENSIONAL MONTE CARLO RAY TRACING CODE IN CYL--ETC(U)
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STREAM: A THREE-DIMENSIONAL MONTE CARLO RAY TRACING CODE IN CYLINDRICAL GEOMETRY

February 1977

Final Report

Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117

This final report was prepared under Job Order 88091701 by the Air Force Weapons Laboratory, Kirtland AFB, NM. Captain John A. Justice (DYS) was the Laboratory Project Officer-in-Charge.

This technical report has been reviewed and is approved for publication.

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This report is a user's guide for STREAM, a code used to theoretically model light transmission through complex, cylindrically symmetric SHIVA-type chamber geometries. Code access at the Air Force Weapons Laboratory (AFWL) and program INPUT are described in detail. Sample output is provided.

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SECTION I

INTRODUCTION

The purpose of the program STREAM is to theoretically test light transmission through complex cylindrically symmetric SHIVA chamber geometries. (SHIVA is a Z-pinch device used to produce hot dense radiating plasmas by the ionization and J x B implosion of a short cylindrical foil.) If sufficient UV light is transmitted from the ionized foil to the chamber insulator, the resulting ionization of the insulator may cause the chamber to break down electrically.

The program STREAM has the following characteristics:

1. Straightforward input.
2. Three-dimensional cylindrical geometry with theta symmetry.
3. Specular or diffuse reflections or any combination of the two phenomena may be specified. Diffuse reflections can be treated in several ways; for example, any distribution (isotropic or cosine distributions are standard) is allowed and it can be oriented around the surface normal or along the specular reflection angle.
4. Absorption is calculated for each reflection and it is a function of the angle of incidence, index of refraction and extinction coefficient. (Values for n and k are found in the American Institute of Physics Handbook for various wavelengths and materials.)
5. The output includes relative intensity crossing designated surfaces in the geometry. The input intensity is unity. An optional output file is available for 2-D microfiche plotting of successful (hits on the insulator) photon paths.

SECTION II

STREAM INPUT

The input for STREAM is free format where a comma begins a card of input and a slash ends it. There is a maximum of five input sections. The first two are the LAB (for label) and UNI (for units) sections which are each very short. The LAB section inputs two title cards which may be changed for each run or series of runs. The UNI section is optional. It allows input in units of inches (standard units are centimeters). This unit conversion applies only to the chamber geometry card. The third section is the SOU (for source) section. It contains the bulk of the input. The source card is followed by nine or ten different input cards (a card in this context contains a stream of input terminated with a slash; several IBM cards can be used for each "card" defined here). The last two sections are the END and STO (for stop) sections. Input for the five sections is outlined on the succeeding pages. Essentially the entire problem setup is contained in the SOU section. (Note: Only the first three characters of a header card are interpreted; the rest of the card may be used for comments.)

LABel STREAM Program

,0,1/

first title card

second title card

UNIts

,1,0,0,1/ Chamber geometry is input in inches.

SOUrce

The first source card inputs several integer parameters for the problem setup:

,1,3, NRMAX, NWAVES, NCCMAX, NCSMAX, NCRMAX, NTIMES

,NDMAX, NPLOT, MAXRAY, NSTEPS, NTOTAL, NORDER, NSCAT, NMMAX, NTORUS/

The above variables are defined as follows:

NRMAX -- the number of R-Z cells in the geometry (each cell must be trapezoidal and have all the interior angles less than 180°). The 2-D geometry is rotated around the Z-axis. Possible values ≥ 1.

NWAVES -- the number of wavelengths considered in each property set. Possible values $1 \leq NWAVES \leq 5$

NCCMAX -- the number of property sets. Each property set's results are printed across a page. Succeeding property sets are printed on new pages. NWAVES x NCCMAX is the total number of wavelengths and materials considered. Additional property sets do not increase the running time, since the Monte Carlo is done once and the amount of absorption per reflection is the only difference between different wavelengths/materials. Possible values ≥ 1

NCSMAX -- the number of points used to describe the source polar distribution. Possible values ≥ 2

NCRMAX -- the number of points used to describe the polar distribution of diffuse reflections relative to the specular reflection angle or the surface normal. Possible values ≥ 2

NTIMES -- the number of time bins

NDMAX -- number of detectors. Possible values ≥ 1

NPLOT -- logical number of the output tape used for creating microfiche plots (0 = no plots). NPLOT = 9 implies a TAPE9 file

MAXRAY -- the maximum number of photon paths to be put on a plot tape

NSTEPS -- the maximum number of paths through which each particle is followed [(NSTEPS - 1) is the number of reflections allowed.]

