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TWODIM, a Computer Code for Unfolding  
Diametral Gamma-Ray Scans on Reactor Fuel Elements



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# TWODIM, a Computer Code for Unfolding Diametral Gamma-Ray Scans on Reactor Fuel Elements

by

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TWODIM, A COMPUTER CODE FOR UNFOLDING  
DIAMETRAL GAMMA-RAY SCANS ON REACTOR FUEL ELEMENTS

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ABSTRACT

A computer code has been written to accept one or more diametral scans taken at different angles around the outside of a fuel element and use this information to determine the distribution of the measured isotope over a cross section of the fuel element. The calculated distribution is plotted both as an isometric projection plot and as a density plot. Fission-product distributions calculated with this code were compared to actual distributions measured on thin cross sections of the fuel.

INTRODUCTION

The most common forms of gamma-ray scans made on reactor fuel elements are the axial and diametral scans. These are scans made from outside the fuel element along the major axis or across the major axis of the fuel element. For the axial scan, changes in the gamma-ray intensity are relatively simple to relate to variations in the amount of the particular isotope being considered. This is so because, in general, the detector is looking at practically a constant amount of fuel in each position as the fuel element is moved in front of the detector. For the diametral scan, on the other hand, variations in intensity are caused by changes in either the isotopic composition of the fuel, the amount of fuel being observed by the collimated detector, or the gamma-ray absorption. This makes interpretation of the diametral scans more difficult. The information desired is the distribution of the isotope over a cross section of the fuel element taken at the location of the diametral scan. While a single diametral scan yields insufficient information to determine this uniquely, an approximation to the distribution may be determined from a single scan. Two or more diametral scans made at different angles around the fuel element improve the approximation of the calculated distribution to the actual isotopic distribution.

PROCEDURE

Two techniques were considered for unfolding the diametral scans to two-dimensional distributions. The first was to subdivide the face of the fuel element cross section into an  $N \times N$  matrix and assume a uniform intensity over each individual  $N \times N$  square element in the face of the section. This would then be treated as a system of  $N^2$  unknowns, and a sufficient number of scans would be made at different angles to yield a total of  $N^2$  separate intensity measurements from outside the fuel element. Each measurement could then be written as a sum of the  $N^2$  intensities across the fuel element, each intensity multiplied by its individual geometrical factor to take into account the collimation of the detector and the absorption of the gamma ray by the fuel element between the point of origin of the gamma rays and the detector. This technique would result in a system of  $N^2$  equations in  $N^2$  unknowns, which could be solved by matrix inversion or elimination techniques to determine the intensities of gamma-ray production and hence the isotope concentrations for each small area.

Although this appears to be the most straightforward technique, it was not used for several reasons. A typical diametral scan across a fuel element may consist of 100 points. To preserve this

accuracy across the sectional face of the fuel element would involve a 100 x 100 matrix or solving a set of 10,000 equations in 10,000 unknowns. Measurements of the intensity would have to be made at 10,000 points, for example, 100 scans of 100 points each, taken at different angles. Both the data acquisition and the data reduction would be very time consuming. The matrix and the scans must be carefully chosen to obtain a nonsingular set of equations for solution. In addition, the usual single diametral scan across a fuel element is not very suitable for calculation by this method. A 100-point scan would determine only a 10 x 10 matrix of values, which is too coarse a grid to be useful. In general, this method of solution would ignore the fact that the variations in intensity of interest are radial, with angular variations existing but not being as significant as the radial variations nor as rapidly changing.

The method actually used for data unfolding was to subdivide the scan region into a series of concentric rings of the same width as the distance between scan points on the diametral scan and to determine the intensities for this geometry. Inverting large matrices was avoided by using a technique that determined intensities at points in these rings one at a time, rather than by simultaneous solution of a set of equations.

In general, the circular scan region is somewhat larger than the diameter of the fuel element being scanned, as the data taken starts off the fuel on one side of the element and goes past the edge of the fuel on the other side of the element. One requirement is that the scan region must be centered on the fuel element, that is, must extend the same distance left and right from the centerline of the fuel element. In the event that this centerline is not known, provision is made to attempt to select a centerline from a single scan by symmetrical considerations.

The details of a diametral scan consisting of eight scan points (rather than the typical 100) are indicated schematically in Fig. 1. The figure is a cross-section drawing with the diametral scan in the plane of the figure. The cross-hatched circle is the fuel element being scanned, which extends above and below the plane of the figure. A typical diameter for fuel elements scanned is 0.25 in.

The detector typically is collimated to view 0.004 in. along the scan direction (in the plane of the figure) and 0.5 in. perpendicular to the scan direction (perpendicular to the plane of the figure). The dashed circles indicate the scan region which would be taken and how it would be subdivided for analysis. The horizontal dashed lines indicate the position of the right edge of the collimator (looking at the fuel element through the collimator) for each scan point. Typically, these scan points are separated by 0.003 in.

The procedure for the reduction of the data is to determine the intensities of the various rings of the scan region, one ring at a time, starting at the outside and working toward the center. Two points are taken from each scan for each ring. For the example shown in Fig. 1, the points labeled 1 and 8 would be used to determine intensities at two points on the outside ring. This is done by using a Monte Carlo technique to evaluate the average absorption over the area of the ring that can be observed by the collimated detector. Note that for points 1 and 8, only areas within the outer ring can be viewed by the detector. A number of points within this observed area are randomly chosen, and the absorption of the gamma rays in traveling from each of these points to the edge of the fuel element is calculated. An average absorption factor is calculated. The area of the fuel element observed by the detector is determined by the same

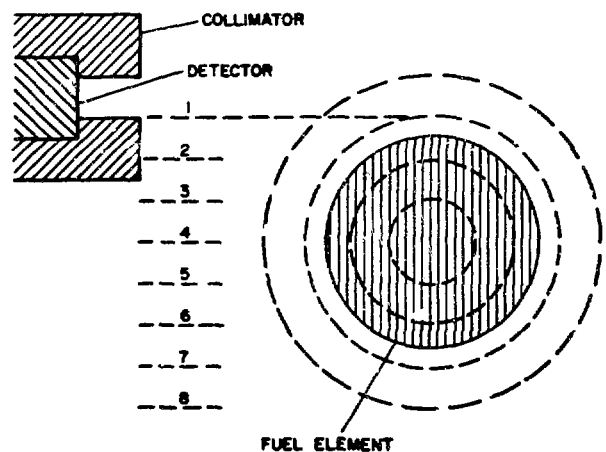


Fig. 1. A typical diametral scan, showing detector, fuel element, and regions used to analyze the data.

Monte Carlo technique. The observed intensity is corrected for absorption and divided by the area to get the intensity per unit area for the two points on the outside ring. These two points, together with any others determined by other scans taken at different angles around the element, are fitted as a function of angle with a spline function by a least squares technique. Thereafter, the intensity of the gamma-ray production around this outer ring is assumed to be known as a function of angle. The intensities in the second ring are calculated using this knowledge of the intensity per unit area from the first ring and points 2 and 7 from Fig. 1. In the case of the second ring and all subsequent rings, the Monte Carlo technique is used to evaluate the contribution from the known rings in the area viewed by the detector, as well as the gamma-ray absorption and the area of the unknown region. By the way the rings and scan points are chosen, there is, in each case, only one unknown region, together with one or more regions for which the intensity is known as a function of angle, thus allowing the intensity of the unknown region to be calculated. Additional intensities are again calculated from any other scans taken at different angles. Again, these points are fitted as a function of angle by the least squares spline fitting function. Thereafter, the intensities of the first and second rings are assumed to be known as a function of angle. This allows intensities to be calculated in the third ring. This procedure is continued until the intensities of all the rings are known as a function of angle. In general, each ring has  $2N$  data points where  $N$  is the number of scans made at different angles around the fuel element. The case  $N = 1$  (a single scan), however, is treated as a special case, and each ring is given four data points by a linear interpolation technique. As this procedure is followed, any error (statistical or systematic) in the determination of intensities in the first rings is carried through into the determination of the intensities on the inner rings. Thus, this technique leads to larger uncertainties for the intensities in the interior of the fuel element than on the exterior. As the intensities have larger uncertainties as one proceeds toward the interior of the fuel element, the least squares spline fitting is used as a smoothing function,

with the degree of smoothing becoming greater as one proceeds toward the interior of the fuel element. This is accomplished by reducing the number of knots of the spline function fitted to the data that has the effect of reducing the free parameters in fitting the spline functions. The spline function fitting program uses the SMOOTH code package (Los Alamos Scientific Laboratory Library Subprogram E203A).\*

After determining the intensities, the program allows the option of using the least squares spline function to resmooth the data in a radial direction from the center to the edge of the fuel element. If this option is selected, spline functions are fitted to sets of data points consisting of one data point from each ring, each set of points being along one radius. These fits are made to as many radii as there are data points in the rings ( $2N$ , in general). The smoothing is effected by fitting a spline function with nine-tenths as many knots as there are data points.

The programs used to plot the results have been described previously,<sup>1</sup> except that the main program (TWOP) was changed to a subroutine (with no arguments) so that it could be called by TWODIM to plot the results. Because TWOP requires a square matrix of data points, the gamma-ray intensity at each point of a  $64 \times 64$  matrix is calculated from the spline function fits as a function of angle and radius. After calculating this square matrix of intensities, it is written on magnetic tape by subroutine TW, and TWOP is called to plot the data both as an isometric projection plot and as a density plot.

#### CODES

The computer code consists of the main program, TWODIM, and six subroutines (Appendix A). An additional eight subroutines are used to plot the results (Appendix B).

#### Program TWODIM

The main program, TWODIM, reads the input data and performs the calculations to unfold the scans

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\* Copies of all Los Alamos Scientific Laboratory Library Subprograms referenced in this report may be obtained by writing C Division, Los Alamos Scientific Laboratory.

to distributions. The intensities as a function of position for the selected gamma ray are taken from magnetic tape. A listing of this program, together with subroutines and typical data, is given in Appendix A. The required input data and formats for card input are given in Table I.

TABLE I  
INPUT FOR TWODIM

Card Number	Variables	Format
1	ITITLE	8A10
2	ADS,RR,AMPS,AMOC	6F12.2
3	NSCAN,NPPSCN,NDPSCN	12I6
4 to (4+NSCAN-1)	REC,RECP	6F12.2

ITITLE is any title desired, up to 80 characters in length, and is printed with the results.

ADS is the gamma-ray adsorption coefficient for the material of the fuel element and for the particular gamma-ray energy being considered. This must be in units of  $\text{mils}^{-1}$  (1/0.001 in.).

RR is the radius of the fuel element being scanned and must be in units of mils (0.001 in.). It is used in calculating the adsorption for the gamma rays in the fuel element.

AMPS is the number of mils per scan point, that is, the number of mils advanced between each scan point taken.

AMOC is the width of the collimator in mils and is measured in the plane of the scan.

NSCAN is the number of scans taken at different angles and must be greater than or equal to 1.

NPPSCN is the number of points per scan, that is, the number of steps taken in one scan across the fuel element. Scans at various angles around the fuel element must have the same number of points in each scan.

NDPSCN is the number of degrees between successive scans at different angles. The program assumes successive scans are made at regular angle increments. Thus, if NDPSCN=45 and NSCAN=4, the program would assume scans were made at 0°, 45°, 90°, and 135°. This is illustrated in Fig. 2. NSCAN\*NDPSCN must be less than 180°.

REC is the record number of the first record on magnetic tape that contains the first point of the scan.

RECP is the record number of the record on magnetic tape containing the last point of the same scan. If RECP=0, the records from REC to REC+NPPSCN-1 are taken to the records on magnetic tape containing the points (measured gamma-ray intensities) of the scan. This can be centered on the fuel element. If RECP≠0, the region from REC to RECP is taken to contain the scan, but it is not assumed that the region is centered on the fuel element. A scan center is chosen by the computer on the basis of symmetry, and the scan is taken to be the longest series of points which can be centered around this scan center and stay within the region between REC and RECP. The option to have the computer locate the center of the fuel element must be used with caution because the physical center of the fuel element is not necessarily the center of symmetry of the distribution of the gamma-ray-producing isotope.

