NBS

Technical Note 249

A PROGRAM FOR PLOTTING CIRCLES OF CONSTANT OVERPRESSURE AROUND TARGETED POINTS

MAI LIIS JOEL AND DOUGLAS D. LOTTRIDGE

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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A Program for Plotting Circles of Constant Overpressure Around Targeted Points

by

Mai Liis Joel

and

Douglas D. Lottridge

Abstract

The Defense Communications Agency is responsible for locating its communications facilities in a manner that will maximize the probability of maintaining communication in the face of nuclear attack. This report describes a program written for the IBM 7094 which produces as its final output one or more tapes to be used as input to a CalComp 570 plotter system. With these tapes the plotter can produce overlays for use with the series of World Aeronautical Charts covering the Continental United States. The overlays comprise circles representing a radius of constant overpressure around the target point of a given nuclear weapon. Based on hypothetical attacks the overlays provide the user with a means of visualizing the hardness required of facilities to survive in particular areas.

1. Introduction

The Defense Communications Agency (DCA) is responsible for the design and implementation of a world-wide communications network. Inherent in such responsibility is the need for DCA to determine where facilities should be located. There are some obvious restrictions in the placement of facilities. Certainly it would be impossible to put facilities in areas controlled by unsympathetic alien powers. Additionally, it is impossible to place facilities in areas which are topographically restrictive. But aside from these more clearly discernible restrictions, certain other limitations are imposed.

A major consideration in the design of a modern military network is the maximization of the probability of network survival in the event of a nuclear attack. The National Bureau of Standards (NBS) was asked to develop a method for presenting graphically the danger areas within the Continental United States (CONUS) where communications facilities might be destroyed if a nuclear attack were to take place.

There are many known effects from a nuclear blast; NBS was asked to consider, at the present time, only the direct blast effect. Data for the project are based on hypothetical attacks which are designed within the Defense Department.

The destructive power of a bomb at a point can be measured in terms of peak overpressure in pounds per square inch (PSI). This overpressure can be calculated from two bomb parameters, height of burst and yield. The distance from the bomb at which the overpressure is calculated is often referred to as the "lethal radius" for that particular PSI value.

The strength of a facility of the communications network to withstand the blast of a bomb is measured in terms of "hardness." If a facility is hardened to 2 PSI, this means that, in all likelihood, it can withstand the blast of bombs with overpressures which are less than 2 PSI at that point. However, if a bomb were to produce an overpressure of 3 PSI at that point, it is likely that the facility would be destroyed.

A factor known as "circular error probable" (CEP) is introduced because it is likely that a bomb targeted at a specific point will not land exactly on that point, but rather will land somewhere in the vicinity of the target. It is possible, therefore, that a facility located immediately outside the lethal radius might be destroyed if the bomb actually hit off target in the direction of the facility. An allowance for this possibility is introduced by adding a specified number of CEP's to the lethal radius. It should be noted, however, that adding CEP's will increase the probability that something located within the radius could actually withstand a blast. The probabilities of these occurrences for given numbers of CEP's have been calculated.

NBS has written a computer program which produces as its final output a magnetic tape which is used as input to the CalComp 570 Magnetic Tape Plotting System. With this tape as input, the CalComp plotter will produce overlays for the series of World Aeronautical Charts (WAC charts). Each of these overlays contains circles which represent lethal radii (including a specified number of CEP's) around targeted points. Each circle bears a label of the PSI value which it represents. By placing an overlay on the appropriate map, then, it is possible to see to what PSI value a facility would have to be hardened in order to withstand the particular nuclear attack being considered.

It should be emphasized that this program does not consider all factors which are essential to the optimal placement of facilities. It does, however, provide readily available guidelines for determining the required hardness of a facility in a particular locale. It eliminates the need for laborious hand calculations and manual mapping.

2. The Maps

Before the programming effort began, it was necessary to select an appropriate map series. It was decided that a scale of 1 inch = 10 to 20 miles provided enough detail without requiring too many maps to provide practical coverage of CONUS. The World Aeronautical Chart (WAC) Series was selected because of appropriate scale (1 inch = 16 miles) and availability. Because the charts are in the Lambert Conformal Conic Projection, the algorithm to convert geographic coordinates to x, y coordinates is somewhat more complex than would be required for conversion from a rectangular projection. The algorithm is discussed in more detail in the section entitled Routines.

3. The Program

3.1 General

This program is written in two phases, both coded for the IBM 7090/94 computers.

Phase I is divided into three parts: the first generates the lethal radius and tags each bomb with the appropriate WAC identification; the second sorts the bombs into ascending WAC chart order; and the third generates the x, y coordinates of targeted points and produces the input tape for the second major phase.

Phase II of the main program calculates the codes required to produce circles whose radii correspond to specified overpressures. These codes, as well as control and labeling codes, make up the plotting tapes which are the main outputs of Phase II.

A general flow chart of the entire program is presented in Figure 1.

3.2 Inputs

This section briefly discusses the data and control card input requirements for the program. Specific details concerning the formats of all of these cards are presented in Appendix A.

The attack data cards are accepted by Part 1 of Phase I in a format which was chosen to make the input compatible with that of the National Military Command System (NMCS) Rapid Damage Assessment (RDA) model. Bombs targeted at the same point should be grouped together in the data deck so that the program can take advantage of the duplicate point deletion feature which is discussed in the section on Routines.

Two or more cards containing control and parameter items are placed in front of the data deck. These give the program flexibility in tape assignment, type of output, number of CEP's to be added to the lethal radii, number of radii to be calculated for each bomb, PSI

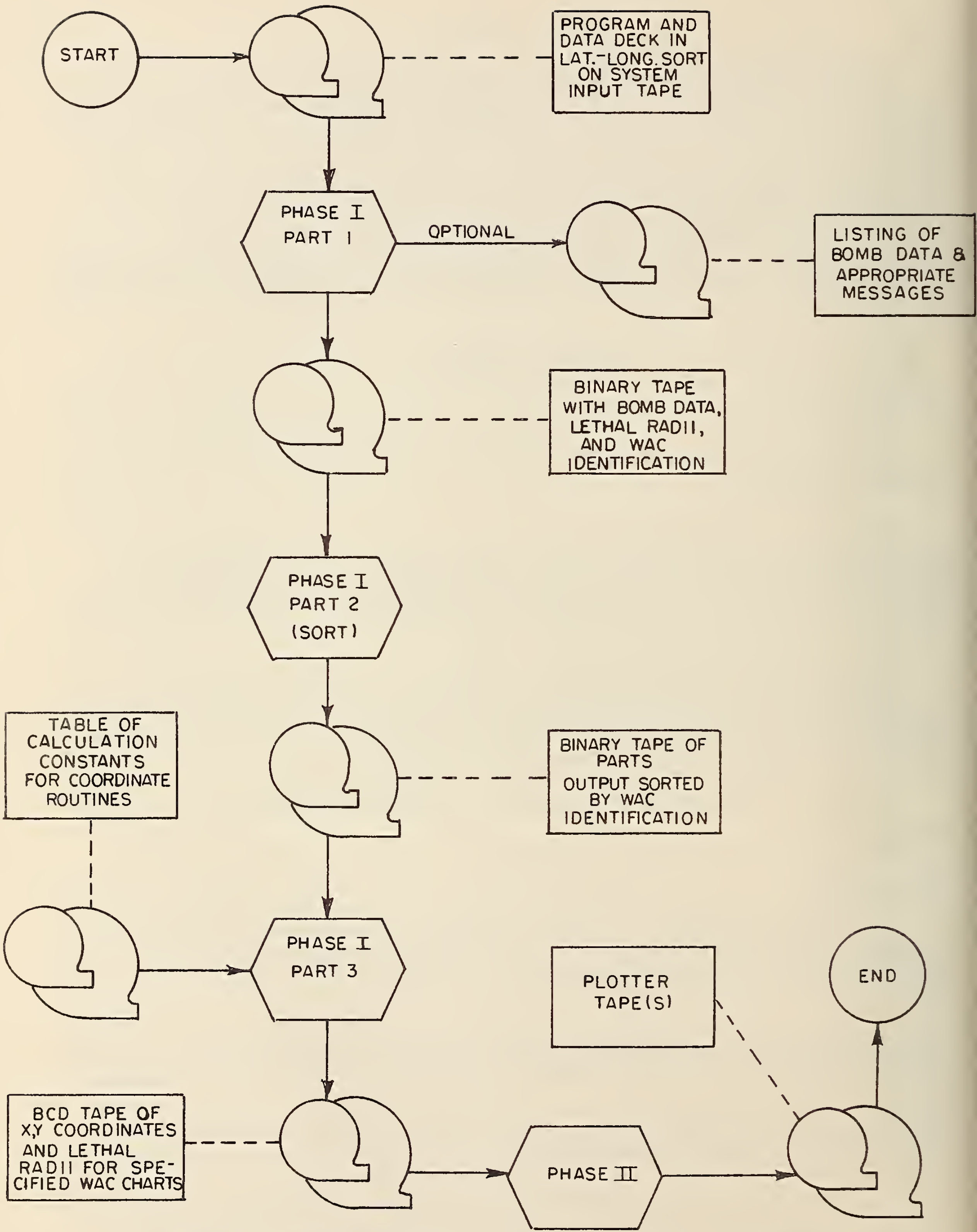

FIGURE 1. LETHAL RADIUS PLOT PROGRAM FLOW CHART

values to be considered in calculating the radii, number of altitude categories to be considered, and coefficients associated with each altitude calculation. A single control card behind the data deck flags the end of the deck.

The input to Part 2 of Phase I is the binary output tape from Part 1. The required control cards for Part 2 (the IBM IBSYS Sort routine) are coded specifically for this sort and are included in the program package.

There are two input tapes required for Part 3 of the first major phase. One is the sorted tape from Part 2; the other is a binary tape (NBS number 1151) of computational constants for each WAC chart. (These constants are discussed in the following section.)

A single parameter card is placed at the end of the Part 3 program deck. Besides specifying the number of radii to be plotted around each point, it allows the programmer to assign specific tape units to the symbolically named tapes in the program.

Inputs to Phase II consist of the tape produced in Part 3 of Phase I (see section entitled Outputs for format description) and of one control card which specifies the number of hardness categories with their associated PSI values. The date of the run and an option for specifying security classification are also included on the control card.

3.3 Routines

Part 1 of Phase I is composed of a main program and two subroutines, all written in FORTRAN. A general flow chart is shown in Figure 2 and a program listing appears in Appendix B. The main program performs general control functions, writes out any necessary diagnostics, deletes duplicate bombs, and calls the following subroutines:

CHART -- This subroutine performs the function of supplying the appropriate WAC identification number for each bomb. The identification number is twice the true WAC chart number for the lower half of a chart, or one plus twice the true WAC chart number for the upper half of a chart.

RLETH -- This subroutine contains the mathematics for computing the lethal radii. The algorithm used is one developed by the RAND Corporation. The basic formula for calculating the lethal radii was taken from Reference 2. The coefficients used for 5,000-foot and ground burst conditions were taken from a listing of the program discussed in Reference 2. As soon as the lethal radius has been computed, the main program adds the specified number of CEP's to it. This gives the radius which is used in plotting.

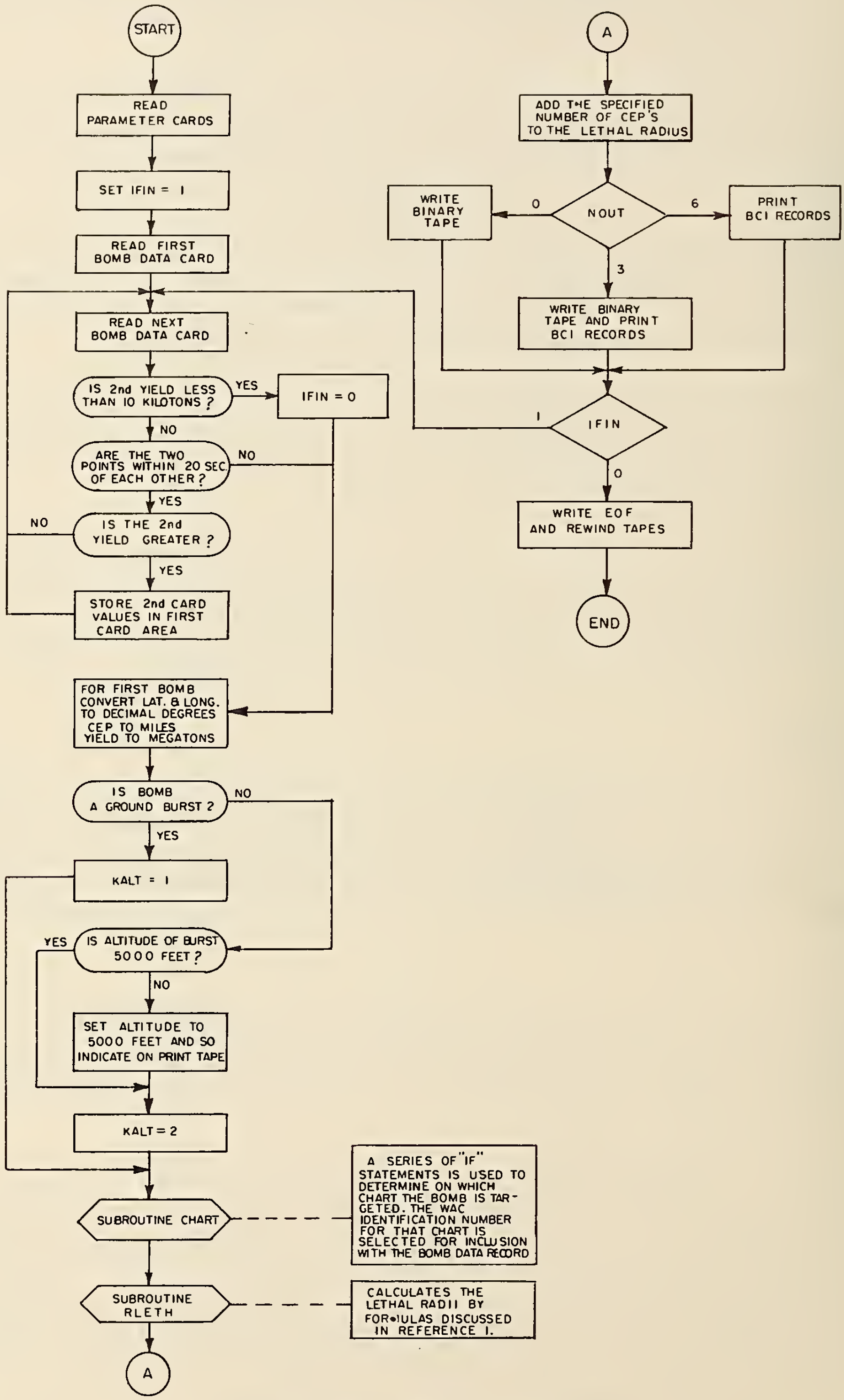

FIGURE 2. PHASE I - PART 1 FLOW CHART

The duplicate point deletion feature in Part 1 eliminates redundant plotting of radii around a multiple weapon target area. As cards are read, the target coordinates are matched. If the geographic coordinates are within 20 seconds of arc of each other the larger yield is maintained with the coordinates of the first target. This process continues until a bomb is found which is not targeted within 20 seconds of arc of the first one. At this point the coordinates of the first bomb and the data of the one with the largest yield are made part of the data for plotting. Then the process continues. Since the plotter is insensitive to distances of less than about 6 seconds on the WAC charts, this feature produces virtually no information loss and provides more readable charts.