NTOTAL -- the total number of histories or particles followed

NORDER -- the number of "order of scatter" edits. If NORDER = (NSTEPS - 1), then all possible scoring paths are edited and printed. Possible values ≥ 0

NSCAT -- diffuse distribution reference direction:
0 = specular reflection direction, 1 = surface normal

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NMMAX -- the number of surface materials allowed in the chamber geometry. Possible values ≥ 0. If NMMAX = 0 or 1, one material is specified. If NMMAX ≥ 2, then additional input is required after card 5 (see remark before card 6 explanation). Also, a card after card 9 is used to describe the surfaces containing materials 2 through NMMAX in the chamber geometry (see card 10 remarks).

NTORUS -- this card indicates how many curved surfaces there are in the geometry. Each curved surface is a portion of a circle in cross section and a portion of a torus in three dimensions. For each curved surface indicated by NTORUS, special input is required in card 9 (see card 9 for a description).

The second source card describes the source plane and the source's reference direction:

,RMIN, RMAX, ZMIN, ZMAX, RDIR, 0,ZDIR/

Definitions of these variables are as follows:

RMIN -- minimum radius of source plane.

RMAX -- maximum radius of source plane.

ZMIN -- minimum height of source plane.

ZMAX -- maximum height of source plane.

RDIR -- R-axis direction cosine of reference direction.

0 -- theta direction cosine

ZDIR -- Z-axis direction cosine of reference direction.

NOTE: RMIN, ZMIN, and ZMAX are in cm, and the following constraint applies:

$$[(RDIR)^2 + (ZDIR)^2]^{0.5} = 1.0$$

The third source card describes the source's relative angular distribution:

$\mu_1, p_1, \mu_2, p_2, \ldots, \mu_{NCSMAX}, p_{NCSMAX}$/

μ_i is the cosine of the angle relative to the cosine direction for which the probability of propagation is p_i. Two special cases are available. ,0,0,1,1/ is a cosine distribution (at 90° the probability is zero; at 0° the probability is 1). ,0,1,1,1/ is an isotropic distribution (at 90° the probability is 1.0; at 0° the

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probability is 1.0). Any other source distribution can be approximated by including several (instead of two) cosine and probability pairs. The code interpolates intermediate values.

The fourth and fifth source cards are input in pairs. They are repeated for each property set (e.g., if there are three property sets, three pairs of cards 4 and 5 must be included in the deck.)

Card 4 contains the mirror reflection fractions for NWAVES wavelengths:

,0.0, 0.0, 0.0, 0.0, 0.0/ mirror fractions

This card indicates 100% diffuse reflection probability for each of five wavelengths in a property set.

Card 5 contains the index of refraction, n, and the extinction coefficient, k, for NWAVES (five in the following case) wavelengths:

$n_1,k_1,n_2,k_2,n_3,k_3,n_4,k_4,n_5,k_5/$

The n and k values are available for metals in the American Institute of Physics Handbook, page 6-124. If NMMAX is 2 or greater, the above sets of cards 4 and 5 (mirror fractions, indices of refraction, and extinction coefficients) must be repeated for each different material.

The sixth card contains the diffuse angular distribution which can be calculated relative to the specular reflection direction (NSCAT = 0). (Experimental evidence, accumulated with sandblasted copper surfaces, suggests that laser light is scattered from that surface in a cosine squared-like distribution about the specular reflection direction.)

$,\mu_1,p_1, \ldots ,\mu_{NCRMAX},p_{NCRMAX}/$

The meaning of μ and p is the same as on source card 3. The special cosine and isotropic distributions are both available.

The seventh card contains the detector information. The detectors are defined on any boundary. They are defined by cell number and boundary index (1, 2, 3, or 4). (The cell and boundary concepts are explained later.)

,NRMAX,4,1,1/

The first detector is on the fourth boundary of the last cell, and the second detector is on the first boundary of the first cell. (NOTE: Any radiation incident on the fourth boundary of the last cell is considered to be absorbed in the insulator.)