The scan data points are taken from magnetic tape and are in the form of one record per scan point. Each record may contain several measured intensities for different gamma-ray energies. The format of the statement reading

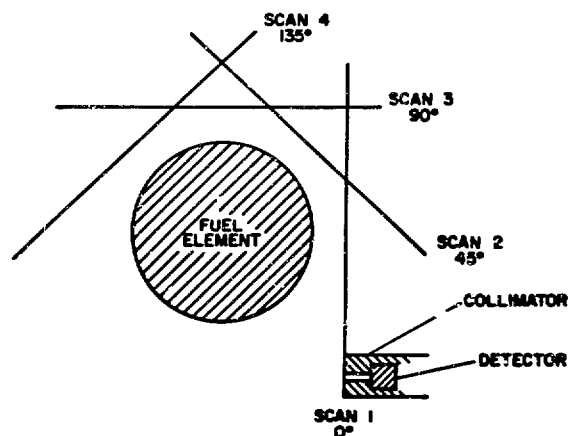


Fig. 2. A typical series of four scans with 45° of rotation between the scans. The lines represent the path of the collimated detector in making the scans. The detector is collimated to view a narrow portion of the fuel element.

the magnetic tape, together with the data list, is easily changed to be compatible with any data. This change is made by changing Card 85, a read statement in program TWODIM (Appendix A), and Card 464 (Format 81), the format used by the read statement. At present, two data tag numbers (ITAG1, ITAG2), the record number (IREC), and three gamma-ray intensities [SUM(1), SUM(2), SUM(3)] are read. The gamma-ray intensity to be used is determined by the value of the variable N, which is set by Card 63 (Appendix A). If N=1, SUM(1) is used, if N=2, SUM(2) is used, etc. The input data for the plot routines has been described.<sup>1</sup>

## RESULTS

The program TWODIM was tested using three known isotopic distributions. These distributions were known from previous two-dimensional scans of a thin section of fuel that was excised from the fuel element. The data represented three distinct distributions in the form of density plots to allow the comparison of the results with the results obtained by ring unfolding. The known distributions were added along the X and Y axes to convert the known two-dimensional scans into two one-dimensional projections, simulating the scans obtained by diametral scanning at 0° and 90° rotation. These projections are identical to the data that would be obtained if the fuel element were diametrically scanned and if there were no absorption of the gamma-ray intensity. The projections used for listing the program are shown in Figs. 3 through 8. Figures 3 and 4 show the distribution of the <sup>95</sup>Nb isotope that would have resulted if the fuel element had been routinely scanned. The distributions of <sup>106</sup>Rh and <sup>137</sup>Cs are shown in Figs. 5 through 8, respectively. The program TWODIM unfolded concentric rings in the projections to generate a 4096-point matrix (64 x 64) which was plotted as both isometric projections and density plots.

The results are shown in Figs. 9 through 14 and should be compared to the known distributions shown in Figs. 15a, b, and c. The density plots of the uniformly distributed <sup>95</sup>Nb isotope calculated from TWODIM (Fig. 9) and from the known

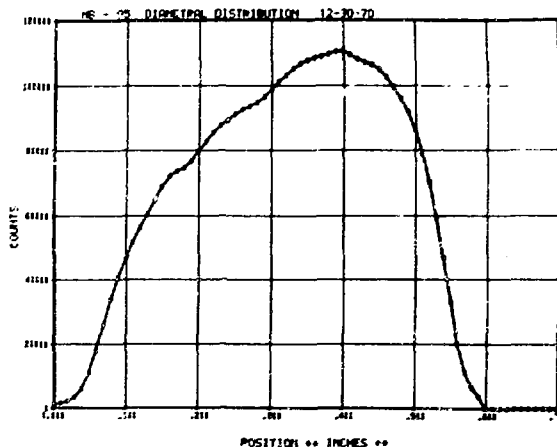


Fig. 3. <sup>95</sup>Nb diametral distribution taken at 0°.

results (Fig. 15a) are nearly identical. The most difficult of the three isotopes was the <sup>106</sup>Rh distribution that was concentrated in a ring offset from the true center. The density plot from ring unfolding (Fig. 11) shows the same distribution as the known distribution (Fig. 15b).

The <sup>137</sup>Cs distribution Figs. 13 and 15c was chosen to show that, if the isotope were concentrated on the outside surface, the program would function normally when calculating the center region.

## CONCLUSIONS

The comparison of the calculated isotopic distribution and the known distributions indicates that, in many cases, it is not necessary to section a fuel element to determine the radial distributions of fission products in the fuel matrix. To obtain

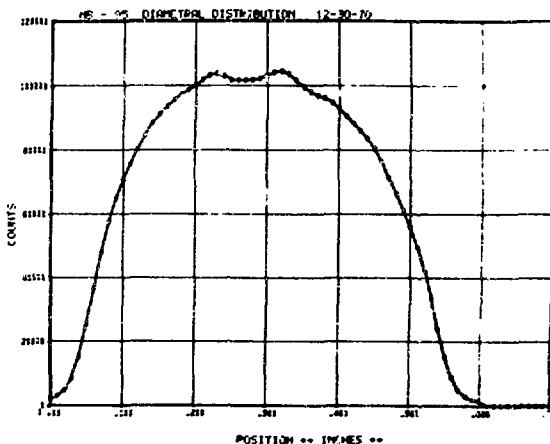


Fig. 4. <sup>95</sup>Nb diametral distribution taken at 90°.



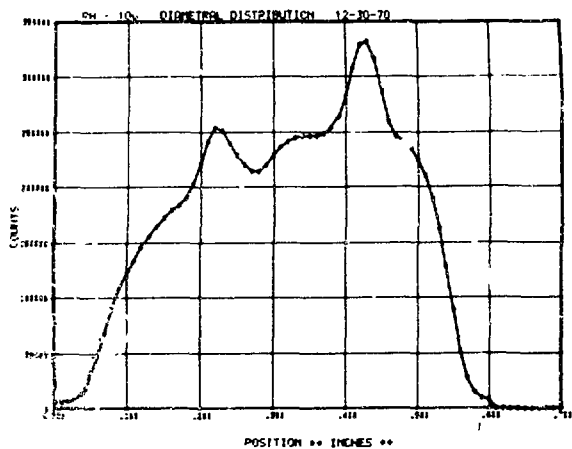


Fig. 5.  $^{106}\text{Rh}$  diametral distribution taken at  $0^\circ$ .

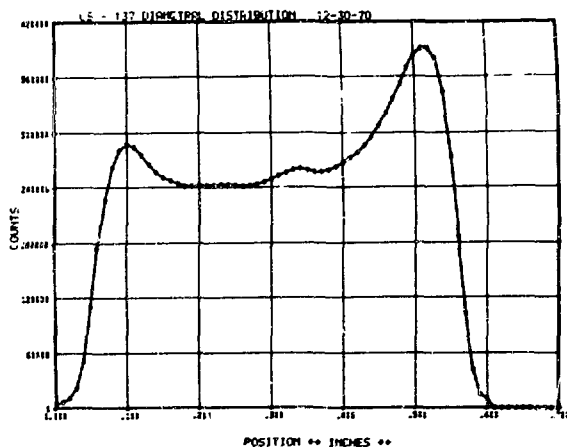


Fig. 7.  $^{137}\text{Cs}$  diametral distribution taken at  $0^\circ$ .

the necessary data for TWODIM, a fuel element has only to be gamma scanned at one or more different rotations. The isotopic distributions are then calculated and plotted as isometric projections and densit, plots.

#### ACKNOWLEDGMENTS

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#### REFERENCE

1. B. K. Barnes and W. M. Sanders, "Computer Codes for Presentation, Interpolation, and Integration of Two-Parameter Data," LA-4326, Los Alamos Scientific Laboratory (1969).

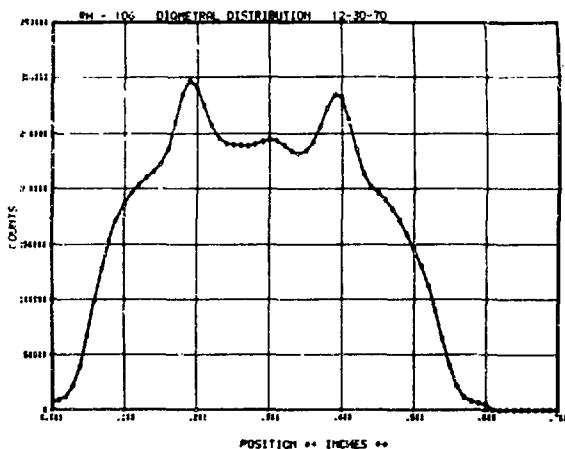


Fig. 6.  $^{106}\text{Rh}$  diametral distribution taken at  $90^\circ$ .

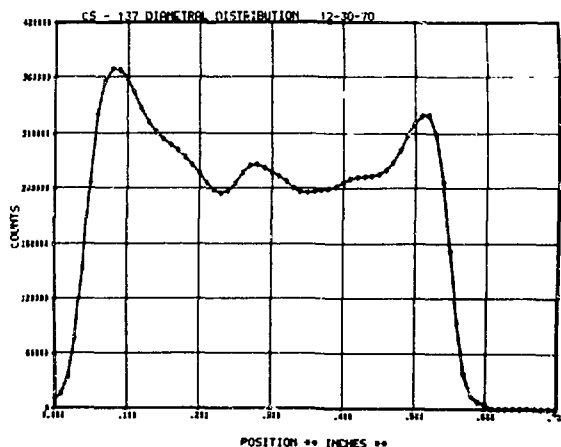


Fig. 8.  $^{137}\text{Cs}$  diametral distribution taken at  $90^\circ$ .

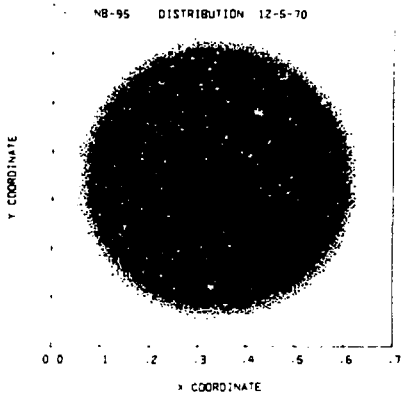


Fig. 9. Density plot of  $^{95}\text{Nb}$  calculated from TWODIM.

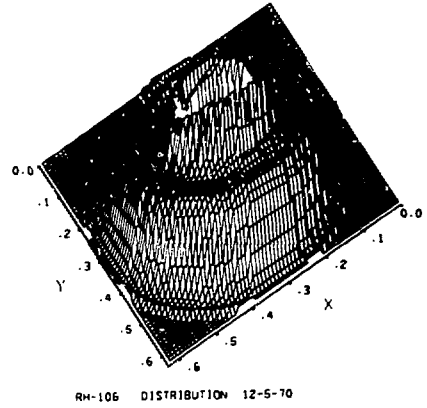


Fig. 12. Isometric projection of  $^{106}\text{Rh}$  calculated from TWODIM.

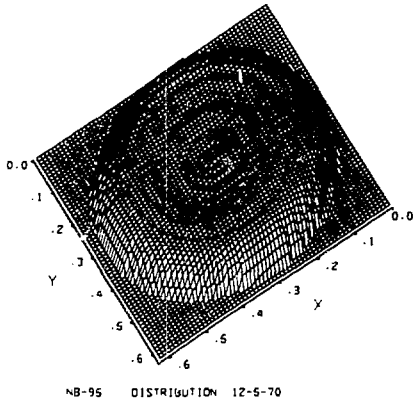


Fig. 10. Isometric projection of  $^{95}\text{Nb}$  calculated from TWODIM.

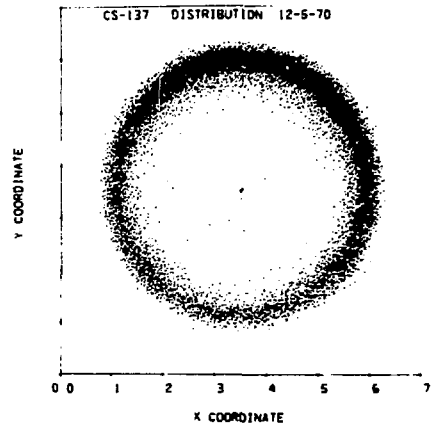


Fig. 13. Density plot of  $^{137}\text{Cs}$  calculated from TWODIM.

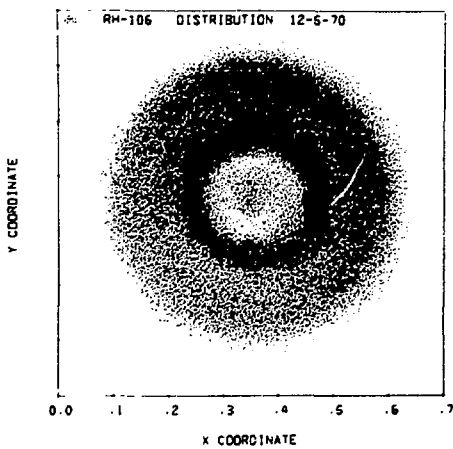


Fig. 11. Density plot of  $^{106}\text{Rh}$  calculated from TWODIM.

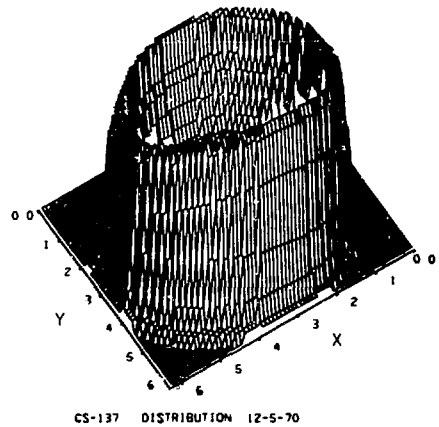


Fig. 14. Isometric projection of  $^{137}\text{Cs}$  calculated from TWODIM.