Part 2 of Phase I is a sort routine run under the IBM IBSYS Monitor System. Its purpose is to arrange the binary records on the Part 1 output tape into ascending order by WAC identification number. The routine was written by IBM and is found on the IBSYS Monitor tape. The control cards required to call the routine are included as part of the program package. Detailed information may be found in Reference 3.

Part 3 of Phase I is a FORTRAN routine which prepares the final Phase I output tape. This tape is used as input to the plotting routines of Phase II. A flow chart of Part 3 appears in Figure 3, and the program listing is given in Appendix B. This routine requires some detailed mathematical procedures to convert geographic positions to x, y coordinates for the WAC overlays. In order to describe the computational procedure a description of the Lambert Conformal Conic Projection must be given.

This projection is of the type which preserves angular relationships in mapped areas. The latitudes (parallels), therefore, are portions of concentric circles and the longitudinal lines (meridians) will intersect at either the north or south pole depending upon whether the mapped area is in the northern or southern hemisphere. (If the central latitude of the projection is the equator the meridians will be parallel.) A given chart will normally be based on two standard parallels. The mathematical relationships among points on the chart are calculated by considering the two standard parallels as the points of intersection of a cone with a sphere. Figure 4 will help clarify this point.

The absence of immediately available values for the angular scale constant and for the meridian radii to given parallels presents a problem in expanding the use of this program to areas outside CONUS. It should readily be seen that any change in standard parallels will change the shape and size of the intersecting cone so that the lengths R and r (see Figure 5) and the angular scale factor will vary. While this problem may not be insurmountable, considerable effort would be required to derive formulas for computing the necessary constants.

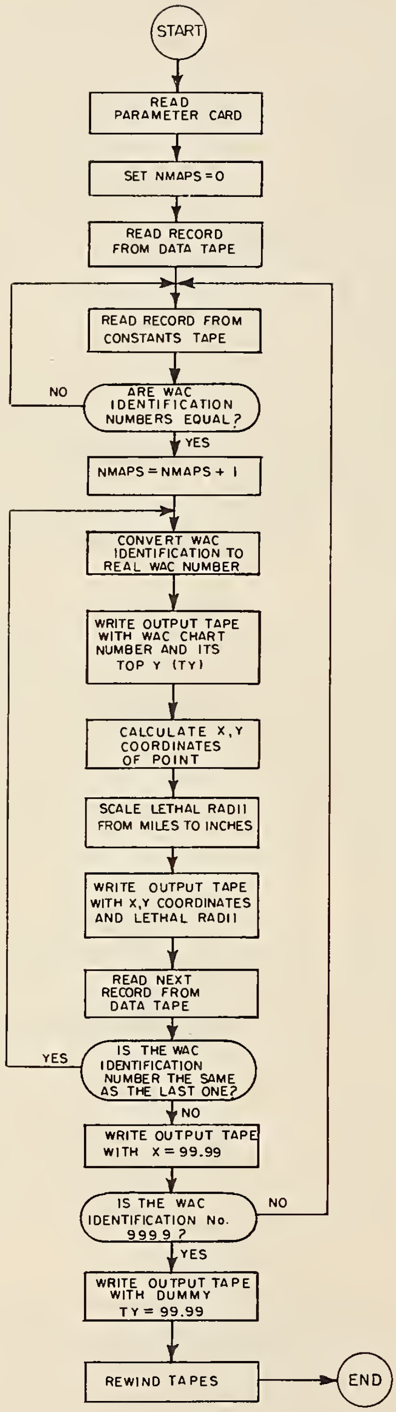

FIGURE 3. PHASE I – PART 3 FLOW CHART

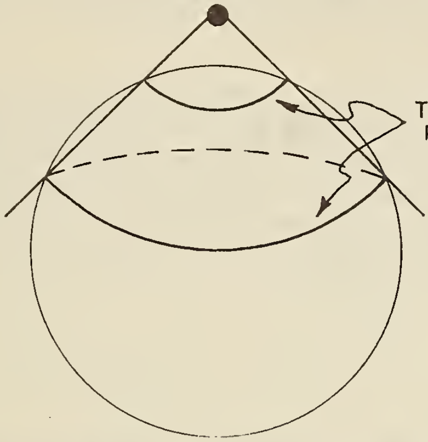

FIGURE 4. STANDARD PARALLELS OF LAMBERT CONFORMAL CONIC PROJECTION

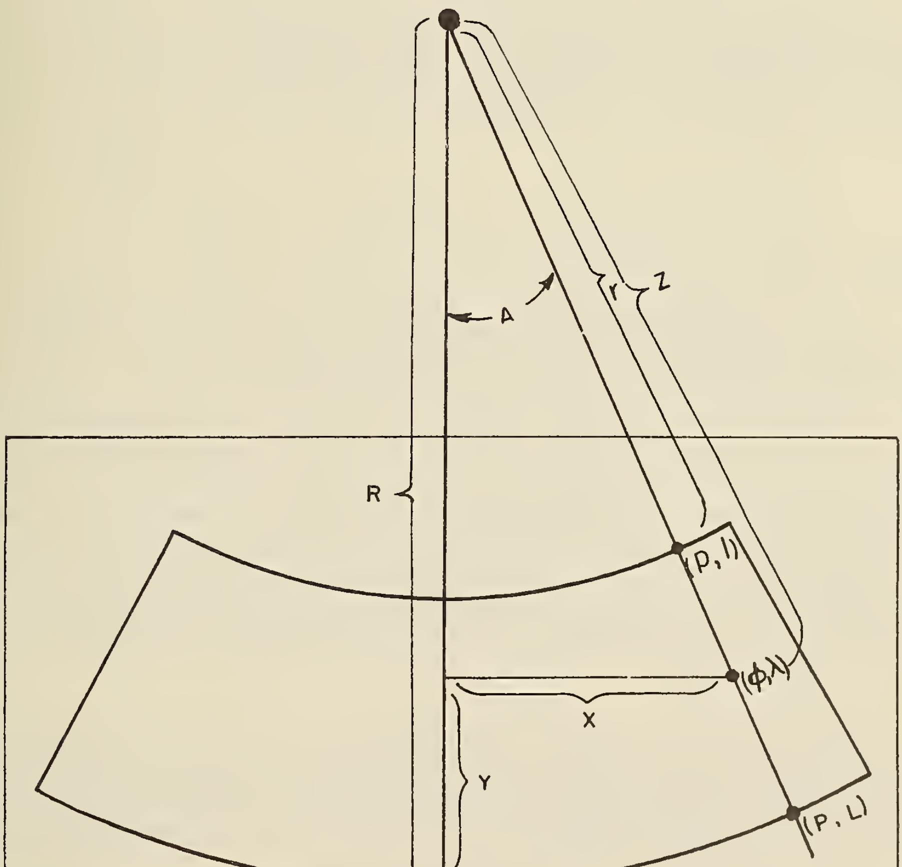

FIGURE 5. DETAIL OF LAMBERT CONFORMAL CONIC PROJECTION

The formulas for calculating x, y coordinates were developed by NBS from information contained in Reference 1. Figure 5 will help to show how the equations were derived.

To calculate the x, y coordinates of the given geographic point ϕ, λ, the origin (0, 0) is set at that point with geographic coordinates P, M. Each chart has an upper and lower parallel with latitudes p and P respectively and a central meridian with longitude M. Values for r, R, and k (defined below) are available from Reference 1 for the WAC chart series of the United States with standard parallels of 33° and 45°. The calculations are as follows:

$$\frac{R-Z}{R-r} = \frac{P-\phi}{P-p}$$

$$Z = R - \frac{(P-\phi)(R-r)}{P-p} \qquad \text{or}$$

Let $\theta = M - \lambda$

and k = a scale constant for angular correction (required when representing a spherical surface on a plane surface).

Then $A = k\,\theta$

$$x = Z \sin A$$

$$y = R - Z \cos A$$

It is now appropriate to specify the contents of the tape of constants (NBS 1151) which is used as input to Part 3. For each chart the tape contains the WAC identification number, the central meridian (M) of the chart in decimal degrees, the maximum value (TY) in inches on M, the unscaled meridian radius (R) in meters to the lower parallel, the unscaled difference (R-r) in meters between the meridian radii to the upper and lower parallels, and the latitude (P) of the lower parallel. The meridian radii to parallels are given for 30-minute intervals in Reference 1. The symbolic names used for these quantities in the program may differ from those used in this description because of FORTRAN requirements and the desire for simplicity in this presentation.

Eight subroutines and a main program which calls these subroutines make up the Phase II program package. The main program and the CIRCLE and CONVRT subroutines were written at NBS specifically for this project. The remaining subroutines are more general, being part of the Standard CalComp On-line Off-line Plotting

(SCOOP) package. See Reference 4.[1/] However, two of these subroutines (PLOT and MSG) have been modified for use in this program and, therefore, should no longer be considered general purpose plotting routines.

The remainder of this section contains descriptions and flow charts (when necessary) of the routines used in Phase II. Figures 9, 10, and 11 have been taken directly from the SCOOP manual. Because of its importance in this problem, the CIRCLE subroutine is described in much greater detail than the others. Appendix B contains listings of all routines in the form required by this program.

Phase II Main Program -- The main program, which is written in FORTRAN, reads the input tape and control card, calls the various subroutines necessary for producing a plotter tape, and produces a listing which shows the correspondence between WAC coverage and location (picture number) on the output tape. See Figure 6.

CIRCLE (CY, R, M, NUMB) -- This FORTRAN subroutine calculates the moves required to produce circles with specific radii. CY represents the y coordinate of the center of the circle and is expressed in floating point inches from the origin. R is the radius in inches, also expressed in floating point. The last two arguments (M, NUMB) are outputs used to call the internal subroutine CONVRT. The transfer vector is convert; that is, the subroutine transfers to CONVRT. See Figure 7.

In order to understand how CIRCLE works, it is necessary to know the following two facts about the CalComp plotter: (1) the plotter can move in eight directions; and (2) each move has a 0.01-inch projection horizontally or vertically, or both. CIRCLE produces a certain number (NUMB) of integers (M) from 0 to 8. These integers correspond to a "no move" code (0) and to the eight possible plotter moves. See Figure 8.

If a circle is divided into eight sectors, a certain combination of only two plotter moves is required to draw the arc for any given sector. For example, the arc from 0° to 45° may be drawn using only north (1) and northwest (8) moves. Similarly, the 45° to 90° arc would require only northwest (8) and west (7) moves, and so on. As long as whole circles are drawn this remains true.

1/ Permission to reproduce material from Reference 4 was given by California Computer Products, Inc. This material may not be reproduced except when authorized by that company.