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The eighth card of the source section contains the time bin information. There should be one more time boundary than NTIMES, the number of time bins.

$,0., \ldots, t_{NTIMES+1}/$ time bin limits

The ninth source data card is the geometry card. The geometry consists of a series of adjacent trapezoids (none of which is allowed to have an interior angle greater than 180° or overlap adjacent trapezoids). It is input by pairs of (r,z) coordinates, two pairs (called quads) at a time. Each quad describes the endpoints of a line. The quads are input in order from one end of the geometry to the other. Trapezoids (called cells) are automatically formed when the code connects the top and bottom points of adjacent quads.

The side described by the first (in order) quad is side 1 of the cell. The side described by the second quad is side 4 of the cell. The bottom border of the cell is side 2, and the top border is side 3. There must be one more quad than cells specified by NRMAX. The three-dimensional characteristics of the geometry occur because the assemblage of trapezoids is symmetric about the line R = 0 (theta symmetry). The easiest way to input the geometry is by quads:

$,r_{low},z_{low},r_{high},z_{high}$ (1st face)

$,r_{low},z_{low},r_{high},z_{high}$ (2nd face)

. . . .

. . . .

. . . .

. . . .

$,r_{low},z_{low},r_{high},z_{high}$ (last face, NRMAX+1 quad)

A diagram of the trapezoidal input approach is in figure 1. The cell surfaces are numbered 1 through 4.

Figure 2 shows a complete geometry with one baffle inserted. In this figure, particles which scatter back through side 1, cell 1, are lost. Particles which impact side 4 of the last cell are successful photon strikes on the insulator and they are terminated. The associated energy is tallied for each wavelength.

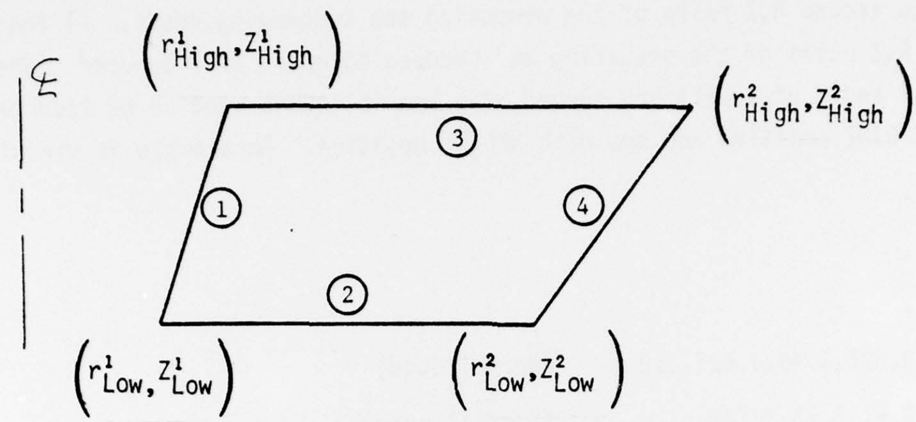

Figure 1. Cell Geometry.

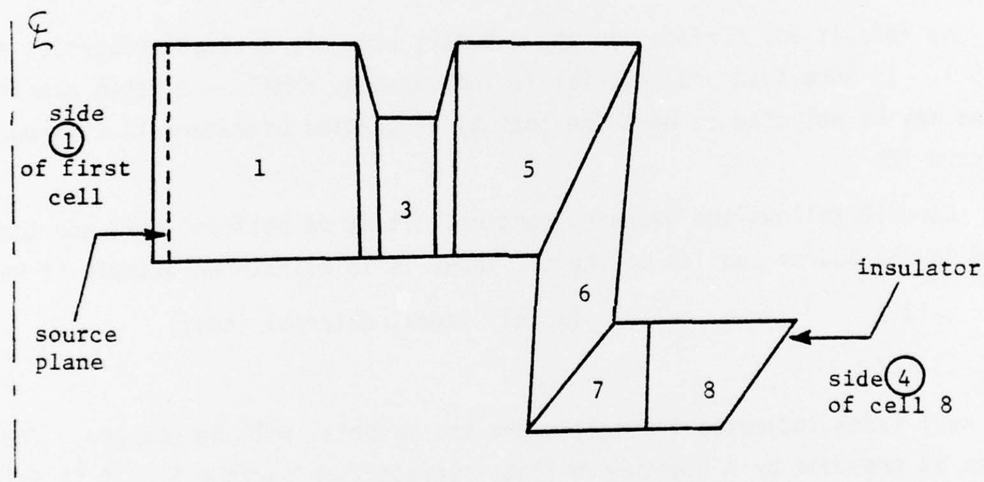

Figure 2. Total Geometry (Example).