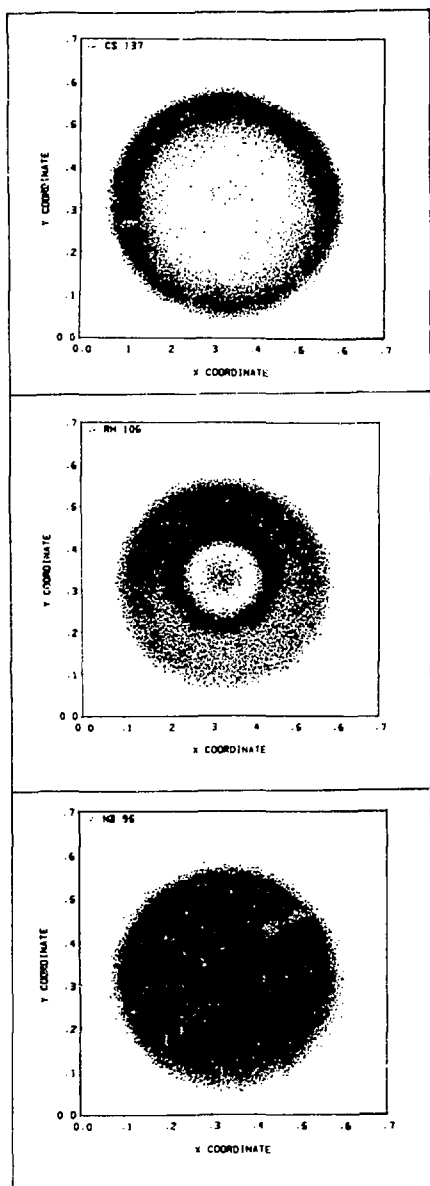


Fig. 15a,b,c. Density plots of the known distributions of  $^{95}\text{Nb}$ ,  $^{106}\text{Rh}$ , and  $^{137}\text{Cs}$ .

APPENDIX A

TWODIM AND SPLINE SUBROUTINES

	PROGRAM TWODIM (INPUT,OUTPUT,BGSB,TAPE7,TAPE2,FILM,TAPE10=INPUT,TA	TWOD	
	IPE9=OUTPUT,TAPE12=FILM)	TWOD	1
	DIMENSION SCAN(10,110), RAND(12100), ANG(10,110), TITLE(8), SUM(3)	TWOD	2
	I, A(10,110), W(10,110), NOPTF(110)	TWOD	3
	COMMON NOPTF,ANG,A,W,NK	TWOD	4
	COMMON /W/ M,TITLE,XS,DELX,YS,DELY,RAND	TWOD	5
	CALL TW	TWOD	6
C	0.002355 MILLS-1 ZR-NB-95 765KEV 85/15 UC/PUC + 10W/O M2C3	TWOD	7
C	0.002837 MILLS-1 RH-106 622KEV 97 0/0 THEORECTICAL (13.6G/CM3)	TWOD	8
	DO 2 J=1,10	TWOD	9
	DO 1 K=1,110	TWOD	10
	A(J,K)=0.	TWOD	11
	W(J,K)=0.	TWOD	12
1	CONTINUE	TWOD	13
2	CONTINUE	TWOD	14
	DC=48000.	TWOD	15
	DCSQ=DC*DC	TWOD	16
C	DC IS DISTANCE FROM DETECTOR TO CENTER OF FUEL	TWOD	17
C	(IN MILLS)	TWOD	18
C	DISC BEING SCANNED IS CENTERED ON THE ORIGIN OF THE COORDINATE SY	TWOD	19
	READ (10,63)TITLE	TWOD	20
	IF (ENDFILE 10) 3,4	TWOD	21
3	CALL EXIT	TWOD	22
4	CONTINUE	TWOD	23
	WRITE (9,64)	TWOD	24
	WRITE (9,63)TITLE	TWOD	25
C	ADS IS THE GAMMA RAY ADSORPTION COEFFICIENT	TWOD	26
C	FOR THE GAMMA RAY BEING CONSIDERED IN	TWOD	27
C	THE MATERIAL OF THE FUEL ELEMENT	TWOD	28
C	THIS MUST BE IN (MILLS)**(-1)	TWOD	29
	READ (10,67)ADS,RD,AMPS,AMOC	TWOD	30
	RR=RD/2.	TWOD	31
	WRITE (9,68)ADS,RR,AMPS,AMOC	TWOD	32
	MPS=AMPS	TWOD	33
C	MOC IS WIDTH OF COLLIMATOR IN MILLS	TWOD	34
C	RR IS THE RADIUS (IN MILLS) OF THE DISC BEING SCANNED	TWOD	35
	RR2=RR**2	TWOD	36
C	MPS IS NUMBER OF MILLS BETWEEN SCAN POINTS	TWOD	37
	READ (10,65)NSCAN,NPPSCN,NDPSCN	TWOD	38
	IF (NSCAN.EQ.1) NDPSCN=90	TWOD	39
C	NSCAN IS NUMBER OF SCANS AT DIFFERENT ANGLES	TWOD	40
	WRITE (9,75)NSCAN,NPPSCN,NDPSCN	TWOD	41
C	NPPSCN IS NUMBER OF POINTS PER SCAN	TWOD	42
C	NDPSCN IS NUMBER OF DEGREES BETWEEN SCANS	TWOD	43
	PTS=5000.0	TWOD	44
C	PTS IS THE NUMBER OF POINTS USED IN MONTE CARLO CALCULATION	TWOD	45
	PCT=(SQRT(PTS)/PTS)*100.	TWOD	46
	WRITE (9,80)PTS,PCT	TWOD	47
	WRITE (9,66)	TWOD	48
C	THE FIRST SCAN IS ACROSS THE BOTTOM OF THE RESULTING TWOD MATRIX,	TWOD	49
C	LOOKING UP AT THE MATRIX. THE DATA POINTS FOR EACH SCAN	TWOD	50
C	ARE ASSUMED TO BE FROM RIGHT TO LEFT WHEN LOOKING DOWN THE	TWOD	51
C	COLLIMATOR. SUCCESSIVE SCANS ARE ASSUMED TO RESULT FROM ROTATING	TWOD	52
C	THE DETECTOR AROUND THE SAMPLE IN A COUNTERCLOCKWISE DIRECTION BY	TWOD	53
C	AMOUNT OF NDPSCN DEGREES.	TWOD	54
	ISCAN=1	TWOD	55
C	ISCAN=1 MEANS THE SCAN WAS LEFT TO RIGHT (BACKWARDS) , SO THE	TWOD	56
C	MATRIX IS LOADED IN REVERSE. ISCAN=NE. 1 MEANS THE SCAN WAS	TWOD	57
C	RIGHT TO LEFT, AS THE PROGRAM ASSUMES, SO MATRIX IS LOADED NORMALL	TWOD	58
C		TWOD	59
C	WHEN THE PIT BUILDING SCANNER SCANS FROM LOW NUMBERS TO HIGH NUMBE	TWOD	60
C	THE COLLIMATOR MOVES FROM LEFT TO RIGHT ACROSS THE SAMPLE (BACKWAR	TWOD	61
5	CONTINUE	TWOD	62
	N=2	TWOD	63
	DO 16 I=1,NSCAN	TWOD	64

	J=0	TWOD 65
	REWIND 2	TWOD 66
	READ (10,67)REC,RECP	TWOD 67
C	REC IS FIRST RECORD OF SCAN	TWOD 68
C	RECP IS LAST RECORD OF SCAN	TWOD 69
C		TWOD 70
C	IF ONLY ONE RECORD IS GIVEN, PROGRAM ASSUMES YOU HAVE LOCATED THE	TWOD 71
C	CENTER OF THE ELEMENT BEING SCANNED AND CENTERED THE REGION GIVEN	TWOD 72
C	BY THE STARTING POINT REC AND NPPSCN AROUND THIS CENTER OF THE	TWOD 73
C	ELEMENT. IF, HOWEVER TWO RECORD NUMBERS ARE GIVEN, THE PROGRAM TA	TWOD 74
C	THESE TO BE THE FIRST AND LAST RECORDS OF THE SCAN AND ATTEMPTS TO	TWOD 75
C	LOCATE THE CENTER OF THE FUEL ELEMENT ITSELF AND SET UP A REGION O	TWOD 76
C	LENGTH NPPSCN AROUND THIS CENTER OF THE FUEL ELEMENT.	TWOD 77
	IF (ENDFILE 10) 6,7	TWOD 78
6	CALL EXIT	TWOD 79
7	CONTINUE	TWOD 80
	WRITE (9,67)REC,RECP	TWOD 81
	IF (RECP.EQ.0.) GO TO 12	TWOD 82
C	LOCATING CENTER OF SYMMETRY OF SCAN	TWOD 83
	M=0	TWOD 84
	READ (2,78)ITG1,ITG2,IREC,SUM(1),SUM(2),SUM(3)	TWOD 85
	IF (IREC.GE.IFIX(REC)) REWIND 2	TWOD 86
	BACKSPACE 2	TWOD 87
	IREC=0	TWOD 88
8	CONTINUE	TWOD 89
	READ (2,78)ITG1,ITG2,IREC,SUM(1),SUM(2),SUM(3)	TWOD 90
	IF (IREC.LT.IFIX(REC)) GO TO 8	TWOD 91
	IF (IREC.GT.IFIX(RECP)) GO TO 9	TWOD 92
	M=M+1	TWOD 93
	RAND(M)=SUM(N)	TWOD 94
	GO TO 8	TWOD 95
9	CONTINUE	TWOD 96
	ASUM=1.E+320	TWOD 97
	M4=M/4	TWOD 98
	M41=M4- 1	TWOD 99
	M34=M*3/4	TWOD 100
	DO 11 J=M4,M34	TWOD 101
	BUM=0.	TWOD 102
	DO 10 K=1,M41	TWOD 103
	BUM=BUM+(RAND(J- K)- RAND(J+K))**2	TWOD 104
10	CONTINUE	TWOD 105
	IF (ASUM.LT.BUM) GO TO 11	TWOD 106
	ASUM=BUM	TWOD 107
	JCENT=J	TWOD 108
11	CONTINUE	TWOD 109
C	JCENT IS THE J VALUE FOR WHICH FOLDING THE SPECTRUM AROUND J	TWOD 110
C	MINIMIZES THE DIFFERENCE BETWEEN THE TWO SIDES.	TWOD 111
	REC=REC+JCENT- NPPSCN/2	TWOD 112
	REWIND 2	TWOD 113
12	CONTINUE	TWOD 114
	WRITE (9,67)REC	TWOD 115
	IRECS= 1	TWOD 116
	J=0	TWOD 117
13	CONTINUE	TWOD 118
	READ (2,79)ITG1,ITG2,IREC,SUM(1),SUM(2),SUM(3)	TWOD 119
14	CONTINUE	TWOD 120
	IRECS=IRECS+1	TWOD 121
	IF (IREC.LT.IFIX(REC)) IRECS=IREC- 1	TWOD 122
	IF (IREC.LT.IFIX(REC)) GO TO 13	TWOD 123
	J=J+1	TWOD 124
	K=J	TWOD 125
	IF (ISCAN.EQ.1) K=NPPSCN- J+1	TWOD 126
	L=K- 1	TWOD 127
	IF (ISCAN.EQ.1) L=K+1	TWOD 128
	IF (IREC.EQ.IRECS+1) GO TO 15	TWOD 129
	SCAN(I,K)=SCAN(I,L)	TWOD 130
	GO TO 14	TWOD 131
15	CONTINUE	TWOD 132
	N=2	TWOD 133
	SCAN(I,K)=SUM(N)	TWOD 134
	IF (IREC+1.LT.IFIX(REC)+NPPSCN) GO TO 13	TWOD 135
	WRITE (9,81)(SCAN(I,K),K=1,J)	TWOD 136