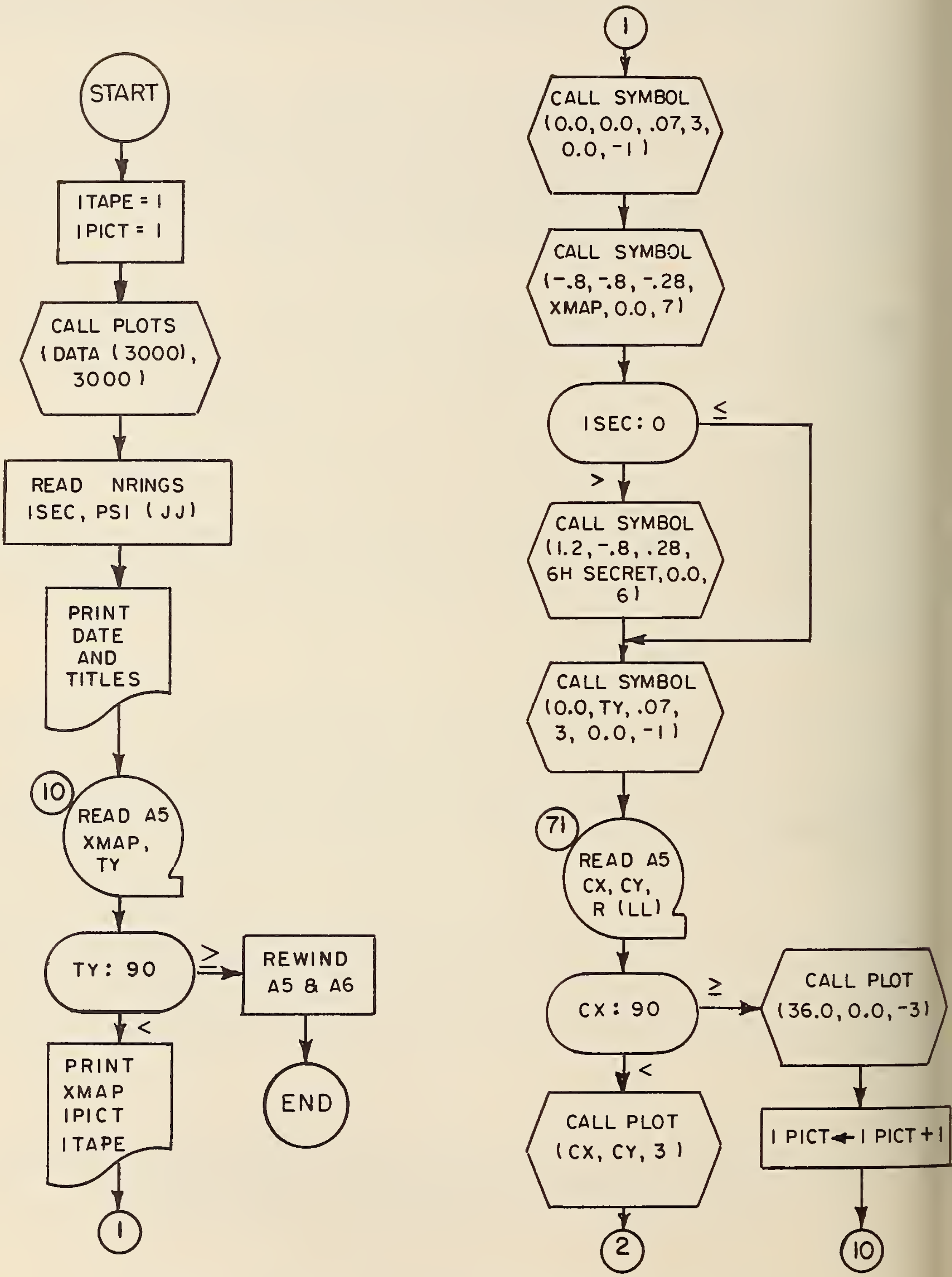

FIGURE 6. PHASE II MAIN PROGRAM FLOW CHART

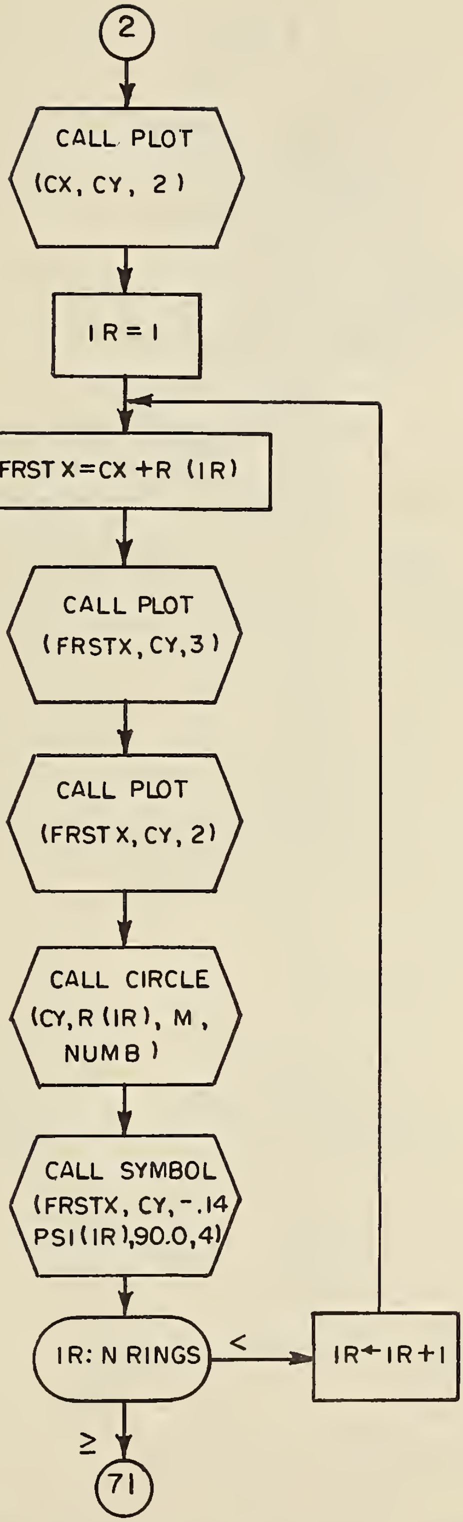

FIGURE 6. (continued)

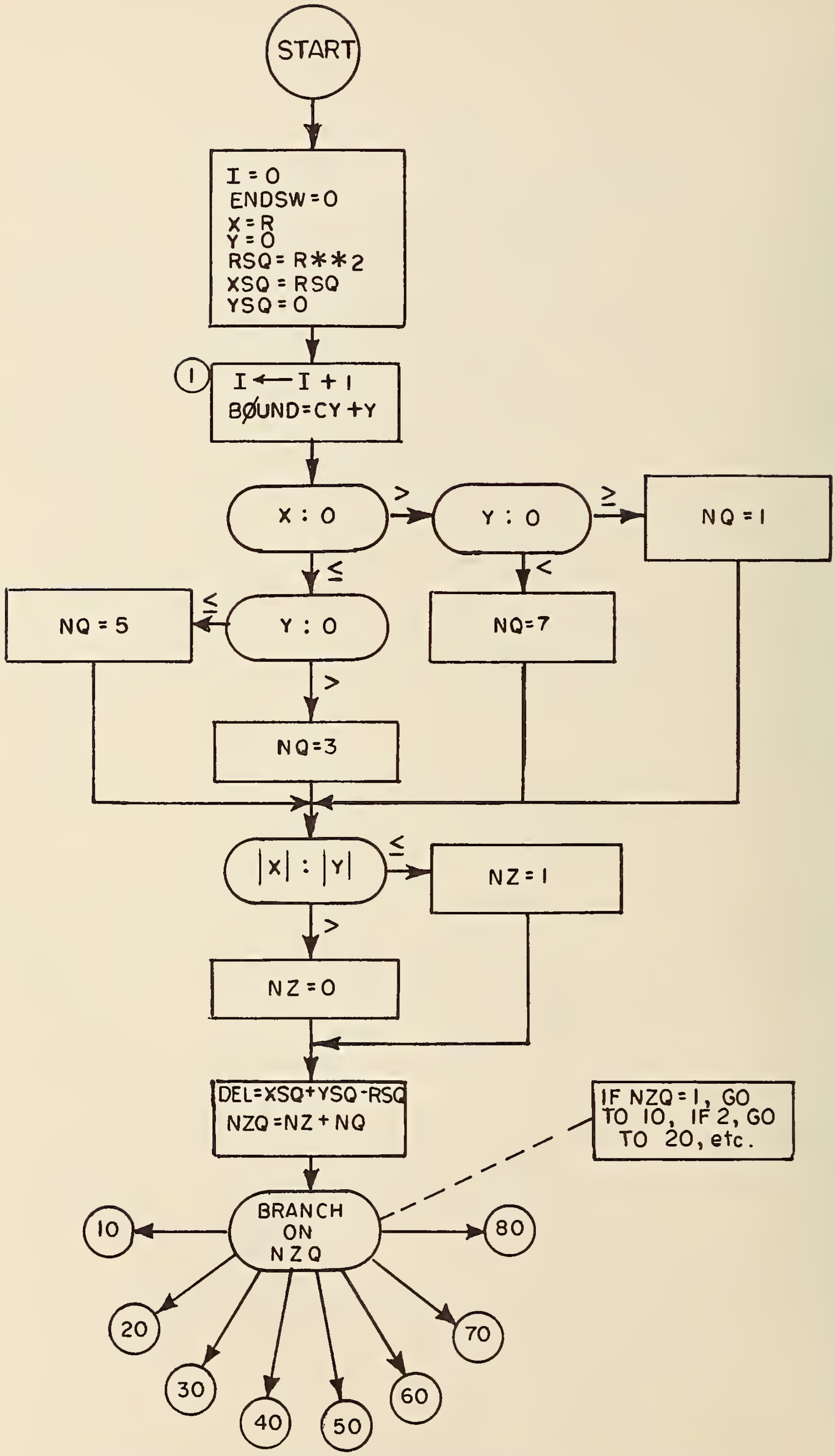

FIGURE 7. CIRCLE SUBROUTINE FLOW CHART

CALL CIRCLE (CY, R, M, NUMB)

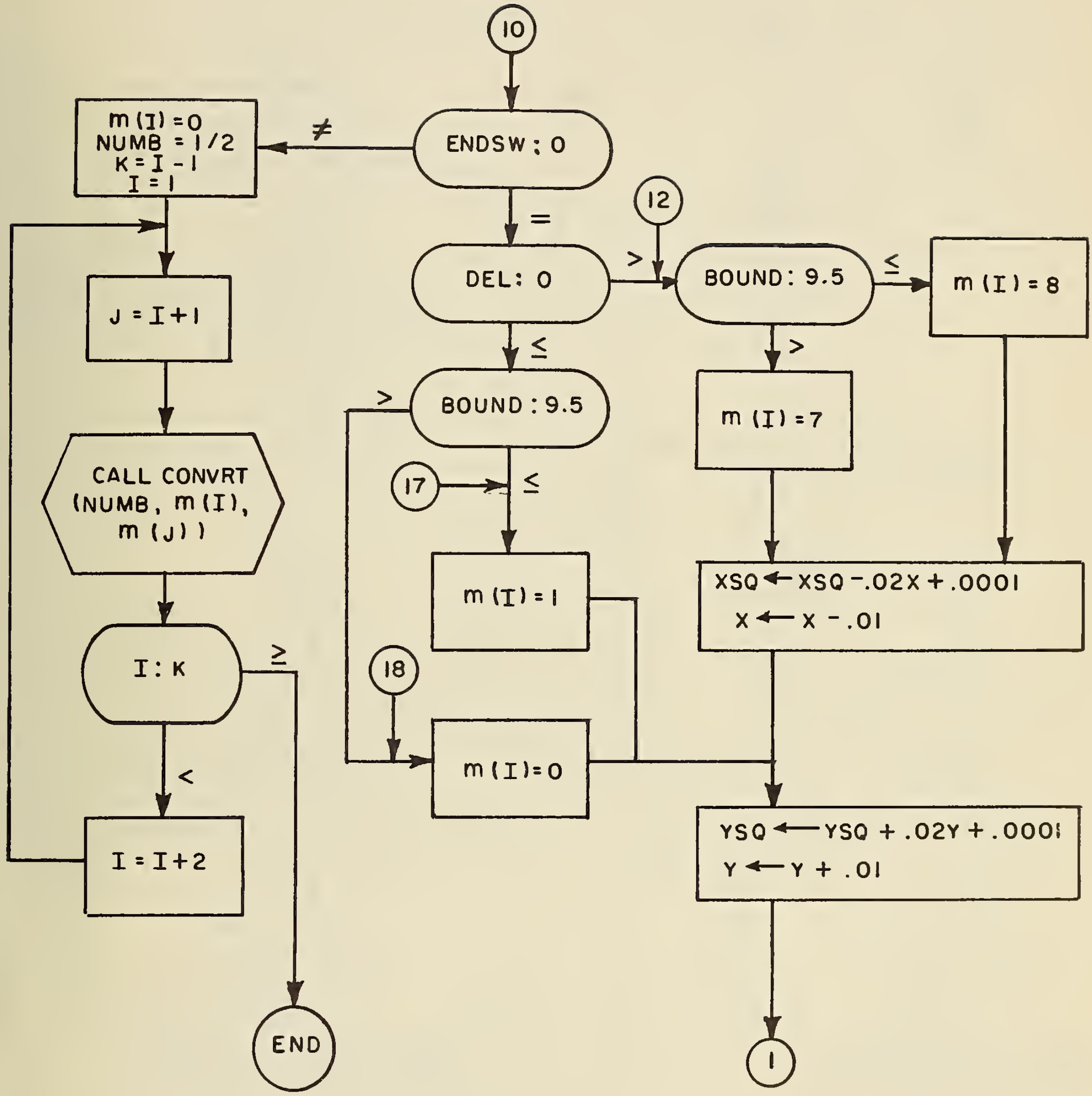

FIGURE 7. (continued)

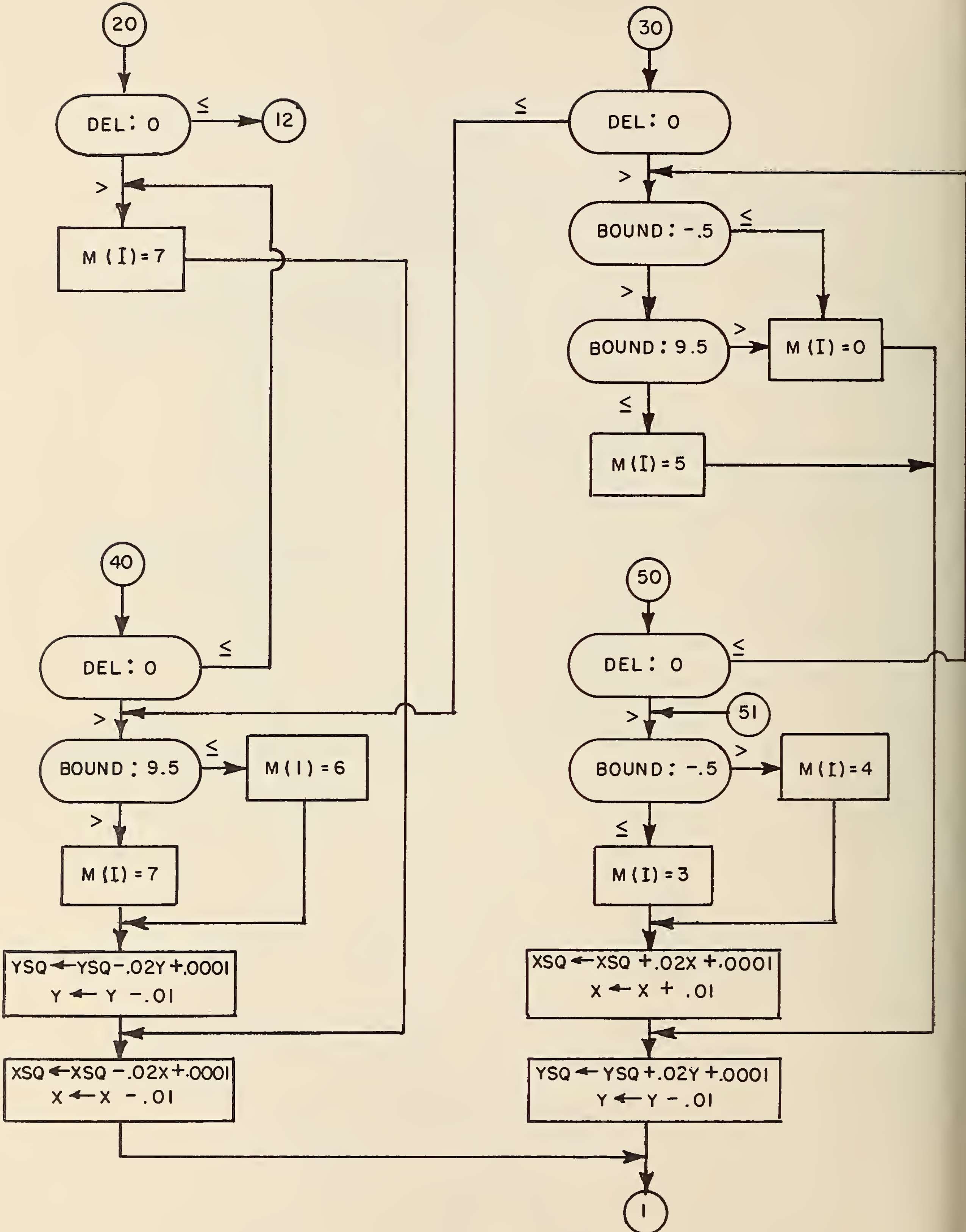

FIGURE 7. (continued)