An additional option has been added to the STREAM program. This option allows curved surfaces (arcs of circles in two dimensions or portions of a toroid in three dimensions) to be included in the geometry boundaries. The number of curved surfaces to be input was specified by NTORUS on the first SOUrce card. A curved surface is input using a special quad as shown:

,NFLAG, NPOINT, R',Z'

where NFLAG = 0 and indicates that this is a special quad.

NPOINT = ±1, and +1 indicates an arc will be drawn through the R',Z' pair and the second R,Z pairs of the preceding and succeeding quads. -1 indicates the first R,Z pairs of the preceding and succeeding quads will be used. When both sides 2 and 3 of a cell are curved, two special quads need to be inserted, one with NPOINT positive and one with NPOINT negative. An example is useful:

.

.

.

,3.625,3.49,3.625,3.9 (Normal quad)

,0,+1,3.75,3.775 (Special quad)

,3.875,3.49,3.875,3.9 (Normal quad)

The above sequence of cards indicates that an arc will be drawn through the points (3.625,3.9), (3.75,3.775), and (3.875,3.9).

By default all surfaces in the geometry have the optical properties of material 1. If more than one material is indicated by NMMAX ≥ 2, then specific surfaces may be selected to have the optical properties of materials 2 through NMMAX on card 10.

Card 10 follows the geometry section. It is an optional card and the last card in the SOUrce section of input. Input is in pairs. An example is helpful:

,-13,2 (± cell index, material index)

,14,2/

The cell index indicates the cell where the material will be changed. The cell index is preceded by a sign which flags surface 2 or surface 3. If it is negative, surface 2 is indicated; if it is positive, surface 3 is indicated. The second value is the material index which applies. The above example indicates that material 2 optical properties will be on surface 2 of cell 13 and surface 2 of cell 14.

To terminate STREAM input, two more input sections are used:

END

STOP

,1/

The following guide will be useful to users of STREAM.

STREAM INPUT

LABel

,0,1/
first title card
second title card

UNIts

,1,0,0,1/ for geometry section (only) in inches

SOUrce

,1,3
,NRMAX,NWAVES,NCCMAX,NCSMAX,NCRMAX,NTIMES
,NDMAX,NPLOT,MAXRAY,NSTEPS,NTOTAL,NORDER,NSCAT,NMMAX,NTORUS/
,RMIN,RMAX,ZMIN,ZMAX,RDIR,0,ZDIR/ Source plane and reference direction

,μ_1,p_1,μ_2,p_2, . . . ,μ_{NCSMAX},p_{NCSMAX}/source angular distribution

,f_1,f_2, . . . ,f_{NWAVES}/mirror fraction

,n_1,k_1,n_2,k_2, . . . ,n_{NWAVES},k_{NWAVES}/

Repeat the last two cards if NCCMAX > 1

Repeat the entire combination of cards 4 and 5 if NMMAX $\geq$ 2.

,μ_1,p_1,μ_2,p_2, . . . ,μ_{NCRMAX},p_{NCRMAX}/diffuse reflection angular distribution

,NRMAX,4,1,1/two detector locations

,0, . . . ,$t_{NTIMES+1}$/time bin limits

C Geometry

,r_{low},z_{low},r_{high},z_{high} (1st face)

. . . .

. . . .