16	CONTINUE	TWOD 137
C	SCAN(I,J) ARE INTENSITIES MEASURED FOR SCAN POINTS	TWOD 138
	R=FLOAT(NPPSCN*MPS)/2.	TWOD 139
	WRITE (9,74)R	TWOD 140
C	R IS RADIUS OF SCAN REGION	TWOD 141
	DA=2.*R*AMOC/PTS	TWOD 142
C	DA IS THE DIFFERENTIAL AREA ASSOCIATED WITH EACH MONTE CARLO	TWOD 143
C	POINT. SUM(DA)=A	TWOD 144
	KF=NPPSCN-1	TWOD 145
	R2=R**2	TWOD 146
	RK=R	TWOD 147
C	RK IS THE CURRENT RADIUS OF THE KNOWN REGION. OUTSIDE	TWOD 148
C	RK, THE VALUES OF THE INTENSITIES CAN BE CALCULATED. ORIGINALLY	TWOD 149
C	THESE ARE TAKEN TO BE ZERO OUTSIDE THE SCAN REGION.	TWOD 150
	NS2=2*NSCAN	TWOD 151
	IF (NSCAN.EQ.1) NSCAN=2	TWOD 152
	DO 17 J=1,NSCAN	TWOD 153
	ANG(J)=(J-1)*NDPSCN	TWOD 154
	ANG(NSCAN+J)=180.+(J-1)*NDPSCN	TWOD 155
17	CONTINUE	TWOD 156
	IF (NS2.EQ.2) NSCAN=1	TWOD 157
	WRITE (9,69)	TWOD 158
	IF (NSCAN.EQ.1) NS2=4	TWOD 159
	WRITE (9,70)(ANG(J),J=1,NS2)	TWOD 160
	IF (NSCAN.EQ.1) NS2=2	TWOD 161
	WRITE (9,71)	TWOD 162
	WRITE (9,72)	TWOD 163
	NK=IFIX(FLOAT(NPPSCN)/2.+5)	TWOD 164
	DO 37 K=1,NK	TWOD 165
C	FOR EACH SCAN ANGLE TWO POINTS ARE TAKEN INTO CONSIDERATION FOR	TWOD 166
C	EACH PASS (INDEX K) OF THE PROGRAM. THESE ARE ONE FOR THE UPPER	TWOD 167
C	HALF OF THE DISC AND ONE FOR THE LOWER HALF OF THE DISC.	TWOD 168
	YL= R+FLOAT((K-1)*MPS)	TWOD 169
	YU=YL+AMOC	TWOD 170
C	THIS SECTION OF THE PROGRAM IS CONCERNED WITH THE LOWER HALF.	TWOD 171
C	FOR Y, L STANDS FOR LOWER EDGE OF BAND, U FOR UPPER EDGE	TWOD 172
	XL=SQRT(R2-YU**2)	TWOD 173
	IF (YU.GT.0.) XL=-R	TWOD 174
C	FOR X, L STANDS FOR THE LEFT EDGE OF THE BAND (AT ITS WIDEST POINT	TWOD 175
	FRACT=-XL/R	TWOD 176
	DELX=-2.*XL	TWOD 177
C	DELX IS THE WIDTH OF THE BAND	TWOD 178
	NP=PTS*FRACT	TWOD 179
	NR=2*NP	TWOD 180
	DO 26 J=1,NSCAN	TWOD 181
	CALL RANVECT (KAND,NR)	TWOD 182
	AK=0.	TWOD 183
	AD=0.	TWOD 184
	DO 23 L=1,NP	TWOD 185
	X=XL+DELX*RAND(L)	TWOD 186
	Y=YL+AMOC*RAND(2*L)	TWOD 187
	RC=SQRT(X**2+Y**2)	TWOD 188
C	RC IS CURRENT RADIUS	TWOD 189
	IF (RC.GT.R) GO TO 23	TWOD 190
	D=DC+X	TWOD 191
C	D IS DISTANCE FROM POINT TO DETECTOR	TWOD 192
	IF (Y**2.LT.RR2) GO TO 18	TWOD 193
	DX=0.	TWOD 194
	GO TO 19	TWOD 195
18	CONTINUE	TWOD 196
	XS=SQRT(RR2-Y**2)	TWOD 197
	DX=X-XS	TWOD 198
19	CONTINUE	TWOD 199
C	DX IS THE DISTANCE OF THE POINT BEING CONSIDERED	TWOD 200
C	FROM THE EDGE OF THE DISC BEING SCANNED	TWOD 201
	GAM=EXP(-ADS*DX)*D**2/DCSQ	TWOD 202
	IF (RC.LT.RK) GO TO 22	TWOD 203
	IF (K.LE.1) WRITE (9,76)	TWOD 204
	THTA=57.2958*ATAN(Y/X)	TWOD 205
	IF (X.LT.0.) THTA=180.+THTA	TWOD 206
	IF (X.GT.0..AND.Y.LT.0.) THTA=360.+THTA	TWOD 207

	THTA=THTA+FLOAT(J-1)*NDPSCN	TWOD 208
	THTA=THTA+90.	TWOD 209
20	IF (THTA.LT.360.) GO TO 21	TWOD 210
	THTA=THTA-360.	TWOD 211
	GO TO 20	TWOD 212
21	CONTINUE	TWOD 213
	KR=(R-RC)/AMPS+1.	TWOD 214
	IF (KR.GT.NK) KR=NK	TWOD 215
	APT=7.	TWOD 216
	CALL SPL (THTA,KR,APT)	TWOD 217
	AK=A/K+APT*GAM*DA	TWOD 218
	GO TO 23	TWOD 219
22	AD=AD+GAM*DA	TWOD 220
23	CONTINUE	TWOD 221
	A(J,K)=(SCAN(J,K)-AK)/AD	TWOD 222
C	A=A1*E**(-ADS*DEL1)+A2*E**(-ADS*DEL2)	TWOD 223
C	THUS A1=(A-A2*E(-ADS*DEL2))/E**(-ADS*DEL1)	TWOD 224
C	OR, A1=(A-AK)/AD	TWOD 225
	IF (A(J,K).GT.0) GO TO 25	TWOD 226
	A(J,K)=0.	TWOD 227
	IF (K.LE.1) GO TO 24	TWOD 228
	CALL SPL (ANG(J,1),K-1,APT)	TWOD 229
	IF (APT.LT.0.) APT=0.	TWOD 230
	A(J,K)=A(J,K)+APT	TWOD 231
24	IF (J.LE.1) GO TO 25	TWOD 232
	A(J,K)=A(J,K)+A(J-1,K)	TWOD 233
	A(J,K)=A(J,K)/2.	TWOD 234
25	CONTINUE	TWOD 235
26	CONTINUE	TWOD 236
C	THIS SECTION OF THE PROGRAM IS CONCERNED WITH THE UPPER HALF.	TWOD 237
	KU=NPPSCN+1-K	TWOD 238
	YU=R-FLOAT((K-1)*MPS)	TWOD 239
	J2=NSCAN+1	TWOD 240
	DO 35 J=J2,NS2	TWOD 241
	CALL RANVECT (RAND,NR)	TWOD 242
	AK=0.	TWOD 243
	AD=0.	TWOD 244
	DO 32 L=1,NP	TWOD 245
	X=XL+DELX*RAND(2*L)	TWOD 246
	Y=YU-AMOC*RAND(L)	TWOD 247
	RC=SQRT(X**2+Y**2)	TWOD 248
	IF (RC.GT.R) GO TO 32	TWOD 249
	D=DC+X	TWOD 250
	IF (Y**2.LT.RR2) GO TO 27	TWOD 251
	DX=0.	TWOD 252
	GO TO 28	TWOD 253
27	CONTINUE	TWOD 254
	XS=SQRT(RR2-Y**2)	TWOD 255
	DX=X-XS	TWOD 256
28	CONTINUE	TWOD 257
	GAM=EXP(-ADS*DX)*D**2/DCSQ	TWOD 258
	IF (RC.LT.RK) GO TO 31	TWOD 259
	IF (K.LE.1) WRITE (9,77)	TWOD 260
	THTA=57.2958*ATAN(Y/X)	TWOD 261
	IF (X.LT.0.) THTA=180.+THTA	TWOD 262
	IF (X.GT.0. AND Y.LT.0.) THTA=360.+THTA	TWOD 263
	THTA=THTA+FLOAT(J-1)*NDPSCN+180.	TWOD 264
	THTA=THTA+90.	TWOD 265
29	IF (THTA.LT.360.) GO TO 30	TWOD 266
	THTA=THTA-360.	TWOD 267
	GO TO 29	TWOD 268
30	CONTINUE	TWOD 269
	KR=(R-RC)/AMPS+1.	TWOD 270
	IF (KR.GT.NK) KR=NK	TWOD 271
	APT=8.	TWOD 272
	CALL SPL (THTA,KR,APT)	TWOD 273
	AK=AK+APT*GAM*DA	TWOD 274
	GO TO 32	TWOD 275
31	AD=AD+GAM*DA	TWOD 276
32	CONTINUE	TWOD 277
	NJ=J-NSCAN	TWOD 278

	A(J,K)=(SCAN(NJ,KU)-AK)/AD	TWOD 279
	IF (A(J,K).GT.0) GO TO 34	TWOD 280
	A(J,K)=0.	TWOD 281
	IF (K.LE.1) GO TO 33	TWOD 282
	CALL SPL (ANG(J,1),K-1,APT)	TWOD 283
	IF (APT.LT.0.) APT=0.	TWOD 284
	A(J,K)=A(J,K)+APT	TWOD 285
33	IF (J.LE.1) GO TO 34	TWOD 286
	A(J,K)=A(J,K)+A(J-1,K)	TWOD 287
	A(J,K)=A(J,K)/2.	TWOD 288
34	CONTINUE	TWOD 289
35	CONTINUE	TWOD 290
	RK=YU-AMPS	TWOD 291
	IF (NSCAN.NE.1) GO TO 36	TWOD 292
	A(3,K)=A(2,K)	TWOD 293
	A(2,K)=(A(1,K)+A(3,K))/2.	TWOD 294
	A(4,K)=A(2,K)	TWOD 295
	NS2=4	TWOD 296
36	CONTINUE	TWOD 297
	RADL=R-FLOAT(MPS*(K-1))	TWOD 298
	RADU=RADL-FLOAT(MPS)	TWOD 299
	IF (RADU.LT.0) RADU=0.	TWOD 300
	WRITE (9,73)(RADL,RADU,(A(J,K),J=1,NS2))	TWOD 301
	CALL SPLF (NS2,K)	TWOD 302
	IF (NSCAN.EQ.1) NS2=2	TWOD 303
37	CONTINUE	TWOD 304
	IRF=2	TWOD 305
	IF (IRF.LT.1) GO TO 39	TWOD 306
	WRITE (9,82)	TWOD 307
	WRITE (9,83)	TWOD 308
	DO 38 K=1,NK	TWOD 309
	RADL=R-FLOAT(MPS*(K-1))	TWOD 310
	RADU=RADL-FLOAT(MPS)	TWOD 311
	IF (RADU.LT.0) RADU=0.	TWOD 312
	NF=NOPTF(K)	TWOD 313
	WRITE (9,73)(RADL,RADU,(A(J,K),J=1,NF))	TWOD 314
38	CONTINUE	TWOD 315
39	CONTINUE	TWOD 316
	IF (NS AN.EQ.1) NS2=4	TWOD 317
	IF (NS2.EQ.4) NSCAN=2	TWOD 318
	IF (IRF.LT.1) GO TO 54	TWOD 319
	DO 43 J=1,NS2	TWOD 320
	DO 42 K=1,NK	TWOD 321
	CALL SPL (ANG(J,1),K,RAND(K))	TWOD 322
	IF (RAND(K).GT.0.) GO TO 41	TWOD 323
	RAND(K)=0.	TWOD 324
	IF (K.LE.1) GO TO 40	TWOD 325
	CALL SPL (ANG(J,1),K-1,APT)	TWOD 326
	IF (APT.LT.0.) APT=0.	TWOD 327
	RAND(K)=RAND(K)+APT/3.	TWOD 328
40	IF (J.LE.1) GO TO 41	TWOD 329
	CALL SPL (ANG(J-1,1),K,APT)	TWOD 330
	IF (APT.LT.0.) APT=0.	TWOD 331
	RAND(K)=RAND(K)+APT/3.	TWOD 332
41	CONTINUE	TWOD 333
42	CONTINUE	TWOD 334
	CALL SPLFR (NK,RAND(1),SCAN(1,1),J)	TWOD 335
43	CONTINUE	TWOD 336
	DO 45 J=1,NS2	TWOD 337
	DO 44 K=1,NK	TWOD 338
	A(J,K)=SCAN(J,K)	TWOD 339
C	RAND(K)=R-FLOAT(MPS*(K-1))-0.5*FLOAT(MPS)	TWOD 340
C	RAND(K+110)=SCAN(J,K)	TWOD 341
44	CONTINUE	TWOD 342
C	CALL SPLOT(1,NK,RAND(1),RAND(111),1,1)	TWOD 343
45	CONTINUE	TWOD 344
	WRITE (9,82)	TWOD 345
	WRITE (9,84)	TWOD 346
	DO 46 K=1,NK	TWOD 347
	RADL=R-FLOAT(MPS*(K-1))	TWOD 348
	RADU=RADL-FLOAT(MPS)	TWOD 349
	IF (RADU.LT.0) RADU=0.	TWOD 350