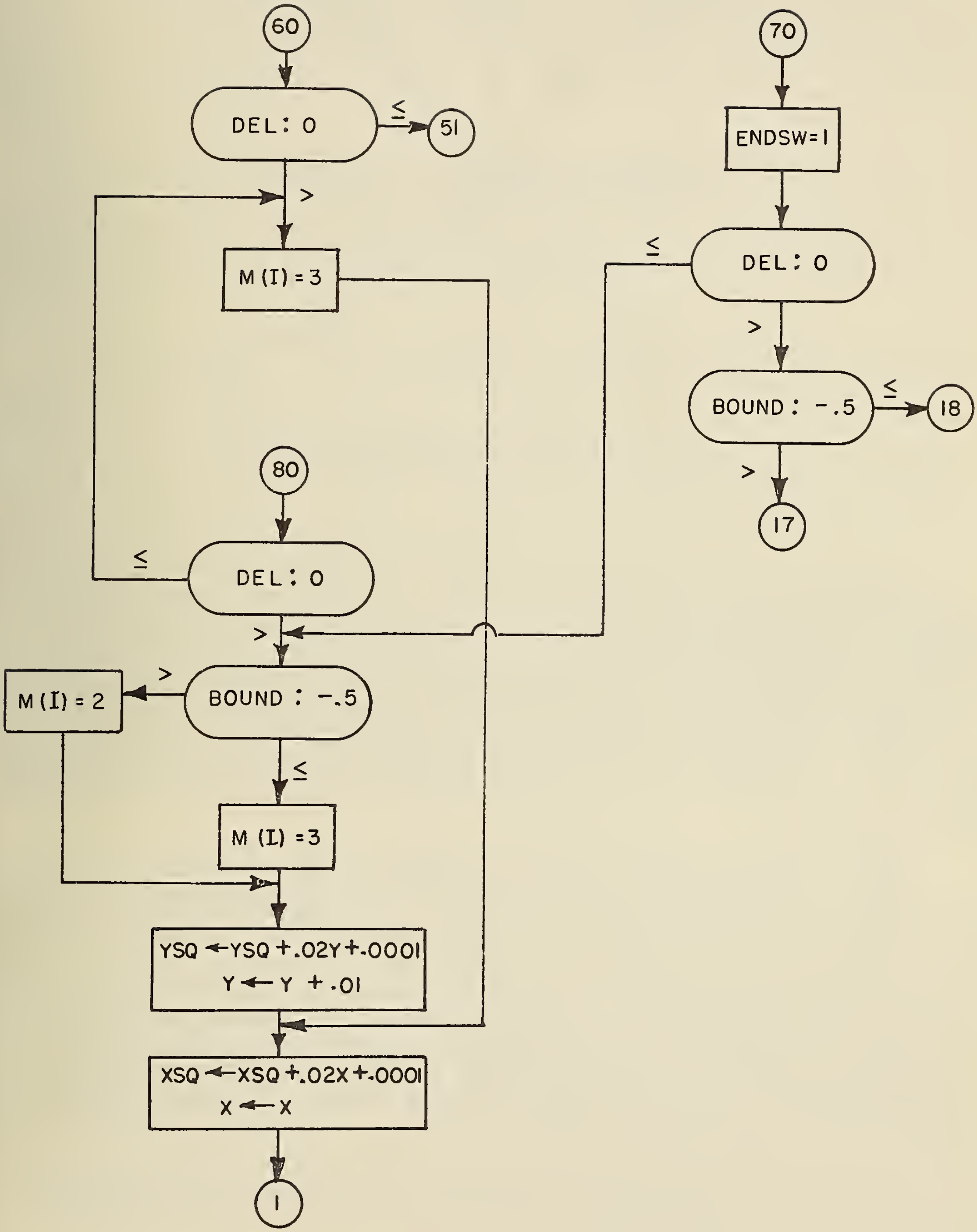

FIGURE 7. (continued)

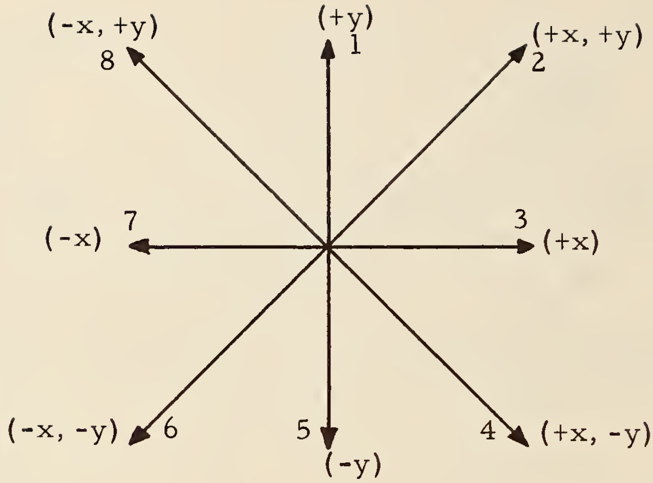

Figure 8. CalComp Plotter Moves

However, if truncation is necessary to prevent hitting the physical stops at the top or bottom of the plotter, the number of possible plotter moves in any given sector may become as high as four. In these instances substitutions for one or both of the two original moves are made. For example, if in moving from 0° to 45° either a north (1) or a northwest (8) move would exceed the physical limits of the plotter, a "no-move" code (0) and a west code (7) would need to be substituted for the two original moves. This action would produce a straight line at the top or bottom of a circle and would indicate that the circle had been truncated.

Phase II has been programmed so that when CIRCLE is called the codes have already been produced for positioning the plotter pen at 0° on the circumference of the circle to be drawn. Since this is true, it is possible for programming purposes to consider the center of the circle as being at a point $x = 0$, $y = 0$. The initial point on the circumference then becomes $x = r$, $y = 0$. With these new reference points it is relatively simple to determine which sector is being drawn and, therefore, which moves are possible. To determine the sector, one needs only to compare the x and y values with zero and the absolute values of x and y with each other.

To determine which combination of the two possible moves for a given sector will produce the most perfect circle, the formula for a circle with center at (0, 0) is used:

$$x^2 + y^2 = r^2$$

To determine whether, for example, a north or northwest move is preferable, the value $x^2 + y^2 - r^2$ (del) is computed. If del is equal to zero, the pen is positioned exactly on the circumference of the circle. If it is less than zero, the pen is inside the circle, and if it is greater, it is outside. The value of del, then, indicates the best next move in order to stay closest to the perfect circumference. Each time a move is made the x and/or y value is changed by 0.01 inch for the next calculations.

For obvious reasons, tests to determine whether truncation is necessary cannot be made using the hypothetical center x = 0, y = 0. Instead, the true center y (CY) value of the circle relative to the overlay is used for truncation tests. The true center x value is never needed, since truncation will occur only at the top and/or bottom of an overlay.

When a circle is truncated, the deleted portion of the circle is not plotted on the adjacent overlay. Although it is relatively simple to visualize the continuation of a truncated circle, it is currently impossible without examining surrounding overlays to know whether or not the area under consideration is affected by bombs targeted near the boundaries of adjacent charts. Further programming would be required to enter parts of circles with centers on adjacent charts. (This is under consideration in future plans.)

CONVRT (NUMB, M(I), M(J)) -- This internal machine language (FAP) subroutine converts a certain number of integers (M) produced in CIRCLE into actual plotter moves. NUMB is the number of computer words (two moves to one word) needed to store these moves. The subroutine then transfers to PLOT with certain control codes as arguments; these codes permit the incorporation of circle-producing plotter moves into the main buffer area.

MSG -- This short, internal, FORTRAN subroutine is used for on-line messages to the computer operator. The original SCOOP version has been modified slightly to aid in producing the listing described under MAIN.

PLOT (X, Y, IPEN) -- The primary purpose of this FAP subroutine is to move the pen from its current location to a new one. The secondary purpose is to signal the end of the plot. X and Y are the coordinates of the point to which the pen is to be moved. The up or down condition of the pen during movement is specified by the magnitude of IPEN, where 1 = no change, 2 = pen down, and 3 = pen up. If the sign of IPEN is positive the entrance is a normal plot entrance; if it is negative the entrance is an end-of-plot entrance and the following occurs:

1. The output buffer is written on tape, and

2. A new reference point is established by storing zero in the present pen position.

The subroutine has been modified to permit the insertion of circle producing codes into the main buffer area. The transfer vector is TRW. See Figure 9.

PLOTS (BUFFER (N), N) -- This short FAP subroutine sets up the tape write routine. BUFFER(N) is the first of N consecutive locations to be used as an output buffer. The transfer vector is TRWS.

SYMBOL (X, Y, HEIGHT, BCD, THETA, N) -- This FAP subroutine draws alphanumeric characters and special symbols on the plot. The coordinates of the lower left-hand corner of the characters are specified for alphanumeric characters; the coordinates of the center of the symbol are specified for special symbols. X and Y are the coordinates of the first character. HEIGHT represents the character height. BCD is the location of the characters to be printed out or the actual string of characters in the form nHxxxxxx. THETA is the angle with the horizontal at which the characters are to be drawn. The absolute value of N is the number of characters to be drawn. If N is positive, the pen will be lifted between characters. When plotting symbols, N should be negative. Transfer vectors are PLOT and the system subroutines SIN and COS. See Figure 10.

TRW (BUFFER) -- This FAP subroutine writes the CalComp plotter commands on tape from an area called BUFFER. If more than one output tape is required, a transfer to MSG takes place.

TRWS (L(B)) -- This FAP subroutine initializes the write buffer. L(B) is an address containing the following:

PZE BLOCK, , m

BLOCK is the first of m consecutive addresses containing the m words to be written on tape. See Figure 11 for both TRW and TRWS.

3.4 Outputs

The output from Part 1 of Phase I is normally only a binary tape containing one record for each bomb. Each record contains a WAC identification number, latitude and longitude of the targeted point, and the computed lethal radii to be plotted around that point. The last record contains a false identification number of 9999 to indicate the end of the data. One field of the first parameter card allows the user to call for a BCI printout from Part I. This printout contains detailed information on all bombs to be plotted. Such information includes latitude and longitude of bomb target,altitude category for height of burst, yield, CEP, CEP multiplier for this run, and the lethal radius for each PSI value specified. If any heights of burst have been altered for computational purposes it will be so stated

BASIC PLOT SUBROUTINE FLOW CHART
CALL PLOT (X,Y,I C)