,r_{low},z_{low},r_{high},z_{high} (last face)

Insert NTORUS cards in the above geometry with the form:

,0,±,r',z';

If NMMAX > 2, insert card with as many pairs as required.

```
,± cell number, material number
    .
    .
    .
,± cell number, material number/
END
STOP
,1/
```

SECTION III

INTERPRETATION OF OUTPUT

STREAM produces both printed and plotted output. The plotted output comes out on microfiche. The printed output includes the geometry outline and the printed plots of several sample particle tracks. These print plots are in pairs: r-z coordinates, then r-θ coordinates. A crossing summary which describes how much energy entered and exited each surface of each cell in the geometry is included. The last set of output is the most important; it has detector results listed both by time bin and by number of collisions needed to score at that detector. This output is in column pairs. The left column of each pair has the outputted result for each wavelength, and the right-hand column has the corresponding error bar. At the top of each pair of columns, the mirror fraction is listed along with the index of refraction and extinction coefficient for the wavelength and material. Totals are tabulated for each column. The order of the "By Collision" output is determined chronologically in the code by the order in which successful hits on each detector occur. Figure 3 has a sample of the order of scatter edit. Figure 4 is a sample microfiche plot of a z-cross section chamber with three baffles.

STREAM PROGRAM — FOUR BAFFLES--STRAIGHT CHAMBER
MASTER FILE(75) — 100% SPECULAR DISTRIBUTION

OUTPUT FOR CELL AND SIDE 21 4,TIME TRANSLATE= 2.6121E-10

TIME DEPENDENT SET 1

T-BIN	TIME	1=WAVE	ERROR	2=WAVE	ERROR
		1.00E+00=MIRROR		1.00E+00=MIRROR	
		1.05E+00=N		9.50E-01=N	
		7.00E-01=K		7.80E-01=K	
1	1.00E-09	7.73E-09	1.63E-01	4.18E-08	1.57E-01
2	2.00E-09	6.75E-22	4.47E-01	1.39E-19	4.11E-01
3	3.00E-09	0.	0.	0.	0.
	TOTALS	7.73E-09	1.63E-01	4.18E-08	1.57E-01

AND BY COLLISION

13		1.68E-13	1.49E-01	3.79E-12	1.48E-01
19		4.25E-18	1.37E-01	3.74E-16	1.32E-01
15		3.73E-15	1.69E-01	1.33E-13	1.65E-01
18		3.61E-17	1.30E-01	2.35E-15	1.27E-01
16		2.60E-15	9.22E-02	1.08E-13	9.03E-02
12		1.82E-12	1.41E-01	3.05E-11	1.39E-01
29		7.08E-27	3.87E-01	5.82E-24	3.32E-01
21		4.61E-20	1.99E-01	6.71E-18	1.91E-01
24		6.18E-22	2.09E-01	1.47E-19	1.94E-01
9		4.65E-10	1.31E-01	3.84E-09	1.31E-01
14		1.14E-13	9.08E-02	2.95E-12	8.95E-02
22		1.10E-20	2.94E-01	1.68E-18	2.72E-01
23		1.50E-21	2.56E-01	3.21E-19	2.38E-01
28		1.11E-25	6.31E-01	6.06E-23	5.75E-01
7		7.12E-09	1.77E-01	3.70E-08	1.77E-01
11		1.48E-12	2.37E-01	2.12E-11	2.36E-01
17		1.88E-16	1.38E-01	1.01E-14	1.36E-01
25		2.42E-23	3.32E-01	8.16E-21	3.13E-01
30		1.12E-26	5.66E-01	7.87E-24	5.24E-01
26		4.88E-24	4.25E-01	1.77E-21	3.90E-01
20		5.20E-19	2.16E-01	5.15E-17	2.08E-01
27		3.75E-25	3.87E-01	2.11E-22	3.59E-01
8		1.40E-10	5.87E-01	9.20E-10	5.73E-01
10		6.69E-13	5.77E-01	8.07E-12	5.77E-01
	TOTALS	7.73E-09	1.63E-01	4.18E-08	1.57E-01

Figure 3. A Sample of a Typical Order of Scatter Edit.