	WRITE (9,73)(RADL,RADU,(A(J,K),J=1,NS2))	TWOD 351
	CALL SPLF (NS2,K)	TWOD 352
46	CONTINUE	TWOD 353
	WRITE (9,82)	TWOD 354
	WRITE (9,85)	TWOD 355
	DO 53 K=1,NK	TWOD 356
	RADL=R- FLOAT(MPS*(K-1))	TWOD 357
	RADU=RADL- FLOAT(MPS)	TWOD 358
	IF (RADU.LT.0) RADU=0.	TWOD 359
	NF=NOPTF(K)	TWOD 360
	SUM1=0.0	TWOD 361
	SUM2=0.0	TWOD 362
	ICHECK=0	TWOD 363
	DO 47 IJ=1,NF	TWOD 364
	IF (A(IJ,K).LE.0.0) ICHECK=1	TWOD 365
47	CONTINUE	TWOD 366
	IF (ICHECK.EQ.0) GO TO 52	TWOD 367
	DO 48 JJ=1,NF	TWOD 368
	SUM1=SUM1+A(JJ,K)/NF	TWOD 369
48	CONTINUE	TWOD 370
	DO 49 KJ=1,NF	TWOD 371
	A(KJ,K)=SUM1	TWOD 372
49	CONTINUE	TWOD 373
	IF (K.EQ.NK) GO TO 52	TWOD 374
	DO 50 LJ=1,NF	TWOD 375
	SUM2=SUM2+A(LJ,K+1)/NF	TWOD 376
50	CONTINUE	TWOD 377
	SUM2=SUM1/2.0+SUM2/2.0	TWOD 378
	DO 51 KJ=1,NF	TWOD 379
	A(KJ,K+1)=SUM2	TWOD 380
51	CONTINUE	TWOD 381
52	CONTINUE	TWOD 382
	WRITE (9,73)(RADL,RADU,(A(J,K),J=1,NF))	TWOD 383
53	CONTINUE	TWOD 384
	WRITE (9,82)	TWOD 385
54	CONTINUE	TWOD 386
	M=64	TWOD 387
	DEL=R/FLOAT(M/2)	TWOD 388
	DO 61 J=1,M	TWOD 389
	X= R+(J-1)*DEL	TWOD 390
	DO 60 K=1,M	TWOD 391
	Y=R- (K-1)*DEL	TWOD 392
	RC=SQRT(X**2+Y**2)	TWOD 393
	JK=(J-1)*M+K	TWOD 394
	IF (RC.LT.R) GO TO 55	TWOD 395
	RAND(JK)=0.	TWOD 396
	GO TO 60	TWOD 397
55	CONTINUE	TWOD 398
	KR=(R- RC)/AMPS+1.	TWOD 399
	IF (KR.GT.NK) KR=NK	TWOD 400
	IF (X.NE.0.) GO TO 56	TWOD 401
	IF (Y.GT.0.) THTA=90.	TWOD 402
	IF (Y.LE.0.) THTA=270.	TWOD 403
	GO TO 57	TWOD 404
56	CONTINUE	TWOD 405
	THTA=57.2958 *.ATAN(Y/X)	TWOD 406
	IF (X.LT.0.) THTA=180.+THTA	TWOD 407
	IF (X.GT.0..AND.Y.LT.0.) THTA=360.+THTA	TWOD 408
57	CONTINUE	TWOD 409
	RAND(JK)=9.	TWOD 410
	CALL SPL (THTA,KR,RAND(JK))	TWOD 411
	IF (RAND(IK).GT.0.) GO TO 59	TWOD 412
	RAND(JK)=0.	TWOD 413
	IF (K.LE.1) GO TO 58	TWOD 414
	JK1=(J-1)*M+K-1	TWOD 415
	RAND(JK)=RAND(JK)+RAND(JK1)/3.	TWOD 416
58	IF (J.LE.1) GO TO 59	TWOD 417
	JK1=(J-2)*M+K	TWOD 418
	RAND(JK)=RAND(JK)+RAND(JK1)/3.	TWOD 419
59	CONTINUE	TWOD 420
	ILOG=0	TWOD 421

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IF (ILOG(.LT.1) GO TO 60
RAND(JK)=10.*RAND(JK)
IF (RAND(JK).LE.1) RAND(JK)=0.
IF (RAND(JK).GT.1) RAND(JK)=ALOG10(RAND(JK))
60 CONTINUE
61 CONTINUE
N=M/16
IF (N.LT.1) N=1
WRITE (9,86)(J,J=1,M,N)
MN=M*N
DO 62 K=1,M,N
KK=K+(M-1)*M
WRITE (9,87)K,(RAND(J),J=K,KK,MN)
WRITE (9,88)
62 CONTINUE
DELX=DEL
DELY=DEL
XS=0.
YS=0.
CALL W2P
CALL TWOP
GO TO 5
C
C
63 FORMAT (8A10)
64 FORMAT (1H1)
65 FORMAT (12I6)
66 FORMAT (*0SCANPOINTS*)
67 FORMAT (6F12.2)
68 FORMAT (*OGAMMAADSORPTIONCOEFFICIENTIS*,1X,F6.5,*/MILL*/*ORADIUSOF
1DISCBEINGSCANNEDIS*,F5.0,*MILLS*/*0SCANSTEPINMILLSIS*,F4.0/*0WIDTH
20FCOLLIMATORINMILLSIS*,F4.0)
69 FORMAT (*0INTENSITYVERSUSANGLEANDRADIUS*)
70 FORMAT (*0ANGLE* 9X,17F7.1)
71 FORMAT (*0RADIUS* 40X,*INTENSITIES*)
72 FORMAT (*0(MILLS)*)
73 FORMAT (1H0,F5.1,1X,*T0*,1X,F5.1,3X,17F7.2)
74 FORMAT (*0RADIUSOFTHESCANREGIONIS*,F6.1,1X,*MILLS.*)
75 FORMAT (*0NUMBEROFSCANSIS*,I3/*0NUMBEROFPOINTSPERSCANIS*,I4/*0NUM
1BEROFDEGREESBETWEENSCANSIS*13)
76 FORMAT (*0KISEQUALTO1,YETINKNOWNRWGIONLOWERHALF*)
77 FORMAT (*0KISEQUALTO1,YETINKNOWNRWGIONUPPERHALF*)
78 FORMAT (3I6,3F12.2)
79 FORMAT (3I6,3F12.2)
80 FORMAT (*0NUMBEROFMONTECARLOPOINTSUSED(NP)IS*,F6.0/10X,*(SQRT(NP)/
1NP)X100IS*,F5.2)
81 FORMAT (1X,16F8.0)
82 FORMAT (1H0)
83 FORMAT (*INTENSITIESAFTERCIRCULARSPLINESMOOTHING*)
84 FORMAT (*INTENSITIESAFTERRADIALSPLINESMOOTHING*)
85 FORMAT (*INTENSITIESAFTERRE-SMOOTHINGCIRCULARLY*)
86 FORMAT (*1CALCULATEDSQUAREMATRIX*/2X,16I8)
87 FORMAT (1X,I2,F7.2,15(1X,F7.2))
88 FORMAT (//)
END

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TWOD 422
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TWOD 476

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C \*\*\*\*\*

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SUBROUTINE SPL (Y,K,A)
C Y IS ANGLE, K IS BAND OR REGION, A IS VALUE AT THAT ANGLE IN THAT
DIMENSION AA(10,110), W(10,110), ANG(10,110), M(110)
COMMON M,ANG,AA,W
N=M(K)
*F (Y.LT.0.001) Y=.001
CALL SEARCH (Y,ANG(1,K),N,I,MFLAG)
IF (I.EQ.N) I=N-1
IF (MFLAG.L7.2) GO TO 1