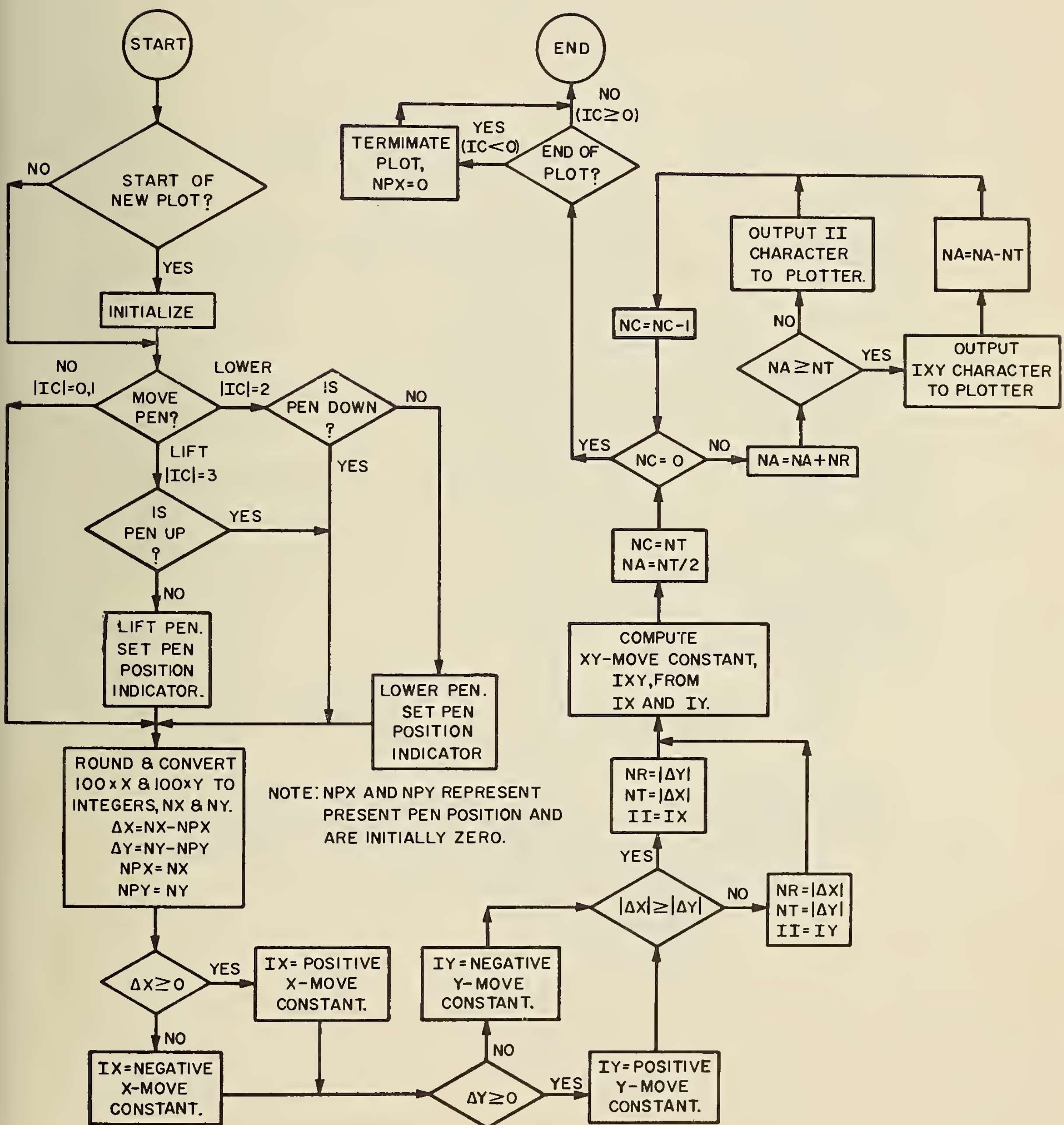

Figure 9

SYMBOL SUBROUTINE FLOW CHART
CALL SYMBL4 (X,Y,H,BCD,THETA,N

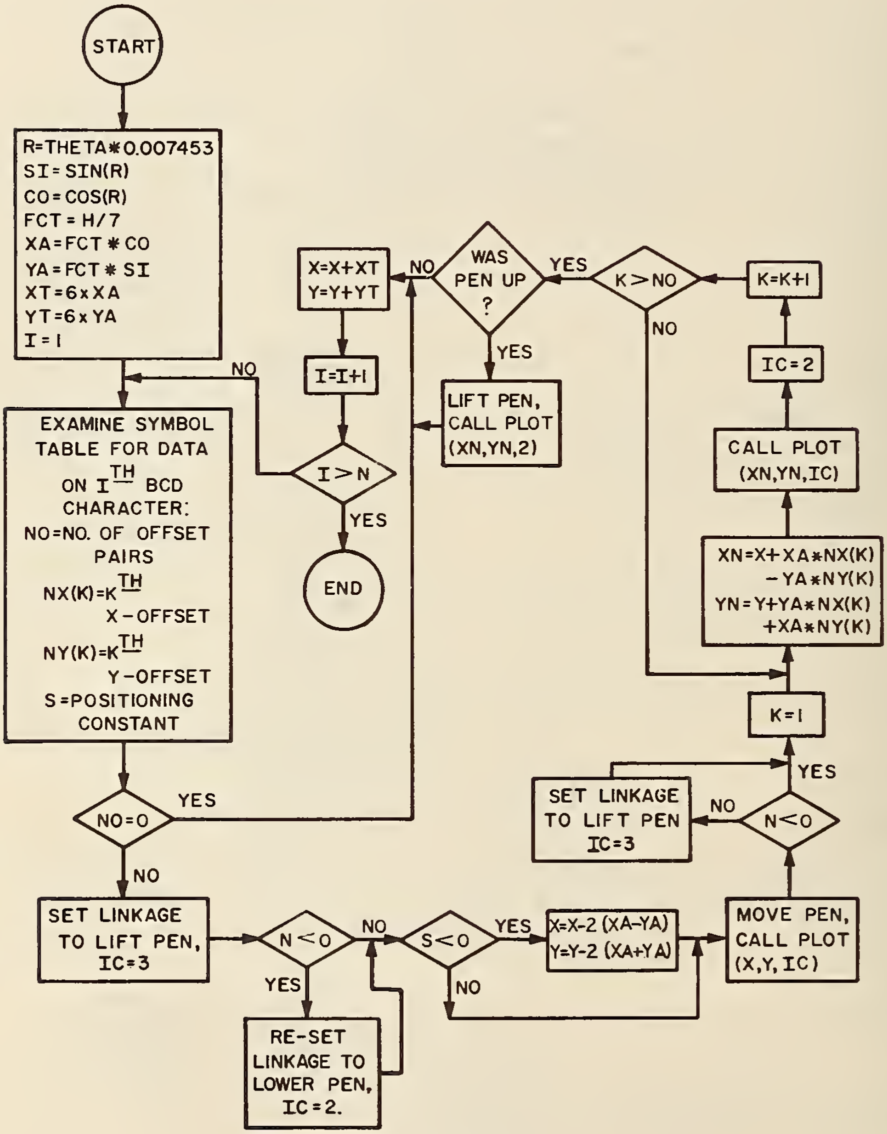

Figure 10

SEMI BUFFERED IBM 709-7090 TAPE WRITE ROUTINE (TRW2)

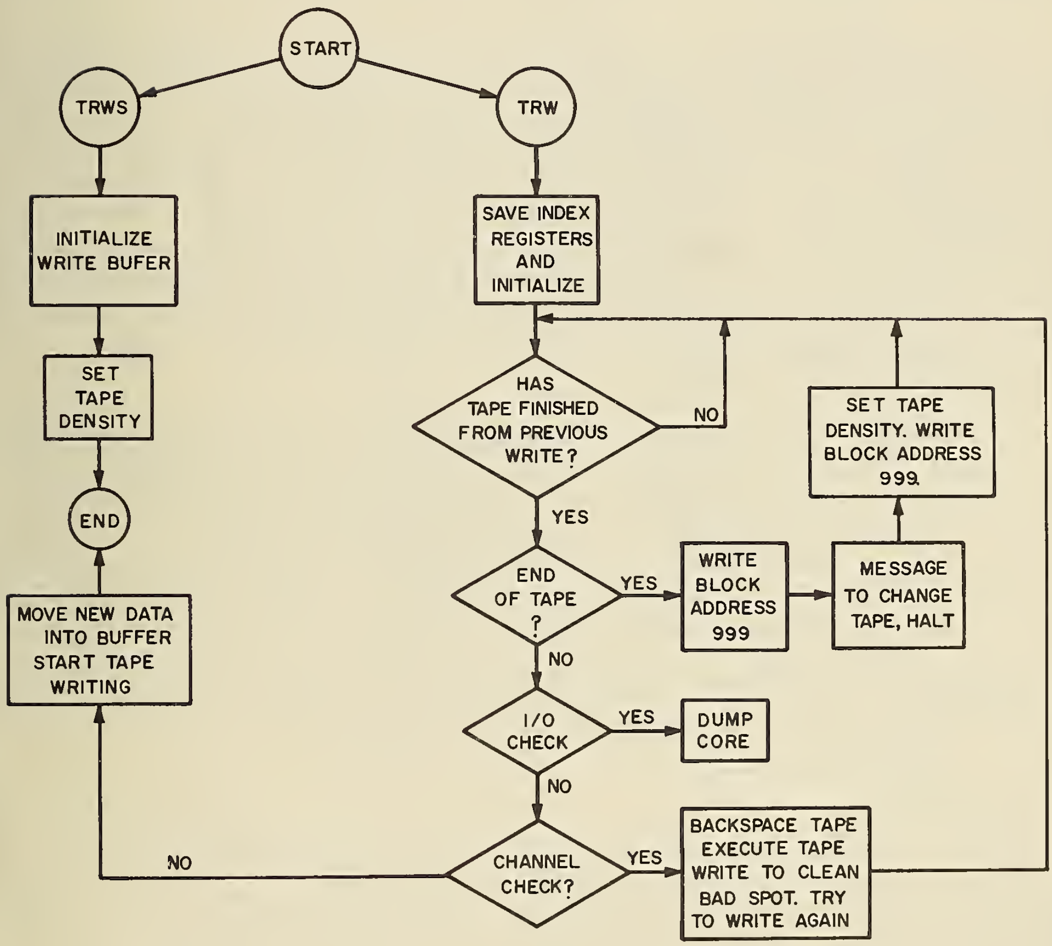

Figure 11

immediately before the data for that bomb. There will also be an appropriate message before each bomb that has been deleted from the plot tape because it falls outside of U.S. chart limits. Bombs which are deleted because they are duplicates of other bombs do not appear on the printout. Since valuable time is used in forming the print tape and in printing, there should be a real interest in some part of the printout before it is requested.

The output from Part 2 (the sort) is a binary tape containing the same record format as the binary output from Part 1 except that the records are arranged so that the WAC identification numbers appear in ascending order.

The output from Part 3 is a BCD tape which is used as input for the plot routines in Phase II. The tape is arranged so that there are at least three records for each WAC chart. The first record contains the WAC chart number and the top y value (TY) which is used as a reference point. The second record contains the x, y coordinates of a point and the lethal radii to be plotted around the point. There are additional records for as many more points as appear on that chart. The final record is in the same format but the x value is set to 99.99 as a flag to indicate the last record for a given chart. To indicate that the last chart has been considered, a dummy chart number is specified with a TY of 99.99.

The primary output from Phase II consists of one or more BCD, low density (200 b.p.i.) tapes. These tapes contain all control and data codes necessary for plotting overlays for targeted WAC chart areas. Figure 12 illustrates the tape format required by the CalComp system. A more detailed description of this format may be found in Reference 4. Another output from Phase II is a computer listing showing the relationship between WAC areas and their location (picture number) on tape. This listing permits the user to select and plot only the areas of interest. The final output of the program consists of the overlays produced on the CalComp 570 system.

3.5 Operation

Part 1 of Phase I is run under the NBS Bell Monitor System. The data deck follows the program on the system input tape with the parameter and control cards placed in the manner described in the section on Inputs. Output from Part 1 should be assigned to channel A for efficient entry to Part 2.

Part 2 is the sort from the IBSYS Monitor. The sort control cards are read in on-line from the card reader. The tape to be sorted is mounted on channel A but not readied until the on-line printer instructs the operator as to which unit number to dial. The output will be on channel B with the particular unit being specified on the on-line printer.

PLOT TAPE FORMAT

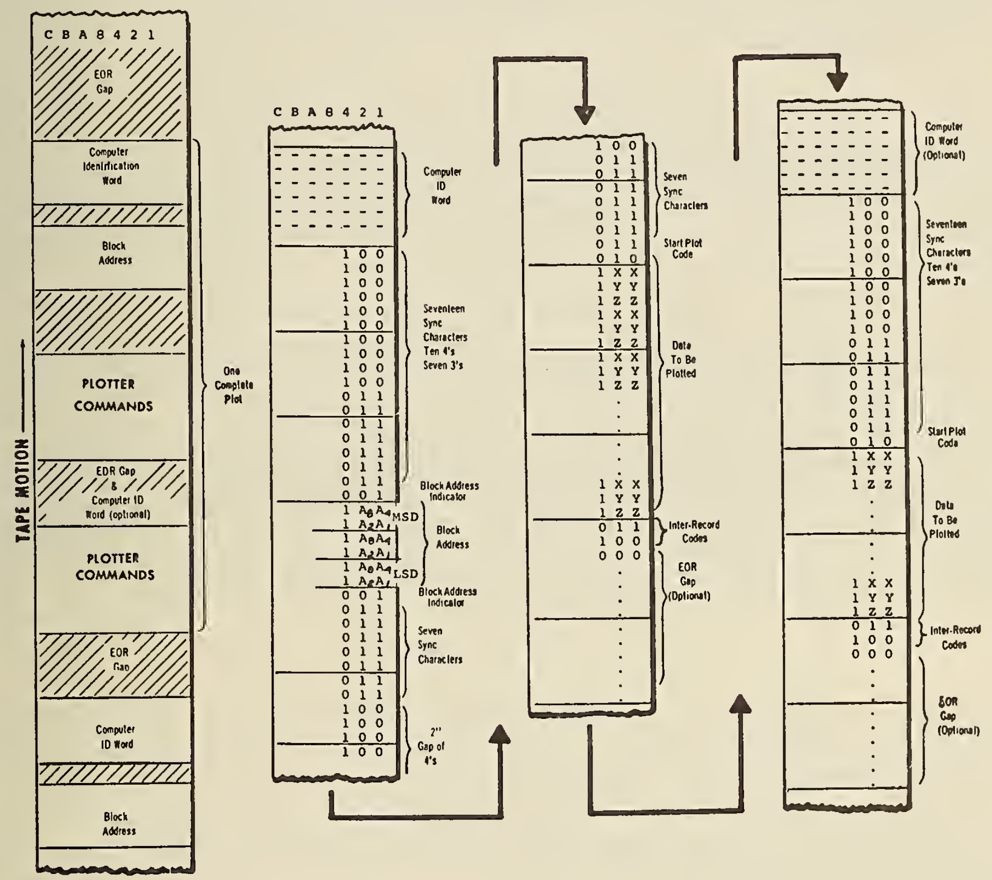

Figure 12

Part 3 is run under the NBS Bell Monitor System. There are three program tapes which may be assigned to units by the control card described in the section on Inputs. The output from Part 3 should be on channel A for efficient entry to Phase II.

Phase II which also runs under the NBS Bell Monitor System uses only two tape units in addition to the system units. The input should be placed on tape unit A5 and the low density output tape will be written on A6. If more than one output tape is needed, an on-line message will instruct the computer operator to save the tape on unit A6 and to mount a new tape on that unit. All A6 tapes should be labeled and saved for plotting.

When the user has selected the WAC charts which he wants plotted, he needs only to refer to the listing produced in Phase II to determine the tape and picture numbers which contain these charts. These numbers should be transmitted with the appropriate tapes to the Cal-Comp operator. The operator should be instructed to position the plotter pen 1 inch from the bottom of the plotter paper before beginning plotting.

When the appropriately labeled overlays have been produced, the user should position them on the WAC charts in the following manner: for WAC chart overlay numbers with a U suffixed, the reference marks (+'s) on the overlays should be placed over the charts at the intersections of the upper and middle parallels with the central meridian; for WAC chart overlay numbers with an L suffixed, the reference marks should be placed over the charts at the intersections of the middle and lower parallels with the central meridian.

4. Future Plans

As time permits, two refinements should be made to the program. The first is an addition to the circle subroutine to handle the plotting of truncated portions of circles with centers on adjacent overlays. This was discussed in the section on Routines. The second refinement would be mainly for the convenience of the computer operator. Slight reprogramming would make it possible to run all parts of both phases under one monitor system.