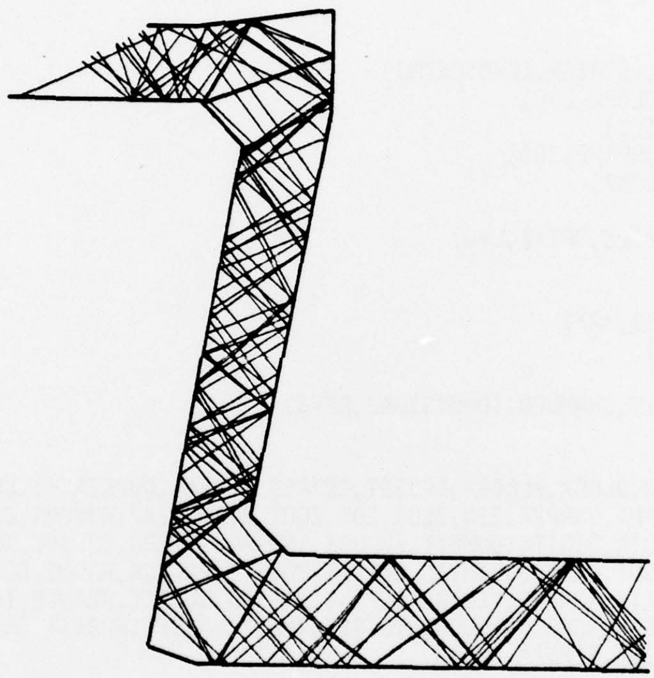

Figure 4. Typical Microfiche Output.

SECTION IV

STREAM ACCESS

The program STREAM may be accessed three ways. A permanent file of the STREAM OLDPL is available on the CDC 7600 computer, a deck of cards is available in the X-Ray Simulation Branch's terminal room, and a copy of the STREAM OLDPL is available on tape BF98 which has the label STREAM.

To access STREAM and run it, the following control cards are used:

```
JOB CARD
ACCOUNT CARD
ATTACH (OLDPL,STREAM,ID=DYSXTMJ)
UPDATE (K,P=OLDPL,L=0)
REWIND (COMPILE)
ATTACH (FTNCOMP4P2L383)
LIBRARY (FTNCOMP)
RFL (160000)
FTN (A,I=COMPILE,OPT=2,L=0)
REDUCE.
LIBRARY.
REQUEST (TAPE9,*PF)
LDSET (MAP=0)
LGO.
CATALOG (TAPE9,CHAMBER,ID=DYSXJAJ,RP=3)
7/8/9
*IDENT FIXIT
*COMPILE MAIN,BLOCK,BLOCKV,ARGSET,GETARG,DUPEMA,DUPEZA,FILLMA,FILLZA
*COMPILE SWAPMA,SWAPZA,ZIN,ZLOG,ZOS,ZQRT,ZTAN2,ZXP,MOVEMA,ZEROUT
*COMPILE CARDIN,DIGIT4,DUMPIT,ERRORS,INTVAL,INTWRD,IOLINE,KOMMON,LABEL
*COMPILE LABOUT,LASTEQ,LIMVAL,LINSET,MOVETT,PACKUN,RANNO,ROTATC,ROTATE
*COMPILE ROTATX,SCALER,VECTOR,DEFINE,MASTER,READIT,HEADER,IARRAY,ICHECK
*COMPILE JCHECK,KCHECK,TABCON,TOCSET,INDEX,LABSET,BOOTIT,DATBAS,DATRUN
*COMPILE BYLINE,STREAM,HELIX
7/8/9
INPUT DECK
6/7/8/9
```

The tape 9 file, which is cataloged at the end of the control card STREAM, contains the raw data which are used for generating two dimensional microfiche plots. The tape 9 file was specified by NPLOT on the SOUrce option card.

SECTION V

MICROFICHE PLOTS

A program called FISHY is used to generate the microfiche plots of photon paths in the chamber geometry. This program gets its input from the permanent file CHAMBER which contains the TAPE9 file created by STREAM. It needs the DYSPLOTLIB to use in generating the microfiche plots.

The following control cards are needed to run FISHY:

```
JOB CARD
ACCOUNT CARD
FTN(A,OPT=2,L=0)
ATTACH(DYSPLOTLIB,ID=DYSXBBB)
LIBRARY (DYSPLOT)
ATTACH (TAPE1,CHAMBER,ID=DYSXJAJ,CY=1)
REWIND (TAPE1)
FILE (JAJFIS,RT=S)
LABEL (JAJFIS,L=CHAMBER)
REQUEST (JAJFIS,PE,E,VSN=HG71)
MAP (ON)
LGO.
7/8/9
FISHY DECK
6/7/8/9
```

In the above case, the microfiche tape that is being generated is HG71. Any nine-track tape may be substituted on the REQUEST card.