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SPL
SPL 1
SPL 2
SPL 3
SPL 4
SPL 5
SPL 6
SPL 7
SPL 8

```

	WRITE (9,2)	SPL	9
	WRITE (9,3)A	SPL	10
	WRITE (9,4)I,N,K	SPL	11
	WRITE (9,3)Y	SPL	12
	WRITE (9,4)(M(J),J=1,K)	SPL	13
	WRITE (9,5)(ANG(I,K),J=1,N)	SPL	14
	WRITE (9,5)AA(I,K),AA(I+1,K),W(I,K),W(I+1,K)	SPL	15
1	CONTINUE	SPL	16
	FLK=ANG(I+1,K)- ANG(I,K)	SPL	17
	A=(W(I,K)*(ANG(I+1,K)- Y)**3+W(I+1,K)*(Y- ANG(I,K))**3)/(6.*FLK)*(AA	SPL	18
	1(I+1,K)/FLK- W(I+1,K)*FLK/6.)*(Y- ANG(I,K))+(AA(I,K)/FLK- FLK*W(I,K)/	SPL	19
	26.)*(ANG(I+1,K)- Y)	SPL	20
	RETURN	SPL	21
C		SPL	22
2	FORMAT (*0ZZZZZZZZZZSPL*)	SPL	23
3	FORMAT (8F10.5)	SPL	24
4	FORMAT (12I10)	SPL	25
5	FORMAT (12F10.3)	SPL	26
	END	SPL	27

C \*\*\*\*\*

	SUBROUTINE SPLF (NSCAN,K)	SPLF	
	DIMENSION A(10,110), ANG(10,110), W(10,110), IOP(2), B(324), F(32)	SPLF	1
	1, N(110), WT(16), THTA(16)	SPLF	2
	COMMON N,ANG,A,W,NK	SPLF	3
	NP=NSCAN+1	SPLF	4
	ANG(NP)=360.	SPLF	5
	A(NP,K)=A(1,K)	SPLF	6
	W(NP,K)=W(1,K)	SPLF	7
	IOP(1)=4	SPLF	8
	IOP(2)=4	SPLF	9
C	THIS ESTABLISHES PERODIC DATA	SPLF	10
	M=FLOAT(NP)*FLOAT(NK-K+1)/FLOAT(NK)	SPLF	11
	IF (M.LE.4) M=4	SPLF	12
	IF (K.LE.1) GO TO 3	SPLF	13
	AVG=0.	SPLF	14
	L=K-1	SPLF	15
	NL=N(L)	SPLF	16
	APT1=1.	SPLF	17
	CALL SPL (ANG(NP-1,1),L,APT1)	SPLF	18
	APT2=2.	SPLF	19
	CALL SPL (ANG(1,1),L,APT2)	SPLF	20
	APT3=3.	SPLF	21
	CALL SPL (ANG(2,1),L,APT3)	SPLF	22
	AVG=(APT1+APT2+APT3)/3.	SPLF	23
	WT(1)=AVG/(AVG+(A(1,K)- AVG)**2)	SPLF	24
	WT(NP)=WT(1)	SPLF	25
	NP1=NP-1	SPLF	26
	DO 1 J=2,NP1	SPLF	27
	APT1=4.	SPLF	28
	CALL SPL (ANG(J-1,1),L,APT1)	SPLF	29
	APT2=5.	SPLF	30
	CALL SPL (ANG(J,1),L,APT2)	SPLF	31
	APT3=6.	SPLF	32
	CALL SPL (ANG(J+1,1),L,APT3)	SPLF	33
	AVG=(APT1+APT2+APT3)/3.	SPLF	34
	WT(J)=AVG/(AVG+(A(J,K)- AVG)**2)	SPLF	35
1	CONTINUE	SPLF	36
	DEL=360./FLOAT(M-2)	SPLF	37
	THTAZ=DEL*RANDOM(L)	SPLF	38
	MP=M-1	SPLF	39
	THTA(1)=0.	SPLF	40
	THTA(M)=360.	SPLF	41
	DO 2 J=2,MP	SPLF	42
	THTA(J)=THTAZ+FLOAT(J-2)*DEL	SPLF	43
2	CONTINUE	SPLF	44
	GO TO 5	SPLF	45

3	DO 4 J=1,NP	SPLF	46
	WT(J)=1.	SPLF	47
	THTA(J)=ANG(J,1)	SPLF	48
4	CONTINUE	SPLF	49
5	CONTINUE	SPLF	50
	M=2*M	SPLF	51
	CALL SMOOTH (NP,M,IOP,ANG,THTA,A(1,K),WT,F,B)	SPLF	52
	M=M/2	SPLF	53
	N(K)=M	SPLF	54
	DO 6 J=1,M	SPLF	55
	ANG(J,K)=THTA(J)	SPLF	56
	A(J,K)=F(J+M)	SPLF	57
	W(J,K)=F(J)	SPLF	58
6	CONTINUE	SPLF	59
C	RETURN	SPLF	60
	END	SPLF	61
		SPLF	62

C .....  
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	SUBROUTINE TW	TAPW	
	REWIND 2	TAPW	1
	IREC=0	TAPW	2
	DUMMY=0.	TAPW	3
	IDMY=0	TAPW	4
	DO 1 J=1,122	TAPW	5
	READ (10,2)DATA	TAPW	6
	IREC=IREC+1	TAPW	7
	WRITE (2,3)IDMY,IDMY,IREC,DUMMY,DATA,DUMMY	TAPW	8
1	WRITE (9,3)NDMY,IDMY,IREC,DUMMY,DATA,DUMMY	TAPW	9
	CONTINUE	TAPW	10
	REWIND 2	TAPW	11
	RETURN	TAPW	12
C		TAPW	13
C		TAPW	14
2	FORMAT (F12.2)	TAPW	15
3	FORMAT (3I6,3F12.2)	TAPW	16
	END	TAPW	17

C .....  
.....

	SUBROUTINE SPLFR (NK,RAND,SCAN,L)	SPLR	
	DIMENSION IOP(2), SCAN(10,110), RAND(1), TAB(3)	SPLR	1
	IOP(1)=5	SPLR	2
	IOP(2)=5	SPLR	3
	KN=NK- NK/10	SPLR	4
	IF (KN.LT.3) KN=3	SPLR	5
	R=FLOAT(NK)/FLOAT(KN)	SPLR	6
	DO 1 J=1,NK	SPLR	7
	IF (RAND(J).LT.0.) RAND(J)=0.	SPLR	8
	RAND(J+110)=SQRT(RAND(J))	SPLR	9
	RAND(J+220)=J	SPLR	10
1	CONTINUE	SPLR	11
	DO 2 J=1,KN	SPLR	12
	RAND(J+330)=FLOAT(J)*R	SPLR	13
2	CONTINUE	SPLR	14
	KN=2*KN	SPLR	15
	CALL SMOOTH (NK,KN,IOP,RAND(221),RAND(331),RAND(1),RAND(111),RAND(1431),RAND(531))	SPLR	16
	KN=KN/2	SPLR	17
	DO 4 J=1,NK	SPLR	18
	X=J	SPLR	19
	CALL SPLID2 (KN,RAND(331),RAND(KN+431),RAND(431),1,X,TAB)	SPLR	20
		SPLR	21

	SCAN(L,J)=TAB(1)	SPLR 22
	IF (SCAN(L,J).GE.0.) GO TO 3	SPLR 23
	SCAN(L,J)=0.	SPLR 24
	IF (J.EQ.1) GO TO 3	SPLR 25
	SCAN(L,J)=SCAN(L,J-1)/2.	SPLR 26
3	CONTINUE	SPLR 27
4	CONTINUE	SPLR 28
	RETURN	SPLR 29
	END	SPLR 30

C \*\*\*\*\*

	SUBROUTINE W2P	W2P	
	DIMENSION TITLE(8), XM(64), YM(64), Z(64,64)	W2P	1
	COMMON /W/ L,TITLE,XS,DELX,YS,DELY,Z	W2P	2
	REWIND 7	W2P	3
	WRITE (7,3)(TITLE(J),J=1,8)	W2P	4
	WRITE (7,4)L	W2P	5
C	L = SIZE OF SQUARE MATRIX.	W2P	6
	XS=XS/1000.0	W2P	7
	DELX=DELX/1000.0	W2P	8
	YS=YS/1000.0	W2P	9
	DELY=DELY/1000.0	W2P	10
	WRITE (7,5)XS,DELX,YS,DELY	W2P	11
	DO 1 I=1,L	W2P	12
	XM(I)=XS+FLOAT(I-1)*DELX	W2P	13
	YM(I)=YS+FLOAT(I-1)*DELY	W2P	14
1	CONTINUE	W2P	15
	DO 2 J=1,L	W2P	16
	WRITE (7,6)J	W2P	17
	WRITE (7,7)(Z(I,J),J=1,L)	W2P	18
2	CONTINUE	W2P	19
	END FILE 7	W2P	20
	END FILE 7	W2P	21
	END FILE 7	W2P	22
	RETURN	W2P	23
C		W2P	24
C		W2P	25
3	FORMAT (8A10)	W2P	26
4	FORMAT (4I6)	W2P	27
5	FORMAT (5F12.3)	W2P	28
6	FORMAT (*COLUMNMATRIX*,I3)	W2P	29
7	FORMAT (1H 8F16.4)	W2P	30
	END	W2P	31

C \*\*\*\*\*

**APPENDIX B**  
**PLOT SUBROUTINES**

	SUBROUTINE TWOP	TWOP	
C	TWO DIMENSIONAL GAMMA-RAY SCAN PLOT PROGRAM	TWOP	1
C	THIS PROGRAM USES RESULTS TAPE FROM SQMAT	TWOP	2
	DIMENSION X(4096), Y(4096), ATTITLE(14), ZC(32), XPLT(64), YPLT(64)	TWOP	3
	1, Z(4096), NOLR(11), NOLL(11), FL(4)	TWOP	4
	DATA ASTER/10H* /	TWOP	5
	DATA AASTER/10H** /	TWOP	6
	DATA BLACK/10HCOLOR /	TWOP	7
	DATA (ATTITLE(I),I=9,14)/10H ,10H ,10HX	TWOP	8
	110H ,10HY ,10H /	TWOP	9
	READ (10,15)BV	TWOP	10
	REWIND 7	TWOP	11
	WRITE (9,11)	TWOP	12
	NITITLE=80	TWOP	13
	NXLBL=12	TWOP	14
	NYLBL=12	TWOP	15
	FL(1)=-.79538	TWOP	16
	FL(3)=120.0	TWOP	17
	FL(4)=120.0	TWOP	18
	FL(2)=1.17797	TWOP	19
	NF=1	TWOP	20
	NPASS=1	TWOP	21
	IADV=1	TWOP	22
	ICZ=1	TWOP	23
	ICP=ICZ+1	TWOP	24
	ICOLOR=ICZ	TWOP	25
	READ (10,10)	TWOP	26
	WRITE (9,10)	TWOP	27
	WRITE (9,13)	TWOP	28
1	READ (10,12)(ATTITLE(J),J=1,3)	TWOP	29
	WRITE (9,12)(ATTITLE(J),J=1,3)	TWOP	30
	IF (ATTITLE(1).EQ.ASTER) GO TO 8	TWOP	31
	IF (ATTITLE(1).EQ.AASTER) RETURN	TWOP	32
	WRITE (9,13)	TWOP	33
	CALL DCARE (NZX,NZY,Z,X,Y,ATTITLE)	TWOP	34
	WRITE (9,14)NZX,NZY	TWOP	35
C	NZX IS THE NUMBER OF X POINTS TO PLOT	TWOP	36
C	NZY IS THE NUMBER OF Y POINTS TO PLOT	TWOP	37
	DO 2 J=1,NZY	TWOP	38
	YPLT(J)=Y((J-1)*NZX+1)-Y(1)	TWOP	39
2	CONTINUE	TWOP	40
	DO 3 J=1,NZX	TWOP	41
	XPLT(J)=X(J)-X(1)	TWOP	42
3	CONTINUE	TWOP	43
	NOPTS=NZX*NZY	TWOP	44
	ZMN=Z(1)	TWOP	45
	ZMX=Z(1)	TWOP	46
	DO 4 J=2,NOPTS	TWOP	47
	IF (Z(J).LT.0.) Z(J)=Z(J-1)	TWOP	48
	ZMN=AMIN1(ZMN,Z(J))	TWOP	49
	ZMX=AMAX1(ZMX,Z(J))	TWOP	50
4	CONTINUE	TWOP	51
	IF (ICOLOR.EQ.ICZ) ZMXSAV=ZMX	TWOP	52
	ICOLOR=ICOLOR+1	TWOP	53
	IF (ICOLOR.GT.3) ICOLOR=1	TWOP	54
	IF (NPASS.NE.1) GO TO 7	TWOP	55
	ICOLOR=1	TWOP	56
	CALL EMPTY	TWOP	57
	CALL ADV (2)	TWOP	58
	ICOLP=3	TWOP	59
	CALL COLOR (ICOLP)	TWOP	60
	IF (BW.NE.BLACK) GO TO 5	TWOP	61
	CALL EXL	TWOP	62
	CALL SWEEP (1,1,1022,1022)	TWOP	63

5	CALL EXH	TWOP 64
	CONTINUE	TWOP 65
	CALL PLS3D (Z,XPLT,YPLT,NZX,NZY,FL,ATITLE,ICOLOR)	TWOP 66
	CALL EMPTY	TWOP 67
	CALL ADV (2)	TWOP 68
	CALL COLOR (ICOLP)	TWOP 69
	IF (BW.NE.BLACK) GO TO 6	TWOP 70
	CALL EXL	TWOP 71
	CALL SWEEP (120,50,980,910)	TWOP 72
	CALL EXH	TWOP 73
6	CONTINUE	TWOP 74
7	CONTINUE	TWOP 75
	NZ=20	TWOP 76
	NC=NZ*IFIX(ZMX/ZMXSAV)	TWOP 77
	IF (NC.LE.4) NC=5	TWOP 78
	IF (ICOLOR.EQ.ICP.AND.NPASS.NE.1) CALL ADV (2)	TWOP 79
	CALL CDEN (XPLT,YPLT,Z,NZX,NZY,NC,ZMN,ZMX,ATITLE,NTITLE,12HX COORD	TWOP 80
	IINATE,NXLBL,12HY COORDINATE,NYLBL,ICOLOR,IADV)	TWOP 81
C	ICOLOR CONTROLLS COLOR 0=WHITE 1=RED 2=GREEN 3=BLUE	TWOP 82
C	IADV=0 MEANS DO NOT ADVANCE FILM AFTER DENSITY PLOT	TWOP 83
	GO TO 1	TWOP 84
8	CONTINUE	TWOP 85
	IF (NPASS.NE.1) GO TO 9	TWOP 86
	ICOLOR=ICZ	TWOP 87
	NPASS=NPASS+1	TWOP 88
	REWIND 7	TWOP 89
	IADV=0	TWOP 90
	GO TO 1	TWOP 91
9	CONTINUE	TWOP 92
	CALL EXIT	TWOP 93
C		TWOP 94
C		TWOP 95
C		TWOP 96
10	FORMAT (72H	TWOP 97
	1 )	TWOP 98
11	FORMAT (1H1)	TWOP 99
12	FORMAT (8A10)	TWOP 100
13	FORMAT (1H0)	TWOP 101
14	FORMAT (30H0NUMBER OF X POINTS PLOTTED IS,14,32H. NUMBER OF Y POI	TWOP 102