5. Acknowledgements

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Thanks are also due to Mr. Eugene Kiley, of the Johns Hopkins Applied Physics Laboratory, who was very helpful in checking out the plotter tape control codes.

6. References

1. Oscar S. Adams, Lambert Projection Tables for the United States, Department of Commerce, U.S. Coast and Geodetic Survey. Special Publication No. 52, Government Printing Office, Washington, D.C. 1918, pp 5-35.

2. W.J. Erickson and C.F. Schemmerling, Operational and Mathematical Specifications for the Blast Vulnerability Model, System Development Corporation, FN 5746, August 3, 1961.

3. IBM 7090/7094 Generalized Sorting System, International Business Machines Corporation, Programming Systems Publications, Form C 28-6307-1, May 1963, pp 12-19.

4. James E. Newland and Robert Stomel, Reference Manual SCOOP Programming System for Digital Incremental Plotters, California Computer Products, Inc., November 1963.

Appendix A - Card Formats

Data Card Format for Part 1 of Phase I

(Columns other than those specified are ignored by the program.)

Columns	Contents
19-24	Latitude in degrees, minutes, and seconds
26-32	Longitude in degrees, minutes, and seconds
55-57	Height of burst in hundreds of feet
58-60	CEP in hundreds of feet
69-74	Yield in kilotons

Parameter Cards for Part 1 of Phase I.

Card 1 (placed in front of the data deck)

Columns	Contents
1-2	"NTAP" - Numerical designation of the Part 1 binary output tape. Column 1 designates channel (0 = channel A, 1 = channel B); column 2 designates the number of the drive on the channel.
4	"NØUT" - Code for the type of output 0 = binary tape only 3 = binary tape and BCI printout 6 = BCI printout only
6-9	"XCEP" - Specifies the number of CEP's to two decimal places to be added to the calculated radius. This enables the user to include a probability measure in the calculated radius around the designated ground zero (DGZ).
11	"NRINGS" - The number of hardness categories for peak over-pressures (PSI values) specified for this run.

Columns	Contents
14-17 20-23 26-29 32-35 38-41 44-47	"P(I)" - PSI values of overpressures to one decimal place. From one to six values may be specified beginning with the leftmost field. Unused fields should be left blank.
Card 2	
1	"NH" - Number of altitude categories, each corresponding to a specific height of burst. (While the program is written to accept up to six heights of burst, polynomial coefficients for calculations are currently available only for ground bursts and bursts at 5,000 feet. If a different altitude is specified on a data card, the program sets the value to 5,000 feet for calculation purposes.)
2-9 11-18 20-27 29-36 38-45 47-54 56-63 65-72	"H(K, J)" - Polynomial coefficients for altitude category K. Four coefficients are required for each category; two categories fit on one card. Coefficients presently available appear on the card in the order H(1,1), H(1,2), H(1,3), H(1,4), H(2,1), H(2,2), H(2,3), H(2,4). Since the decimal place and sign may vary among coefficients, it is necessary to punch the decimal point and a sign (a plus sign need not be punched) into the field with the number. Additional coefficients for more categories would continue in the same format on additional cards. (Column 1 would be left blank.)
Last Data Card (placed at the end of the data deck)	
69-74	"000000" - These six zeros indicate a bomb with zero yield and flag the end of Part 1 of Phase I. Because of the way the test is made, it is imperative that a data card never contain a yield of less than 10 kilotons. If it does, the end of the routine will be falsely indicated.

Control Card for Part 3 of Phase I

(placed at the end of the program deck)

Columns	Contents
1-2	"NRINGS" - The number of radii to be plotted around each point in this run.
3-4	"NTAP" - A two-digit number specifying channel and unit number for the sorted data tape, 0 = channel A, 1 = channel B.
5-6	"ICØN" - A two-digit number specifying channel and unit number for the tape of WAC constants.
7-8	"KØ" - A two-digit number specifying channel and unit number for the output tape to be used in Phase II.

Phase II. Control Card

(to be placed at the end of the program deck)

Columns	Contents	Example
1-2	Number of hardness categories. This is equal to the number of circles (maximum of six) plotted around each targeted point.	02
3-4	To print SECRET on each overlay enter 01; to suppress printing enter 00.	01
5-12	Date of run (used for plotting tape identification).	05-30-64
13-16 17-20 21-24 25-28 29-32 33-36	PSI values associated with hardness categories. The number of 4-column fields used equals the number of categories specified in columns 1 and 2.	05.0 02.5

PHASE I - PART 1

```
          PART 1 OF PHASE I OF THE LETHAL RADIUS CIRCLE PROGRAM

    NOUT=0 FOR BINARY TAPE ONLY
    NOUT=3 FOR BINARY TAPE AND BCI PRINTOUT
    NOUT=6 FOR BCI PRINTOUT ONLY

    DIMENSION H(6,4),P(6),NAME(2),R(6)
    COMMON NRINGS
    READ 1,NTAP,NOUT,XCEP,NRINGS,(P(I),I=1,NRINGS)
  1 FORMAT (I2,1X,I1,1X,F4.2,1X,I1,6(2X,F4.1))
    READ 2, NH, ((H(K,J), J=1,4), K=1,NH)
  2 FORMAT(I1,7(F8.0,1X),F8.0/(8(1X,F8.0)))
    IFIN=1
    IPAGE=1
 17 READ 3, ILAD, ILAM, ILAS, ILOD, ILOM, ILOS, KALT, CEP, XW
  3 FORMAT(18X, 3I2, 1X, I3, 2I2, 22X, I3, F3.0, 8X, F6.0)
 14 READ 3, JLAD, JLAM, JLAS, JLOD, JLOM, JLOS, JALT, YEP, YW
    IF(YW-9.)18,75,75
 18 IFIN=0
    GO TO 400
 75 ZLATI=3600*ILAD + 60*ILAM + ILAS
    ZLATJ=3600*JLAD + 60*JLAM + JLAS
    IF(ABSF(ZLATI-ZLATJ)-20.)76,400,400
 76 ZLONI=3600*ILOD + 60*ILOM + ILOS
    ZLONJ=3600*JLOD + 60*JLOM + JLOS
    IF(ABSF(ZLONI-ZLONJ)-20.)19,400,400
 19 IF(XW-YW)300,14,14
200 ILAD=JLAD
    ILAM=JLAM
    ILAS=JLAS
    ILOD=JLOD
    ILOM=JLOM
    ILOS=JLOS
300 KALT=JALT
    CEP=YEP
    XW=YW
    GO TO 14
400 XLAD=ILAD
    XLAM=ILAM
    XLAS=ILAS
    XLOD=ILOD
    XLOM=ILOM
    XLOS=ILOS
```

```
      XLAT=XLAD+XLAM/60.+XLAS/3600.
      XLON=XLOD+XLOM/60.+XLOS/3600.
      CEP=(CEP*100.)/5280.
      W=XW/1000.
      IF(KALT)20,55,20
   55 KALT=1
      GO TO 60
   20 IF(KALT-50)30,50,30
   30 IALT=KALT*100
   35 PRINT 40, IALT
   40 FORMAT(39H0ACTUAL HEIGHT OF BURST FOR NEXT BOMB =I6, 59H FEET.  HE
     1IGHT SET AT 5000 FEET FOR COMPUTATIONAL PURPOSES.)
   50 KALT=2
   60 CALL CHART (XLAT, XLON, ID)
    4 DO 6 I=1,NRINGS
      CALL RLETH(W,P(I),KALT,H,R(I))
    6 R(I) = R(I) + XCEP*CEP
   80 IF(IPAGE)85,90,85
   85 PRINT 86
   86 FORMAT(1H1)
   87 IPAGE=0
   90 IF(NOUT) 11,11,21
   21 IF(ID-9999) 7,22,7
   22 PRINT 23
   23 FORMAT(108H THE FOLLOWING BOMB IS TARGETED OUTSIDE THE UNITED STAT
     1ES CHART LIMITS AND DOES NOT APPEAR ON THE PLOT TAPE.)
    7 PRINT 8, XLAT, XLON, KALT, W, CEP, XCEP
    8 FORMAT(14H0 BOMB DATA---, 3X, 4HLAT=F7.2, 3X, 5HLONG=F7.2, 3X,
     1 10HALT. CAT.=I1, 3X, 6HYIELD=F5.2, 3X, 4HCEP=F4.2, 3X, 15HCEP MUL
     1TIPLIER=F4.2)
      DO 9 I=1,NRINGS
    9 PRINT 10,P(I),R(I)
   10 FORMAT(4H FOR,F4.1,20H PSI, LETHAL RADIUS=,F6.2)
      IF(ID-9999) 11,13,11
   11 IF(NOUT-5) 12,12,13
   12 WRITE TAPE NTAP, ID, XLAT, XLON, (R(I),I=1,NRINGS)
   13 IF(IFIN)500,5,200
  500 PRINT 550
  550 FORMAT(41H ERROR FOUND IN IFIN TEST AT STATEMENT 13)
    5 IF(NOUT-5) 15,15,16
   15 ID=9999
      WRITE TAPE NTAP, ID, XLAT, XLON, (R(I), I=1,NRINGS)
      END FILE NTAP
      REWIND NTAP
   16 CALL SYSTEM
      END
```

SUBROUTINE CHART

```
      SUBROUTINE CHART (XLAT, XLON, ID)

      IF(XLAT-040.)0010,0010,0020
 0010 IF(XLAT-036.)0030,0040,0040
 0020 IF(XLAT-044.)0050,0050,0060
 0030 IF(XLAT-032.)0070,0080,0080
```

```
0040 IF(XLAT-038.)0090,0100,0100
0050 IF(XLAT-042.)0110,0110,0120
0060 IF(XLAT-048.)0130,0130,0065
0065 IF(XLAT-050.)0140,0140,1600
0070 IF(XLAT-028.)0150,0160,0160
0080 IF(XLAT-034.)0170,0180,0180
0090 IF(XLON-100.)0250,0250,0260
0100 IF(XLON-100.)0270,0270,0280
0110 IF(XLON-101.)0290,0290,0300
0120 IF(XLON-101.)0310,0310,0320
0130 IF(XLAT-046.)0190,0190,0200
0140 IF(XLON-114.)0330,0340,0340
0150 IF(XLAT-026.)0155,0220,0220
0155 IF(XLAT-024.)1600,0210,0210
0160 IF(XLAT-030.)0230,0240,0240
0170 IF(XLON-094.)0350,0360,0360
0180 IF(XLON-094.)0370,0380,0380
0190 IF(XLON-093.)0390,0400,0400
0200 IF(XLON-093.)0410,0410,0420
0210 IF(XLON-097.)0430,0440,0440
0220 IF(XLON-097.)0450,0460,0460
0230 IF(XLON-096.)0470,0480,0480
0240 IF(XLON-096.)0490,0500,0500
0250 IF(XLON-086.)0510,0510,0520
0260 IF(XLON-114.)0530,0540,0540
0270 IF(XLON-086.)0550,0550,0560
0280 IF(XLON-114.)0570,0580,0580
0290 IF(XLON-085.)0590,0590,0600
0300 IF(XLON-109.)0610,0620,0620
0310 IF(XLON-085.)0630,0630,0640
0320 IF(XLON-109.)0650,0660,0660
0330 IF(XLON-105.)0670,0670,0680
0340 IF(XLON-123.)0690,0700,0700
0350 IF(XLON-087.)0710,0710,0720
0360 IF(XLON-108.)0730,0740,0740
0370 IF(XLON-087.)0750,0750,0760
0380 IF(XLON-108.)0770,0780,0780
0390 IF(XLON-077.)0790,0790,0800
0400 IF(XLON-109.)0810,0820,0820
0410 IF(XLON-077.)0830,0830,0840
0420 IF(XLON-109.)0850,0860,0860
0430 IF(XLON-085.)0431,0435,1600
0431 IF(XLON-079.)1600,0435,0435
0435 ID=1050
     RETURN
0440 IF(XLON-103.)0445,0445,1600
0445 ID=1044
     RETURN
0450 IF(XLON-085.)0451,0451,1600
0451 IF(XLON-079.)1600,0455,0455
0455 ID=1051
     RETURN
0460 IF(XLON-103.)0465,0465,1600
0465 ID=1045
     RETURN
0470 IF(XLON-090.)0865,0865,0870
0480 IF(XLON-102.)0880,0890,0890
0490 IF(XLON-090.)0900,0900,0910
0500 IF(XLON-102.)0920,0930,0930
0510 IF(XLON-079.)0940,0940,0950
0520 IF(XLON-093.)0960,0960,0970
0530 IF(XLON-107.)0980,0980,0990
0540 IF(XLON-121.)1000,1010,1010
0550 IF(XLON-079.)1020,1020,1030
0560 IF(XLON-093.)1040,1040,1050
```

```
0570 IF(XLON-107.)1060,1060,1070
0580 IF(XLON-121.)1080,1090,1090
0590 IF(XLON-077.)1100,1110,1110
0600 IF(XLON-093.)1120,1130,1130
0610 ID=0612
     RETURN
0620 IF(XLON-117.)1140,1140,1150
0630 IF(XLON-077.)1160,1170,1170
0640 IF(XLON-093.)1180,1190,1190
0650 ID=0613
     RETURN
0660 IF(XLON-117.)1200,1200,1210
0670 IF(XLON-096.)1220,1230,1230
0680 ID=0434
     RETURN
0690 ID=0432
     RETURN
0700 IF(XLON-132.)0705,0705,1600
0705 ID=0430
     RETURN
0710 IF(XLON-080.)1240,1250,1250
0720 ID=0816
     RETURN
0730 IF(XLON-101.)1260,1260,1270
0740 IF(XLON-115.)1280,1290,1290
0750 IF(XLON-080.)1300,1310,1310
0760 ID=0817
     RETURN
0770 IF(XLON-101.)1320,1320,1330
0780 IF(XLON-115.)1340,1350,1350
0790 IF(XLON-069.)1360,1370,1370
0800 IF(XLON-085.)1380,1390,1390
0810 IF(XLON-101.)1400,1400,1410
0820 IF(XLON-117.)1420,1420,1430
0830 IF(XLON-069.)1440,1450,1450
0840 IF(XLON-085.)1460,1470,1470
0850 IF(XLON-101.)1480,1480,1490
0860 IF(XLON-117.)1500,1500,1510
0865 IF(XLON-084.)1520,1530,1530
0870 ID=0936
     RETURN
0880 ID=0938
     RETURN
0890 IF(XLON-108.)1540,1540,1550
0900 IF(XLON-084.)1560,1570,1570
0910 ID=0937
     RETURN
0920 ID=0939
     RETURN
0930 IF(XLON-108.)1580,1580,1590
0940 IF(XLON-072.)1600,0945,0945
0945 ID=0714
     RETURN
0950 ID=0716
     RETURN
0960 ID=0718
     RETURN
0970 ID=0720
     RETURN
0980 ID=0722
     RETURN
0990 ID=0724
     RETURN
1000 ID=0726
     RETURN
```

```
1010 IF(XLON-128.)1015,1015,1600
1015 ID=0728
     RETURN
1020 IF(XLON-072.)1600,1025,1025
1025 ID=0715
     RETURN
1030 ID=0717
     RETURN
1040 ID=0719
     RETURN
1050 ID=0721
     RETURN
1060 ID=0723
     RETURN
1070 ID=0725
     RETURN
1080 ID=0727
     RETURN
1090 IF(XLON-128.)1095,1095,1600
1095 ID=0729
     RETURN
1100 IF(XLON-067.)1600,1105,1105
1105 ID=0620
     RETURN
1110 ID=0618
     RETURN
1120 ID=0616
     RETURN
1130 ID=0614
     RETURN
1140 ID=0610
     RETURN
1150 IF(XLON-125.)1155,1155,1600
1155 ID=0608
     RETURN
1160 IF(XLON-067.)1600,1165,1165
1165 ID=0621
     RETURN
1170 ID=0619
     RETURN
1180 ID=0617
     RETURN
1190 ID=0615
     RETURN
1200 ID=0611
     RETURN
1210 IF(XLON-125.)1215,1215,1600
1215 ID=0609
     RETURN
1220 IF(XLON-087.)1600,1225,1225
1225 ID=0438
     RETURN
1230 ID=0436
     RETURN
1240 IF(XLON-073.)1600,1245,1245
1245 ID=0820
     RETURN
1250 ID=0818
     RETURN
1260 ID=0814
     RETURN
1270 ID=0812
     RETURN
1280 ID=0810
     RETURN
```

```
1290 IF(XLON-122.)1295,1295,1600
1295 ID=0808
     RETURN
1300 IF(XLON-073.)1600,1305,1305
1305 ID=0821
     RETURN
1310 ID=0819
     RETURN
1320 ID=0815
     RETURN
1330 ID=0813
     RETURN
1340 ID=0811
     RETURN
1350 IF(XLON-122.)1355,1355,1600
1355 ID=0809
     RETURN
1360 IF(XLON-061.)1600,1365,1365
1365 ID=0524
     RETURN
1370 ID=0526
     RETURN
1380 ID=0528
     RETURN
1390 ID=0530
     RETURN
1400 ID=0532
     RETURN
1410 ID=0534
     RETURN
1420 ID=0536
     RETURN
1430 IF(XLON-125.)1435,1435,1600
1435 ID=0538
     RETURN
1440 IF(XLON-061.)1600,1445,1445
1445 ID=0525
     RETURN
1450 ID=0527
     RETURN
1460 ID=0529
     RETURN
1470 ID=0531
     RETURN
1480 ID=0533
     RETURN
1490 ID=0535
     RETURN
1500 ID=0537
     RETURN
1510 IF(XLON-125.)1515,1515,1600
1515 ID=0539
     RETURN
1520 IF(XLON-078.)1600,1525,1525
1525 ID=0932
     RETURN
1530 ID=0934
     RETURN
1540 ID=0940
     RETURN
1550 IF(XLON-114.)1555,1555,1600
1555 ID=0942
     RETURN
1560 IF(XLON-078.)1600,1565,1565
1565 ID=0933
```

```
      RETURN
 1570 ID=0935
      RETURN
 1580 ID=0941
      RETURN
 1590 IF(XLON-114.)1595,1595,1600
 1595 ID=0943
      RETURN
 1600 ID=9999
      RETURN
      END
```