A listing of FISHY follows:

```
LOADER VERSION 1.0   06/24/76  07.10.52   PAGE    1

SCM LENGTH      5173          LCM LENGTH          0

          S C O P E   2   L O A D   M A P

 PROGRAM  WILL BE ENTERED AT  LIST1       (   145)

          BLOCK          ADDRESS    LENGTH

          LIST1             100        422
           /STP.END/        522          1
           /FCL.C./         523         23
           /Q8.IO./         546        136
          Q8NTRY=           704          1
          COMIO=            705         44
          EOF               751         24
          FECMSK=           775         41
          FLTIN=           1036        154
          FLTOUT=          1212        315
          FMTAP=           1527        372
          FORSYS=          2121        557
          FORUTL=          2700         16
          GETFIT=          2716         43
          INCOM=           2761        256
          INPC=            3237        173
          KODER=           3432        467
          KRAKER=          4121        454
          OUTC=            4575        171
          OUTCOM=          4766        204
          SYSAID=          5172          1
```

```
      PROGRAM FISHY(INPUT,OUTPUT,JAJFIS,FILMPL=JAJFIS,TAPE1)
      COMMON/01/R(100),Z(100),N,DIST,R1(99),Z1(99),R2(99),Z2(99),N1,N2
      COMMON/C2/    RMIN,RMAX,ZMIN,ZMAX
      CALL INITPLT
      NUM=0
      NPQ=20
      CALL TWO
      CALL SETUP
      CALL FRAME
 10   CONTINUE
      KLM=0
      NUM1=0
      CALL SETUP
 15   CONTINUE
      KLM=KLM+1
      READ(1,11) N,DIST
      IF(EOF(1)) 20,21
 20   CONTINUE
      PRINT 19,NUM,NUM1
      STOP
 19   FORMAT(1X,*NUMBER OF FRAMES PLOTTED = *,I5,* NUMBER OF PATHS LEFT
     1= *,I5)
 21   CONTINUE
      READ(1,12) (R(I),Z(I),I=1,N)
 11   FORMAT(I10,E10.3)
 12   FORMAT(8E10.3)
      CALL TRACE(R,Z,N)
      NUM1=NUM1+1
      IF(KLM.LT.NPQ) GO TO 15
      NUM=NUM+1
      GO TO 10
      END
```

```
      SUBROUTINE TWO
      COMMON/01/R(100),Z(100),N,DIST,R1(99),Z1(99),R2(99),Z2(99),N1,N2
      COMMON/02/   RMIN,RMAX,ZMIN,ZMAX
   11 FORMAT(I10,E10.3)
   12 FORMAT(8E10.3)
      READ(1,11) N1,DIST
      IF(N1.GT.99.OR.N1.LT.1)  STOP101
      READ(1,12) (R1(I),Z1(I),I=1,N1)
      READ(1,11) N2,DIST
      IF(N2.GT.99.OR.N2.LT.1) STOP102
      READ(1,12) (R2(I),Z2(I),I=1,N2)
      RMIN=RMAX=R1(1)
      ZMIN=ZMAX=Z1(1)
      DO 5 I=1,N1
      RMIN=AMIN1(RMIN,R1(I))
      RMAX=AMAX1(RMAX,R1(I))
      ZMIN=AMIN1(ZMIN,Z1(I))
      ZMAX=AMAX1(ZMAX,Z1(I))
    5 CONTINUE
      DO 6 I=1,N2
      RMIN=AMIN1(RMIN,R2(I))
      RMAX=AMAX1(RMAX,R2(I))
      ZMIN=AMIN1(ZMIN,Z2(I))
      ZMAX=AMAX1(ZMAX,Z2(I))
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SETUP
      COMMON/01/R(100),Z(100),N,DIST,R1(99),Z1(99),R2(99),Z2(99),N1,N2
      COMMON/02/   RMIN,RMAX,ZMIN,ZMAX
      DIMENSION ALABLE(3)
      DO 10 I=1,3
      ALABLE(3)=1H
10    CONTINUE
      CALL FRAME
      CALL SETCH(15.,1.,1,0,1,0,0)
      ENCODE(25,20,ALABLE)
20    FORMAT(25HUV PATHS IN SHIVA CHAMBER)
      CALL WOT100(ALABLE,31)
      CALL MAP(RMIN,RMAX,ZMIN,ZMAX,.12,1.,.12,1.)
      CALL TRACE(R1,Z1,N1)
      CALL TRACE(R2,Z2,N2)
      RETURN
      END
```