	INTS PLOTTED IS,14,1H.)	TWOP 103
15	FORMAT (A10)	TWOP 104
	END	TWOP 105

C \*\*\*\*\*

	SUBROUTINE DCARE (NZX,NZY,ZZ,XX,YY,ATITLE)	DCR	
	DIMENSION TITLE(8), ZZ(1), XX(1), YY(1), ATITLE(1)	DCR	1
	DATA BLANK/10H /	DCR	2
	READ (7,14)TITLE	DCR	3
	IF (ENDFILE 7) 11,1	DCR	4
1	WRITE (9,14)TITLE	DCR	5
	IF (ATITLE(1).NE.BLANK) GO TO 3	DCR	6
	DO 2 J=1,8	DCR	7
	ATITLE(J)=TITLE(J)	DCR	8
2	CONTINUE	DCR	9
3	CONTINUE	DCR	10
	READ (7,15)L	DCR	11
	IF (ENDFILE 7) 11,4	DCR	12
4	CONTINUE	DCR	13
	NZX=L	DCR	14
	NZY=L	DCR	15
	READ (7,16)XS,DELX,YS,DELY	DCR	16
	IF (ENDFILE 7) 11,5	DCR	17
5	CONTINUE	DCR	18
	WRITE (9,16)XS,DELX,YS,DELY	DCR	19
	DO 10 J=1,NZY	DCR	20
	READ (7,17)ICOL	DCR	21

6	IF (ENDFILE 7) 11,6	DCR 22
	CONTINUE	DCR 23
	I=(J-1)*NZX+1	DCR 24
	IP=J*NZX	DCR 25
	READ (7,18)(ZZ(K),K=1,IP)	DCR 26
	IF (ENDFILE 7) 11,7	DCR 27
7	CONTINUE	DCR 28
	DO 8 K=1,IP	DCR 29
	IF (ZZ(K).LT.0.) ZZ(K)=0.	DCR 30
8	CONTINUE	DCR 31
	DO 9 K=1,NZX	DCR 32
	I=(J-1)*NZX+K	DCR 33
	XX(I)=XS+FLOAT(K-1)*DELX	DCR 34
	YY(I)=YS+FLOAT(J-1)*DELY	DCR 35
9	CONTINUE	DCR 36
10	CONTINUE	DCR 37
	RETURN	DCR 38
11	READ (7,14)TITLE	DCR 39
	IF (ENDFILE 7) 13,12	DCR 40
12	CONTINUE	DCR 41
	WRITE (9,14)TITLE	DCR 42
	GO TO 1	DCR 43
13	WRITE (9,19)	DCR 44
	CALL EXIT	DCR 45
C	51 CONTINUE	DCR 46
	CALL EXIT	DCR 47
C		DCR 48
C		DCR 49
C		DCR 50
14	FORMAT (8A10)	DCR 51
15	FORMAT (4I6)	DCR 52
16	FORMAT (4F12,3)	DCR 53
17	FORMAT (15X,I3)	DCR 54
18	FORMAT (1X,8F16,4)	DCR 55
19	FORMAT (6H TWOEF)	DCR 56
	END	DCR 57

C \*\*\*\*\*

	SUBROUTINE CDEN (X,Y,Z,NOX,NOY,NC,ZMN,ZMX,ITITLE,NTITLE,XLABEL,NXL	CDEN
	1BL,YLABEL,NYLBL,ICOLOR,IADV)	CDEN 1
	DIMENSION X(1), Y(1), Z(1,1)	CDEN 2
	DIMENSION IX(64), IY(64)	CDEN 3
	DIMENSION XX(900), YY(900)	CDEN 4
	CALL COLOR (0)	CDEN 5
	DMPX=NOX	CDEN 6
	DMPY=NOY	CDEN 7
	XMIN=X(1)	CDEN 8
	XMAX=X(1)	CDEN 9
	DO 1 I=1,NOX	CDEN 10
	IF (X(I).LT.XMIN) XMIN=X(I)	CDEN 11
	IF (X(I).GT.XMAX) XMAX=X(I)	CDEN 12
1	CONTINUE	
		CDEN 13
	YMIN=Y(1)	CDEN 14
	YMAX=Y(1)	CDEN 15
	DO 2 I=1,NOY	CDEN 16
	IF (Y(I).LT.YMIN) YMIN=Y(I)	CDEN 17
	IF (Y(I).GT.YMAX) YMAX=Y(I)	CDEN 18
2	CONTINUE	CDEN 19
	XMX=XMAX	CDEN 20
	XMN=XMIN	CDEN 21
	YMX=YMAX	CDEN 22
	YMN=YMIN	CDEN 23
	CALL ASCL (5,XMN,XMX,MAJX,MINX,KKX)	CDEN 24
	CALL ASCL (5,YMN,YMX,MAJY,MINY,KKY)	CDEN 25
	FACT=860./AMAX1(DMPX,DMPY)	CDEN 26
	IXR=120.+IFIX(FACT*DMPX)	CDEN 27



	IXL=120.	CDEN 28
	IYB=50.+IFIX(FACT*DMPY)	CDEN 29
	JYT=50.	CDEN 30
	CALL DGA (IXL,IXR,IYT,IYB,XMN,XXM,XXY,XXZ)	CDEN 31
	IF (IADV.EQ.0.AND.ICOLOR.NE.2) GO TO 3	CDEN 32
	CALL FRAME (IXL,IXR,IYT,IYB)	CDEN 33
	CALL SBLIN (MAJX,KKX)	CDEN 34
	CALL SLLIN (MAJY,KKY)	CDEN 35
	INCX=120+(IXR-120-NXLBL*18)/2	CDEN 36
	CALL DLCH (INCX,IYB+90,NXLBL,XLABEL,2)	CDEN 37
	INCY=IYB-(IYB-50-NYLBL*18)/2	CDEN 38
	CALL DLCV (10,INCY,NYLBL,YLABEL,2)	CDEN 39
	INCZ=120+(IXR-120-NTITLE*8)/2	CDEN 40
3	CONTINUE	CDEN 41
	ITYP=60+(ICOLOR-1)*29	CDEN 42
	IF (IADV.NE.0) IITYP=60	CDEN 43
	CALL DLCH (170,ITYP,NTITLE,IITLE,2)	CDEN 44
	CALL COLOR (ICOLOR)	CDEN 45
	A=FLOAT(NC)	CDEN 46
	B=A/2.	CDEN 47
	NTPTS=0	CDEN 48
	DO 5 K=1,5	CDEN 49
	DO 4 J=1,5	CDEN 50
	NTPTS=NTPTS+1	CDEN 51
	JX=130+J*6+IFIX((1.-2.*RANDOM(A))*3.)	CDEN 52
	JY=ITYP+K*4+IFIX((1.-2.*RANDOM(B))*2.)-2	CDEN 53
	CALL PLT (JX,JY,42)	CDEN 54
4	CONTINUE	CDEN 55
5	CONTINUE	CDEN 56
	DELX=X(2)-X(1)	CDEN 57
	DELY=Y(2)-Y(1)	CDEN 58
	NPTS=NOX*NOY	CDEN 59
	DO 10 J=1,NPTS	CDEN 60
	FN=Z(J)/ZMX*FLOAT(NC)	CDEN 61
	N=IFIX(FN)	CDEN 62
	IF (N.EQ.0) GO TO 10	CDEN 63
	NTPTS=0	CDEN 64
	JY=J/NOX+1	CDEN 65
	JX=J-(JY-1)*NOX	CDEN 66
	IF (JX.EQ.0) JY=JY-1	CDEN 67
	IF (JX.EQ.0) JX=NOX	CDEN 68
6	FNS=SQRT(DELY/DELX*FN)	CDEN 69
	NS=IFIX(FNS)	CDEN 70
	IF (NS.EQ.0) NS=1	CDEN 71
	NR=N/NS	CDEN 72
	IF (NR.EQ.0) NR=1	CDEN 73
	DDELX=DELX/FLOAT(NR)	CDEN 74
	DDELY=DELY/FLOAT(NS)	CDEN 75
	XC=X(JX)-DELX/2.-DDELX/2.	CDEN 76
	YC=Y(JY)-DELY/2.-DDELY/2.	CDEN 77
	DO 8 K=1,NS	CDEN 78
	YC=YC+DDELY	CDEN 79
	DO 7 L=1,NR	CDEN 80
	NTPTS=NTPTS+1	CDEN 81
	A=FLOAT(K*L)	CDEN 82
	B=FLOAT(X*L+1)	CDEN 83
	XX(NTPTS)=XC+FLOAT(L)*DDELX+(1.-2.*RANDOM(A))*DDELX/2.	CDEN 84
	YY(NTPTS)=YC+(1.-2.*RANDOM(B))*DDELY/2.	CDEN 85
7	CONTINUE	CDEN 86
8	CONTINUE	CDEN 87
	N=N-NS*NR	CDEN 88
	FN=FLOAT(N)	CDEN 89
	IF (N.GT.0) GO TO 6	CDEN 90
	DO 9 I=1,NTPTS	CDEN 91
	YY(I)=YY(I)+0.030	CDEN 92
	XX(I)=XX(I)+0.030	CDEN 93
9	CONTINUE	CDEN 94
	CALL PLOT (NTPTS,XX,1,YY,1,42,0)	CDEN 95
10	CONTINUE	CDEN 96
	IF (IADV.NE.0) CALL ADV (1)	CDEN 97
	RETURN	CDEN 98
C		CDEN 99

END

CDEN 100

C .....  
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	SUBROUTINE SLLIN (NNY,NK)	SLL	
	COMMON /CJE07/ DXL,IXR,IYT,IYB,XL,XR,YT,YB	SLL	1
	DIMENSION FMT(14), OUT(2)	SLL	2
	DATA (FMT(K),K=1,14)/6H(F6.0),8H(0PF7.1),6H(F8.2),6H(F9.3),7H(F10.	SLL	3
	14),7H(F11.5),7H(F12.6),8H(IPE7.0),8H(IPE8.1),8H(IPE9.2),9H(IPE10.3	SLL	4
	2),9H(IPE11.4),9H(IPE12.5),9H(IPE13.6)/	SLL	5
	IF (NK.GT.6) GO TO 1	SLL	6
	K=MIN0(6,MAX0(0,NK))+1	SLL	7
	NC=K+1	SLL	8
	GO TO 2	SLL	9
1	K=MIN0(16,MAX0(10,NK))- 2	SLL	10
	NC=K-1	SLL	11
2	A=FMT(K)	SLL	12
	ENCODE (20,A,OUT)YB	SLL	13
	IXT=IXL- 18*NC-9	SLL	14
	IYK=IYB- 11	SLL	15
	CALL DLCH (IXT,IYK,NC,OUT,2)	SLL	16
	CALL TSP (DXL,IYB,1,1H+)	SLL	17
	IF (NNY.LE.0) RETURN	SLL	18
	NY=MIN0(128,NNY)	SLL	19
	IYC=IYB	SLL	20
	DY=(YT- YB)/NY	SLL	21
	DDY=FLOAT(IYT- IYB)/NY	SLL	22
	DO 3 I=1,NY	SLL	23
	YC=YB+I*DY	SLL	24
	IYC=IYB+I*DDY	SLL	25
	IYD=IYC- 6	SLL	26
	ENCODE (20,A,OUT)YC	SLL	27
	CALL DLCH (IXT,IYD,NC,OUT,2)	SLL	28
3	CALL TSP (IXL,IYC,1,1H+)	SLL	29
	RETURN	SLL	30
	END	SLL	31

C .....  
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	SUBROUTINE SBLIN (NNX,NK)	SBL	
	COMMON /CJE07/ IXL,IXR,IYT,IYB,XL,XR,YT,YB	SBL	1
	DIMENSION FMT(12), OUT(2)	SBL	2
	DATA (FMT(K),K=1,12)/2H(F,1H ,1H ,1H ,1H),8H(IPE7.0),8H(IPE8.1),8H	SBL	3
	1(IPE9.2),9H(IPE10.3),9H(IPE11.4),9H(IPE12.5),9H(IPE13.6)/	SBL	4
	IY=IYB	SBL	5
	IYDEL=22	SBL	6
	GO TO 1	SBL	7
	ENTRY STLIN	SBL	8
	IY=IYT	SBL	9
	IYDEL= 22	SBL	10
1	IF (NK.GT.9) GO TO 2	SBL	11
	NC=MAX0(INT(ALOG10(AMAX1(ABS(XL),ABS(XR))))+.00001)+1,1)	SBL	12
	IF (MIN0(XL,XR).LT.0) NC=NC+1	SBL	13
	IF (NK.GT.0) NC=NC+1	SBL	14
	NC=NC+NK	SBL	15
	ENCODE (10,5,FMT(2))NC	SBL	16
	ENCODE (10,5,FMT(4))NK	SBL	17
	K=1	SBL	18
	GO TO 3	SBL	19
2	K=MIN0(16,MAX0(10,NK))- 4	SBL	20
	NC=K+1	SBL	21
3	ENCODE (20,FMT(K),OUT)XL	SBL	22
	CALL TSP (IXL,IY,1,1H+)	SBL	23
	IXTT=IXL- 9*NC+9	SBL	24

	IYC=IY+IYDEL	SBL 25
	CALL DLCH (IXTT,IYC,NC,OUT,2)	SBL 26
	IF (NNX.LE.0) RETURN	SBL 27
	NX=MIN0(NNX,128)	SBL 28
	IXC=IXL	SBL 29
	DDX=FLGAT(IXR-IXL)/NX	SBL 30
	DX=(XR-XL)/NX	SBL 31
	DO 4 I=1,NX	SBL 32
	XC=XL+I*DX	SBL 33
	IXT=IXTT+I*DDX-9	SBL 34
	IXC=IXL+I*DDX	SBL 35
	ENCODE (20,FMT(K),OUT)XC	SBL 36
	CALL TSF (IXC,IY,1,1H+)	SBL 37
4	CALL DLCH (IXT,IYC,NC,OUT,2)	SBL 38
	RETURN	SBL 39
C		SBL 40
C		SBL 41
C		SBL 42
5	FORMAT (14)	SBL 43
	END	SBL 44

C \*\*\*\*\*

	SUBROUTINE PLS3D (F,X,Y,IM,JM,FL,WR,ICOLOR)	PL3D
	DIMENSION F(1), X(1), Y(1), AA(64), AB(64), RA(64), RB(64), ER(64)	PL3D 1
	1, WR(1), FL(1), T(4), YMX(901), XMX(901), YMZ(901), OUT(2)	PL3D 2
	CALL COLOR (0)	PL3D 3
	YT=SINF(FL(1))*FL(3)	PL3D 4
	XT=COSE(FL(1))*FL(3)	PL3D 5
	YP=SINF(FL(2))*FL(4)	PL3D 6
	XP=COSE(FL(2))*FL(4)	PL3D 7
	YTB=YT*X(IM)	PL3D 8
	XTB=XT*X(IM)	PL3D 9
	YPB=YP*Y(JM)	PL3D 10
	XPB=XP*Y(JM)	PL3D 11
	XA=XTB+XPB	PL3D 12
	EA=0.	PL3D 13
	EB=1000.	PL3D 14
	NX=901	PL3D 15
	DX=XA/900	PL3D 16
	DO 1 J=1,NX	PL3D 17
	YMZ(J)=0.	PL3D 18
	XMX(J)=FLOAT(J-1)*DX	PL3D 19
1	CONTINUE	PL3D 20
	DO 2 I=1,IM	PL3D 21
	L=1	PL3D 22
	DO 2 J=1,JM	PL3D 23
	E=F(L)-X(I)*YT-Y(J)*YP	PL3D 24
	EA=MAX1F(EA,E)	PL3D 25
	EB=MIN1F(EB,E)	PL3D 26