SUBROUTINE RLETH

```
      SUBROUTINE RLETH (W,P,K,H,R)
      DIMENSION H(6,4)
      Q=LOGF(P)
      R=.18939394*W**.33333333*EXPF(H(K,1)+H(K,2)*Q+H(K,3)*Q**2
     1+H(K,4)*Q**3)
      RETURN
      END
```

PHASE I - PART 2

CONTROL CARDS FOR IBSYS SORT ($ID CARD IS OPTIONAL)

```
$ATTACH         RDA
$AS             SYSIN1
$RELEASE        SYSUT2
$RELEASE        SYSUT3
$RELEASE        SYSUT4
$ATTACH         B7,H
$AS             SYSCK2
$EXECUTE        SORT
$ID             13780,PR,DDLOTT                   06/10/64
       REM, ASCENDING ORDER SORT OF BINARY RECORDS BY WAC CHART ID NUMBER
       FIL,INP/1,MOD/B,BLO/6,PAD/H
       CHA,INP/A,MER/(AR,BR,UTR),OUT/BR
       OPT,CAR,TAP
       REC,TYP/F,LEN/6,FIE/(36B,36B,144B)
       SOR,FIL/1,SEQ/S,ORD/2,FIE/2
       FIL,OUT,MOD/B,DEN/H,BLO/6
       END
$IBSYS
$RESTORE
$PAUSE
```

PHASE I - PART 3

ROUTINE TO CONVERT GEODETIC POSITIONS AND RADII TO PLOTTER INCHES

```
      NMAPS=0
   75 READ TAPE NTAP,       ID, XLAT, XLON, (R(I), I=1,NRINGS)
  200 READ TAPE ICON,      IWAC, CM, RLRU, TY, RL, PL
  205 IF(IWAC-ID)200,210,900
  210 NMAPS=NMAPS+1
  400 IMAP=ID/2
      IMAP2=IMAP*2
      ITEST=ID-IMAP2
  450 IF(ITEST)1500,500,550
  500 WRITE OUTPUT TAPE KO, 510, IMAP, TY
  510 FORMAT (3HWACI3, 1HL, 1X, F5.2)
      GO TO 250
  550 WRITE OUTPUT TAPE KO, 560, IMAP, TY
  560 FORMAT (3HWACI3, 1HU, 1X, F5.2)
  250 ANG=(CM-XLON)*0.6305
      SANG=SINF(ANG*0.01745)
      RP=RL-((XLAT-PL)*RLRU)/2.
      CANG=COSF(ANG*0.01745)
      XCX=RP*SANG
      XCY=RL-(RP*CANG)
      CX=(XCX*39.37)/1000000.
      CY=(XCY*39.37)/1000000.
      DO 300 I=1,NRINGS
  300 R(I)=R(I)*0.06336
      WRITE OUTPUT TAPE KO, 610, CX, CY,(R(I), I=1,NRINGS)
  610 FORMAT(F6.2,11F5.2)
  100 READ TAPE NTAP,      ID, XLAT, XLON,(R(I), I=1,NRINGS)
  650 IF(IWAC-ID)700,250,1000
  700 CX=99.99
      WRITE OUTPUT TAPE KO, 610, CX, CY,(R(I), I=1,NRINGS)
  750 IF(ID-9999)200,1700,800
  800 PRINT 850
  850 FORMAT(59HOPROGRAM STOPPED WHEN IWAC GREATER THAN ID AT STATEMENT
     1750)
      GO TO 1700
  900 PRINT 950
  950 FORMAT(59HOPROGRAM STOPPED WHEN IWAC GREATER THAN ID AT STATEMENT
     1205)
      GO TO 1700
 1500 PRINT 1600
 1600 FORMAT(59HOPROGRAM STOPPED WHEN ITEST FOUND NEGATIVE AT STATEMENT
     1450)
      GO TO 1700
 1000 CX=99.99
      WRITE OUTPUT TAPE KO, 610, CX, CY,(R(I), I=1,NRINGS)
      PRINT 1200
 1200 FORMAT(59HOPROGRAM STOPPED WHEN IWAC GREATER THAN ID AT STATEMENT
     1650)
 1700 TY=99.99
      IMAP=0
      WRITE OUTPUT TAPE KO, 1750, IMAP, TY
 1750 FORMAT (3HWACI3, 1HX, 1X, F5.2)
      WRITE OUTPUT TAPE KO, 1800, NMAPS
 1800 FORMAT (40H TOTAL NUMBER OF OVERLAYS FOR THIS RUN =1X, I2)
      END FILE KO
      REWIND KO
      REWIND ICON
      REWIND NTAP
 2000 CALL SYSTEM
      END
```

PHASE II - MAIN PROGRAM

```
      MAIN PROGRAM
      PHASE II OF LETHAL RADIUS PLOT PROGRAM
      DIMENSION DATA(3000),R(6),PSI(6),XMAP(2),M(3000)
      COMMON ITAPE
   12 FORMAT(2I2,A6,A2,6A4)
   14 FORMAT(A6,A1,1X,F5.2)
   16 FORMAT(F6.2,7F5.2)
   18 FORMAT(1H1,A6,A2)
   20 FORMAT(42HOWAC NUMBER - PICTURE NUMBER - TAPE NUMBER)
   22 FORMAT(2H  A6,A1,10X,I3,13X,I1)
      ITAPE=1
      IPICT=1
      CALL PLOTS(DATA(3000),3000)
      READ 12,NRINGS,ISEC,DATE(1),DATE(2),(PSI(JJ),JJ=1,NRINGS)
      PRINT 18,DATE(1),DATE(2)
      PRINT 20
   10 READ INPUT TAPE 5,14,XMAP(1),XMAP(2),TY
      IF(TY-90.00)11,99,99
   11 PRINT 22,XMAP(1),XMAP(2),IPICT,ITAPE
      CALL SYMBOL(0.0,0.0,.07,3,0.0,-1)
   40 CALL SYMBOL(-.8,-.8,-.28,XMAP(1),0.0,7)
      IF(ISEC)50,50,45
   45 CALL SYMBOL (1.2,-.8,.28,6HSECRET,0.0,6)
   50 CALL SYMBOL(0.0,TY,.07,3,0.0,-1)
   71 READ INPUT TAPE 5,16,CX,CY,(R(LL),LL=1,NRINGS)
      IF(CX-90.00)75,25,25
   75 CALL PLOT(CX,CY,3)
      CALL PLOT(CX,CY,2)
   90 DO 23 IR=1,NRINGS
      FRSTX=CX+R(IR)
      CALL PLOT(FRSTX,CY,3)
      CALL PLOT(FRSTX,CY,2)
      CALL CIRCLE(CY,R(IR),M,NUMB)
      CALL SYMBOL(FRSTX,CY,-.14,PSI(IR),90.0,4)
   23 CONTINUE
      GO TO 71
   25 CALL PLOT(36.0,0.0,-3)
      IPICT=IPICT+1
      GO TO 10
   99 REWIND 5
      REWIND 6
      CALL SYSTEM
      END
```