2	L=L+1M	PL3D 27
	YC=YTB+YPB	PL3D 28
	IF (EB) 3,5,5	PL3D 29
3	DIF=YC+EB	PL3D 30
	IF (DIF) 4,5,5	PL3D 31
4	YB=-DIF	PL3D 32
	GO TO 6	PL3D 33
5	YB=0.	PL3D 34
6	YA=YC+YB+EA	PL3D 35
	T(1)=0.	PL3D 36
	T(2)=XA	PL3D 37
	T(3)=0.	PL3D 38
	T(4)=YA	PL3D 39
	CALL DGA (63,963,0,900,0.,XA,YA,0.)	PL3D 40
	YD=YB+YTB	PL3D 41
	IA=IM+1	PL3D 42
	NSCALE=10	PL3D 43

	iS=IM/2	PL3D 44
	DC 11 L=1,IM	PL3D 45
	I=IA-L	PL3D 46
	NSCALE=NSCALE+1	PL3D 47
	AB(I)=XPB+XTB-XT*X(L)	PL3D 48
	RB(I)=YD-YT*X(L)	PL3D 49
	IF (L.NE.IS) GO TO 7	PL3D 50
	SAB=AB(I)	PL3D 51
	SRB=RB(I)	PL3D 52
7	CONTINUE	PL3D 53
	IF (NSCALE.LT.10) GO TO 8	PL3D 54
	CALL CONVRT (AB(I),IAB,0,XA,63,963)	PL3D 55
	CALL CONVRT (RB(I),IRB,0,YA,900,0)	PL3D 56
	IAB=IAB+2	PL3D 57
	IRB=IRB+2	PL3D 58
	CALL TSP (IAB,IRB,1,1H*)	PL3D 59
	IRB=IRB+9	PL3D 60
	ENCODE (20,31,OUT)X(L)	PL3D 61
	CALL DLCH (IAB,IRB,3,OUT,2)	PL3D 62
	NSCALE=0	PL3D 63
8	CONTINUE	PL3D 64
	NR=AB(I)/DX+1.	PL3D 65
	IF (L.EQ.1) NS=NR	PL3D 66
	IF (L.EQ.1) YMZ(NR)=RB(I)	PL3D 67
	IF (NR.EQ.NS) GO TO 10	PL3D 68
	NMIN=AMIN0(NS,NR)	PL3D 69
	NMAX=AMAX0(NS,NR)	PL3D 70
	YSAVE=YMZ(NS)	PL3D 71
	DO 9 K=NMIN,NMAX	PL3D 72
	YMZ(K)=YSAVE+FLOAT(K-NS)/FLOAT(NR-NS)*(RB(I)-YSAVE)	PL3D 73
9	CONTINUE	PL3D 74
	NS=NR	PL3D 75
10	CONTINUE	PL3D 76
11	CONTINUE	PL3D 77
	CALL PLOT (IM,AB,1,IRB,1,32,1)	PL3D 78
	YE=YB+YPB	PL3D 79
	NSCALE=10	PL3D 80
	IS=JM/2	PL3E 81
	DO 16 J=1,JM	PL50 82
	NSCALE=NSCALE+1	PL3D 83
	AA(J)=XP*Y(J)	PL3D 84
	RA(J)=YE-YP*Y(J)	PL3D 85
	IF (J.NE.IS) GO TO 12	PL3D 86
	SAA=AA(J)	PL3D 87
	SRA=RA(J)	PL3D 88
12	CONTINUE	PL3D 89
	IF (NSCALE.LT.10) GO TO 13	PL3D 90
	CALL CONVRT (AA(J),JAA,0,XA,63,963)	PL3D 91
	CALL CONVRT (RA(J),JRA,0,YA,900,0)	PL3D 92
	JRA=JRA+2	PL3D 93
	JAA=JAA-2	PL3D 94
	CALL TSP (JAA,JRA,1,1H*)	PL3D 95
	JAA=JAA-4*18	PL3D 96
	IF (JAA.LT.0) JAA=0	PL3D 97
	ENCODE (20,31,OUT)Y(J)	PL3D 98
	CALL DLCH (JAA,JRA,3,OUT,2)	PL3D 99
	NSCALE=0	PL3D 100
13	CONTINUE	PL3D 101
	NR=AA(J)/DX+1.	PL3D 102
	IF (J.EQ.1) NS=NR	PL3D 103
	IF (J.EQ.1) YMZ(NR)=RA(J)	PL3D 104
	IF (NR.EQ.NS) GO TO 15	PL3D 105
	NMIN=AMIN0(NS,NR)	PL3D 106
	NMAX=AMAX0(NS,NR)	PL3D 107
	YSAVE=YMZ(NS)	PL3D 108
	DO 14 K=NMIN,NMAX	PL3D 109
	YMZ(K)=YSAVE+FLOAT(K-NS)/FLOAT(NR-NS)*(RA(J)-YSAVE)	PL3D 110
14	CONTINUE	PL3D 111
	NS=NR	PL3D 112
15	CONTINUE	PL3D 113
16	CONTINUE	PL3D 114

	CALL PLOT (JM,AA,1,RA,1,32,1)	PL3D 115
	ZH=.05*EA	PL3D 116
	YF=YC+YB	PL3D 117
	CALL COLOR (ICOLOR)	PL3D 118
	DO 17 J=1,NX	PL3D 119
	YMX(J)=YMZ(J)	PL3D 120
17	CONTINUE	PL3D 121
	DO 23 IJ=1,JM	PL3D 122
	I=IM- IJ+1	PL3D 123
	N=0	PL3D 124
	DO 22 JJ=1,JM	PL3D 125
	J=JM- JJ+1	PL3D 126
	N=N+1	PL3D 127
	AA(N)=XTB- X(I)*XT+Y(J)*XP	PL3D 128
	L=(J- 1)*IM+1	PL3D 129
	RA(N)=YF- X(I)*YT- Y(J)*YP+F(L)	PL3D 130
	NR=AA(N)/DX+1.	PL3D 131
	IF (RA(N).GE.YMX(NR)) GO TO 18	PL3D 132
	N=N- 1	PL3D 133
	IF (N.LE.1) N=0	PL3D 134
	IF (N.EQ.0) GO TO 22	PL3D 135
	CALL PLOT (N,AA,1,RA,1,42,1)	PL3D 136
	N=0	PL3D 137
	GO TO 22	PL3D 138
18	CONTINUE	PL3D 139
	IF (JJ.NE.1) GO TO 19	PL3D 140
	NS=NR	PL3D 141
	YMX(NS)=RA(N)	PL3D 142
	GO TO 21	PL3D 143
19	CONTINUE	PL3D 144
	IF (N.LE.1) GO TO 21	PL3D 145
	NMIN=AMINO(NS,NR)	PL3D 146
	NMAX=AMAXO(NS,NR)	PL3D 147
	YSAVE=YMX(NS)	PL3D 148
	DO 20 K=NMIN,NMAX	PL3D 149
	YMX(K)=YSAVE+FLOAT(K- NS)/FLOAT(NR- NS)*(RA(N)- YSAVE)	PL3D 150
20	CONTINUE	PL3D 151
21	CONTINUE	PL3D 152
	NS=NR	PL3D 153
22	CONTINUE	PL3D 154
	IF (N.LE.1) GO TO 23	PL3D 155
	CALL PLOT (N,AA,1,RA,1,42,1)	PL3D 156
23	CONTINUE	PL3D 157
	DO 24 J=1,NX	PL3D 158
	YMX(J)=YMZ(J)	PL3D 159
24	CONTINUE	PL3D 160
	DO 30 JJ=1,JM	PL3D 161
	J=JM- JJ+1	PL3D 162
	N=0	PL3D 163
	DO 29 IJ=1,JM	PL3D 164
	I=IM- IJ+1	PL3D 165
	N=N+1	PL3D 166
	AA(N)=XTB- X(I)*XT+Y(J)*XP	PL3D 167
	L=(J- 1)*IM+1	PL3D 168
	RA(N)=YF- X(I)*YT- Y(J)*YP+F(L)	PL3D 169
	NR=AA(N)/DX+1.	PL3D 170
	IF (RA(N).GE.YMX(NR)) GO TO 25	PL3D 171
	N=N- 1	PL3D 172
	IF (N.EQ.1) N=0	PL3D 173
	IF (N.EQ.0) GO TO 29	PL3D 174
	CALL PLOT (N,AA,1,RA,1,42,1)	PL3D 175
	N=0	PL3D 176
	GO TO 29	PL3D 177
25	CONTINUE	PL3D 178
	IF (IJ.NE.1) GO TO 26	PL3D 179
	NS=NR	PL3D 180
	YMX(NS)=RA(N)	PL3D 181
	GO TO 28	PL3D 182
26	CONTINUE	PL3D 183
	IF (N.LE.1) GO TO 28	PL3D 184
	NMIN=AMINO(NS,NR)	PL3D 185

	NMAX=AMAX0(NS,NR)	PL3D 186
	YSAVE=YMX(NS)	PL3D 187
	DO 27 K=NMIN,NMAX	PL3D 188
	YMX(K)=YSAVE+FLOAT(K- NS)/FLOAT(NR- NS)*(RA(N)- YSAVE)	PL3D 189
27	CONTINUE	PL3D 190
28	CONTINUE	PL3D 191
	NS=NR	PL3D 192
29	CONTINUE	PL3D 193
	IF (N.LE.1) GO TO 30	PL3D 194
	CALL PLOT (N,AA,1,RA,1,42,1)	PL3D 195
30	CONTINUE	PL3D 196
	CALL CONVRT (SAB,IAB,0,XA,63,963)	PL3D 197
	CALL CONVRT (SAA,JAA,0,XA,63,963)	PL3D 198
	CALL CONVRT (SRB,IRB,0,YA,900,0)	PL3D 199
	CALL CONVRT (SRA,JRA,0,YA,900,0)	PL3D 200
	IAB=IAB+2*18+2*30	PL3D 201
	JAA=JAA- 3*18- 2*30	PL3D 202
	IRB=IRB+36	PL3D 203
	JRA=JRA+36	PL3D 204
	CALL COLOR (0)	PL3D 205
	CALL DLCH (JAA,JRA,20,WR(13),4)	PL3D 206
	CALL DLCH (IAB,IRB,20,WR(11),4)	PL3D 207
	CALL DLCH (100,960,100,WR,2)	PL3D 208
	CALL ADV (1)	PL3D 209
	RETURN	PL3D 210
C		PL3D 211
C		PL3D 212
C		PL3D 213
31	FORMAT (F3.1)	PL3D 214
	END	PL3D 215

C \*\*\*\*\*

	SUBROUTINE SWEEP (IX1,IY1,IX2,IY2)	SWEP
*		SWEP 1
*		SWEP 2
*		SWEP 3
	DIMENSION WORD(8)	SWEP 4
	DATA WORD/8*10H * * * * *,XONE,YONE,XTWO,YTWO,XDIFF,YDIFF/10H	SWEP 5
1	X1,10H Y1,10H X2,10H Y2,10H X1 AND X2,10H	SWEP 6
	2 Y1 AND Y2/	SWEP 7
*		SWEP 8
	IERROR=0	SWEP 9
*	CHECK FOR ARGUMENT LESS THAN ZERO	SWEP 10
	IF (IX1.GE.0) GO TO 1	SWEP 11
	IERROR=IERROR+1	SWEP 12
	PRINT 21, XONE	SWEP 13
1	IF (IX2.GE.0) GO TO 2	SWEP 14
	IERROR=IERROR+1	SWEP 15
	PRINT 21, XTWO	SWEP 16
2	IF (IY1.GE.0) GO TO 3	SWEP 17
	IERROR=IERROR+1	SWEP 18
	PRINT 21, YONE	SWEP 19
3	IF (IY2.GE.0) GO TO 4	SWEP 20
	IERROR=IERROR+1	SWEP 21
	PRINT 21, YTWO	SWEP 22
*	CHECK FOR ARGUMENT GREATER THAN 1023	SWEP 23
4	IF (IX1.LE.1023) GO TO 5	SWEP 24
	IERROR=IERROR+1	SWEP 25
	PRINT 22, XONE	SWEP 26
5	IF (IX2.LE.1023) GO TO 6	SWEP 27
	IERROR=IERROR+1	SWEP 28
	PRINT 22, XTWO	SWEP 29
6	IF (IY1.LE.1023) GO TO 7	SWEP 30
	IERROR=IERROR+1	SWEP 31
	PRINT 22, YONE	SWEP 32
7	IF (IY2.LE.1023) GO TO 8	SWEP 33
	IERROR=IERROR+1	SWEP 34

PRINT 22, Y TWO	SWEP 35
* CHECK FOR DIFFERENCE GREATER THAN 63	SWEP 36
8 IF (IABS(IX1-IX2).GE.64) GO TO 9	SWEP 37
IERROR=IERROR+1	SWEP 38
PRINT 23, XDIF	SWEP 39
9 IF (IABS(IY1-IY2).GE.64) GO TO 10	SWEP 40
IERROR=IERROR+1	SWEP 41
PRINT 23, YDIFF	SWEP 42
* RETURN TO CALLER IF ANY ERRORS HAVE BEEN DETECTED	SWEP 43
10 IF (IERROR.EQ.0) GO TO 11	SWEP 44
PRINT 20	SWEP 45
RETURN	SWEP 46
*	SWEP 47
11 IF (IY1.GT.IY2) GO TO 13	SWEP 48
DO 12 I=IY1,IY2	SWEP 49
12 CALL GX A (IX1,IX2,J)	SWEP 50
GO TO 15	SWEP 51
13 DO 14 I=IY2,IY1	SWEP 52
14 CALL GX A (IX1,IX2,J)	SWEP 53
*	SWEP 54
15 IF (IX1.GT.IX2) GO TO 17	SWEP 55
DO 16 I=IX1,IX2	SWEP 56
16 CALL GY A (IY1,IY2,J)	SWEP 57
GO TO 19	SWEP 58
17 DO 18 I=IX2,IX1	SWEP 59
18 CALL GY A (IY1,IY2,J)	SWEP 60
*	SWEP 61
19 RETURN	SWEP 62
C	SWEP 63
20 FORMAT (/10X,43H * ARGUMENT ERROR(S) - EXECUTION DELETED *)	SWEP 64
21 FORMAT (10X,A10,10H NEGATIVE )	SWEP 65
22 FORMAT (10X,A10,21H GREATER THAN 1023 )	SWEP 66
23 FORMAT (10X,19H DIFFERENCE BETWEEN,A10,13H LESS THAN 64)	SWEP 67
END	SWEP 68

C .....

	IDENT COLOR		COLOR
	ENTRY COLOR		COLOR
	EXT BS4020		COLOR
COLOR	BSSZ 1		COLOR
	SA1 B1	PICK UP ARG	COLOR
	MX6 58		COLOR
	BX6 - X6*X1	0,1,2,3 INSURED	COLOR
	SB2 X6		COLOR
	BX6 - X6*X1	0,1,2,3 INSURED	COLOR
	SB2 X6		COLOR
	SA1 WHITE+B2		COLOR
	RJ BS4020	INTO BUFFER	COLOR
	JP COLOR		COLOR
WHITE	DATA 400000000000B	WHITE	COLOR
	DATA 410000000000B	RED	COLOR
	DATA 420000000000B	GREEN	COLOR
	DATA 430000000000B	BLUE	COLOR
	END		COLOR

CM/tb:355(50)