SUBROUTINES PLOTS, PLOT, CONVRT

```
*       LABEL
*        FAP
*PLOT2
         COUNT    340
         ENTRY    PLOT
         ENTRY    PLOTS
         ENTRY    CONVRT
```

```
       REM FORTRAN LINKAGE
       REM CALL PLOT(X,Y,I)
       REM X AND Y ARE COORDINATES OF NEW POINT
       REM I IS INDICATOR FOR PEN MOVEMENT AND
       REM END OF PICTURE.  3 IS PEN UP,2 IS
       REM PEN DOWN.-IS END PICTURE.
       REM
BUFFER EQU 0
PLOTS  SXD X4,4
       CLA 2,4
       STA MANY
       CLA 1,4
       STA W2
       STA W3
       STA W4
       ADD THREE
       STA WX
       STA WY
       COM
SVN    PAX 7,4
       TXI *+1,4,1
       SXD BCON,4
MANY   LXD **,4
LINK   PXA **,4
       ARS 1
       STA BCON
W5     ADD W2
       STA SAVE
       COM
       PAX 0,4
       TXI *+1,4,2
       SXD LIMIT,4
       SXD LIM,4
       TSX $TRWS,4
SAVE   PZE LINK
       LXD X4,4
       TRA 3,4
PLOT   SXD X1,1                       SAVE INDEX REGISTERS
       SXD X2,2
       SXD X4,4
       CLA 1,4                        PICK UP DATA LOCATIONS
       STA     XXX
       CLA 2,4
       STA Y                          FOR Y COPRDINATE
THREE  CLA 3,4
       STA EPE
EPE    CLA **
       STO EPIND
       CLS BLOCK
       TMI TOTO
       STO BLOCK
       CLA N                          INCREMENT BLOCK ADDRESS
       ADD ONE
       STO N
       LXA CLM,4
       CLA START
       STO ABSDX
       LDQ N
CLM    PXD 36,0
       DVP TEN
       STQ ABSDY
TWO    LRS 2
       ALS 4
       LLS 38,4
       ORS ABSDX
```

```
        LDQ  ABSDY
        TIX  CLM,4,12
        TSX  $TRW,4
        PZE  START,0,SVN
        TSX  $TRW,4
        PZE       CHANGE,0,THREE
        LXA  THREE,4
        CLA  START+3,4
 WX     STO  BUFFER+3,4
        TIX  *-2,4,1
        ADD  ONE
 WY     STO  BUFFER+3,4
        LXD  BCON,1                BCON=-BUFFER-3
        SXD  ST,1
        LXA  ONE,2
        SXD  FF,2
TOTO    LXD  FRIND,1
        LXA  TEN,4
 ONED   TXL  X,1,1
        CLA  PENZ
        TXH  PENUP,1,2
 PENDN  NOP
        CLA  DOWN
 REIT   LXD  ST,1
        LXD  FF,2
        STO  PENZ
        TXL  FL,2,0
        SLW  BUFFER,1
 LF     CLA  CON
 TXI    TXI  LIM,1,-1
 PENUP  TMI  X
        CLA  UPM
 X1     TXI  REIT,0,**
 LIM    TXH  STO,1,**              DECREMENT=-BUFER-(COUNT+1
        CLA  END
        STO  BUFFER,1
        TSX  $TRW,4
 W2     PZE  BUFFER,0,BCON
        LXD  BCON,1
 X4     TXI  TRAV,0,**
 FL     STA  BUFFER,1
        CLA  ONED
        STD  FF
 X2     TXI  LF,0,**
 STO    STO  BUFER,1
        TIX  TXI,4,1
 TRAV   SXD  ST,1
 X      CLA*      XXX
        FSB       F89
        TPL       MINE
 XXX    LDQ       **
        FMP  F100
        STO  XPLTC
        SSP
        FAD  P005                  ROUND OFF
        ARS  1
        ANA  MASK
        LDQ  XPLTC
        LLS  0                     RESTORE DY SIGN
        STO  XT
        SUB  PENX
        LDQ  XCON
        LRS  0
        STO  XPLTC
        SLW  ABSDX                 ABSOLUTE DX
```

```
 Y      LDQ **                              MULTIPLY Y BY 100
        FMP F100
        STO YPLTC
        SSP
        FAD P005
        ARS 1
        ANA MASK
        LDQ YPLTC
        LLS 0
        STO YT
        SUB PENY
        LDQ YCON
        LRS 0                               GIVE DY SIGN TO CONSTANT
        STO YPLTC
        SSP
        STO ABSDY
        SUB ABSDX
        TMI XBASIC
YBASIC  CLA XPLTC
        LDQ YPLTC
        STQ YPLTC
        STO XPLTC
        CLA ABSDY
K       PAX 0,4
        STO TEST                              SET UP TEST VALUE
        LDQ ABSDX
 REENT  ARS 1
        TXL EOP,4,0
        STQ RATIO
        STO ACCUM
        CLA CON
        ADD XPLTC
        STO XPLTC
        ADD YPLTC
        STO YPLTC
        CLA XT
        STO PENX
        CLA YT
        STO PENY
        LXD FF,2
        LXD ST,1
 BACK   CLA RATIO
        ADD ACCUM
        STO ACCUM
        SUB TEST
        TMI SKIP
        STO ACCUM
        CLA YPLTC
 FF     TXI SKIP+1,0,1
 MINE   LXD      FF,2
        LXD      ST,1
        CLA      BSIZE
        PAX      ,4
        ADD      CONSA
        STA      PICK1
 PICK   SLN      1
 PICK1  CLA      **,4
        STO      BUFFER,1
        TRA      FLIP+2
XBASIC  CLA ABSDX
        PAX 0,4
        STO TEST
        LDQ ABSDY
 ST     TXI REENT,0,**
 SKIP   CLA XPLTC
```

```
        TXL  FLIP,2,0
        STO  BUFFER,1
        TXI  OR,2,-1
 FLIP   ARS  18
        STA  BUFFER,1
        TXI  *+1,1,-1
 LIMIT  TXH  UP,1,**                         DECR=-BUFFER-COUNT+1
        CLA  END
        STO  BUFFER,1
        SXD  SAVE,4
        TSX  $TRW,4
 W3     PZE  BUFFER,0,BCON
        LXD  SAVE,4
        LXD  BCON,1
 UP     LXA  ONE,2
 OR     SLT       1
        TRA       ORCC
 ORMN   TIX       PICK,4,1
        TRA       *+2
 ORCC   TIX       BACK,4,1
        SXD  ST,1
        SXD  FF,2
 EOP    CLA  EPIND
        STO  BLOCK
        TPL  OVER
        STZ  PENX
        STZ  PENY
        LXD  FF,2
        LXD  ST,1
        CLA  END
        TXI  *+1,1,-2
        TXH  *+3,2,0
        TXI  *+1,1,-1
        TXI  *+1,2,1
        STO  BUFER-2,1
        SXD  FF,2
        PXA  0,1
        COM
        SSP
        SUB  W2
        STA  K
        LXD  BCON,1
        SXD  ST,1
        TSX  $TRW,4
 W4     PZE  BUFFER,0,K
 OVER   LXD  X1,1
        LXD  X2,2
        LXD  X4,4
        CLA  TPL
        STO  PENDN
        CLA  *+2
        STO  *-3
        TRA  4,4
 TPL    TPL  X
 P005   OCT  232400000001
 XT     PZE  0
 YT     PZE  0
MASK    PZE  -1,0,0
 TEST   PZE  0
 CON    BCD  1666666
 YCON   BCD  1010000
 START  BCD  344444444443333333331
 ABSDX  PZE  0
        BCD  313333333444444444
END     BCD  1463400
```

```
CHANGE BCD 3334444444444444433
 F89   DEC       89.0
 F100  DEC 100.0
 PENX  PZE 0
 PENY  PZE 0
 ABSDY PZE 0
 XCON  BCD 1100000
 XPLTC PZE 0
 YPLTC PZE 0
 RATIO PZE 0
 ACCUM PZE 0
 BLOCK MZE 0
 ONE   PZE 1
 TEN   PZE 10
 PENZ  PZE
 DOWN  BCD 1667667
 UPM   BCD 1065665
 BCON  PZE 0,0,**
 N     PZE 0
 FPIND PZE 0
CONVRT SXA       CON5,1
       SXA       CON6,2
       SXA       CON4,4
CONCON NOP       CON2
       CLA*      1,4
       ARS       18
       STA       BSIZE
       STA       CON2
       ADD       CONSA
       STA       CON3
       LDQ       =0002000000000
       SLQ       CONCON
 CON2  AXT       **,1
       CLA*      2,4
       ARS       18
       PAC       ,2
       CAL       LIST,2
       SLW       TEMP
       CLA*      3,4
       ARS       18
       PAC       ,4
       CAL       LIST,4
       ARS       18
       ORA       TEMP
 CON3  SLW       **,1
       TIX       CON8,1,1
       LDQ       =0076100000000
       SLQ       CONCON
       TSX       PLOT,4
       PZE       FNIN
       PZE       FNIN
       PZE       CONPEN
 CON8  SXA       CON2,1
 CON4  AXT       **,4
 CON5  AXT       **,1
 CON6  AXT       **,2
       TRA       4,4
 FNIN  DEC       90.0
CONPEN PZE       ,,2
 LIST  BCI ,666000676000776000766000756000656000556000566000576000667000
 CONSA PZE       DBUFF
 BSIZE PZE       0
 TEMP  PZE       0
 DBUFF BSS       1500
       END
```

```
      SUBROUTINE CIRCLE

      FORTRAN LINKAGE
      CALL CIRCLE(CY,R,M,NUMB)
      CY=CENTER Y COORDINATE OF CIRCLE
      R=RADIUS
      M AND NUMB ARE OUTPUTS
      SUBROUTINE CIRCLE(CY,R,M,NUMB)
      DIMENSION M(3000)
      I=0
      ENDSW=0
      X=R
      Y=0
      RSQ=R**2
      XSQ=RSQ
      YSQ=0
    1 I=I+1
      BOUND=CY+Y
      IF(X)2,2,4
    2 IF(Y)7,7,3
    3 NQ=3
      GO TO 8
    4 IF(Y)5,6,6
    5 NQ=7
      GO TO 8
    6 NQ=1
      GO TO 8
    7 NQ=5
    8 IF(ABSF(X)-ABSF(Y))90,90,9
    9 NZ=0
      GO TO 91
   90 NZ=1
   91 DEL=XSQ+YSQ-RSQ
      NZQ=NZ+NQ
      GO TO(10,20,30,40,50,60,70,80),NZQ
   10 IF(ENDSW)99,11,99
   99 M(I)=0
      NUMB=I/2
      K=I-1
      DO 37 I=1,K,2
      J=I+1
   37 CALL CONVRT (NUMB,M(I),M(J))
      RETURN
   11 IF(DEL)13,13,12
   12 IF(BOUND-9.5)14,14,15
   14 M(I)=8
      GO TO 16
   15 M(I)=7
   16 XSQ=XSQ-.02*X+.0001
      X=X-.01
   22 YSQ=YSQ+.02*Y+.0001
      Y=Y+.01
      GO TO 1
   13 IF(BOUND-9.5)17,17,18
   17 M(I)=1
      GO TO 22
   18 M(I)=0
      GO TO 22
   20 IF(DEL)12,12,21
   21 M(I)=7
      GO TO 45
   40 IF(DEL)21,21,41
   41 IF(BOUND-9.5)42,42,43
   42 M(I)=6
      GO TO 44
```

```
   43 M(I)=7
   44 YSQ=YSQ-.02*Y+.0001
      Y=Y-.01
   45 XSQ=XSQ-.02*X+.0001
      X=X-.01
      GO TO 1
   30 IF(DEL)41,41,31
   31 IF(BOUND+.5)33,33,35
   35 IF(BOUND-9.5)32,32,33
   32 M(I)=5
      GO TO 55
   33 M(I)=0
      GO TO 55
   50 IF(DEL)31,31,51
   51 IF(BOUND+.5)53,53,52
   52 M(I)=4
      GO TO 54
   53 M(I)=3
   54 XSQ=XSQ+.02*X+.0001
      X=X+.01
   55 YSQ=YSQ-.02*Y+.0001
      Y=Y-.01
      GO TO 1
   60 IF(DEL)51,51,61
   61 M(I)=3
      GO TO 85
   80 IF(DEL)61,61,81
   81 IF(BOUND+.5)83,83,82
   82 M(I)=2
      GO TO 84
   83 M(I)=3
   84 YSQ=YSQ+.02*Y+.0001
      Y=Y+.01
   85 XSQ=XSQ+.02*X+.0001
      X=X+.01
      GO TO 1
   70 ENDSW=1
      IF(DEL)81,81,100
  100 IF(BOUND+.5)18,18,17
      END
```

```
         SUBROUTINE MSG

*     LABEL
*     LIST8
CMSG
      SUBROUTINE MSG
      COMMON ITAPE
      ITAPE=ITAPE+1
      WRITE OUTPUT TAPE 81,2
    2 FORMAT (52H REMOVE TAPE ON A-6 AND MOUNT NEW TAPE. PRESS START   )
      WRITE OUTPUT TAPE 81,3
    3 FORMAT (47H RETURN ALL REELS WRITTEN ON A-6 TO PROGRAMMER.      )
      RETURN
      END
```

```
          SUBROUTINE SYMBOL
*       LABEL
*       FAP
*SYMBL5
        REM
        COUNT 250
        ENTRY   SYMBOL
        REM
        REM FORTRAN LINKAGE
        REM CALL SYMBOL(X,Y,SIZE,BCD,THETA,N)
        REM
        REM SOS TSX SYMBOL,4
        REM     PZE X
        REM     PZE Y
        REM     PZE SIZE
        REM     PZE BCD
        REM     PZE THETA
        REM     PZE N
        REM
        REM WHERE X AND Y ARE THE PAGE COORDINATES OF THE
        REM LOWER LEFT CORNER OF THE FIRST CHARACTER.
        REM SIZE IS THE DESIRED LETTER HEIGHT. BCD IS THE
        REM LOCATION OF ALPHA-NUMBERIC INFO. THETA IS THE
        REM ANGLE OF LETTERING WITH RESPECT TO X AXIS.
        REM N IS THE NUMBER OF CHARACTERS TO BE DRAWN.
        REM X,Y,SIZE,THETA ARE FLOATING POINT NOS. THETA IS DEGREES
        REM BCD IS BCD AND N IS FIXED AT A BINARY OF 17.
        REM SIZE MAY BE NEGATIVE. THIS INDICATES THE BCD
        REM INFO IS STACKED BACKWARD AND VICE-VERSA.
        REM N MAY BE NEGATIVE. THIS MEANS BCD INFO IS A
        REM FIXED POINT NUMBER AT A BINARY OF 17 AND
        REM IS A SPECIAL SYMBOL. FOR SPECIAL SYMBOLS N MAY BE -1 OR -2.
        REM -2 INDICATES A LINE IS TO BE DRAWN FROM CURRENT LOCATION
        REM TO POSITION (X,Y) IN LINKAGE.
        REM
SYMBOL  SXD X1,1                        SAVE INDEX REGISTERS
        SXD X2,2
        SXD X4,4
        REM
        CLA COM                         SET UP VARIABLE INSTRUCTION
        STO VAR
        REM
        REM
        CLA 1,4                         PICK UP LOC. OF X COORD.
        STA *+1
        CLA **                          PICK UP X COORD.
        STO X0
        REM
        CLA 2,4                         PICK UP LOC. OF Y COORD.
        STA *+1
        CLA **                          PICK UP Y COORD.
        STO Y0
        REM
        CLA 3,4                         PICK UP LOC. OF LETTER HEIHGT
        STA *+1
        CLA **                          PICK UP LETTER HEIGHT
        TMI OUT
        LXA FWD,2                       SET INDEX FOR FWD STACK DATA
 BACK   SXD FF,2
        FDP F7                          DIVIDE HEIGHT BY 7
        STQ FACT
        REM
        CLA 4,4                         PICK UP LOC. OF BCD INFO.
        STA LOC
```

```
       REM
       CLA 5,4                    PICK UP LOC. OF THETA
       STA TH
       REM
       CLA 6,4                    PICK UP LOC. OF COUNT
       STA NN
NN     CLA **                     PICK UP NUMBER OF CHARS.
       STO XXK                    SET UP SPECIAL CHARACTER INDICATOR
       TMI SPECL                  TRANSFER FOR SPECIAL CHARS.
ZERO   PDX 0,1                    INDEX1=NUMBER OF CHARS.
       LXA 36N,2                  SET X2 TO PICK UP FIRST BCD CHAR.
LRTN   CLA L3                     LINKAGE SET UP FOR PEN UP
RTN    STD VL                     SET UP VARIABLE LINKAGE
       REM
TH     LDQ **                     PICK UP THETA(DEGREES)
       FMP CONST
       STO INCC                   SAVE THETA(RADIANS)
       TSX $SIN,4                 COMPUTE SIN THETA
       LRS 35
       FMP FACT
       STO INCS                   SAVE FACTOR * SIN THETA
       CLA INCC
       TSX $COS,4                 COMPUTE COS THETA
       LRS 35
       FMP FACT
       STO INCC                   FACTOR * COS THETA
       REM
       LDQ INCC                   COMPUTE THE LENGTH BETWEENCHARS.
       FMP F6                     SIX TIMES FACTOR (HEIGHT/7)
       STO XT                     CHANGE IN X
       LDQ INCS
       FMP F6
       STO YT                     CHANGE IN Y
       REM
       LXA ZERO,4                 6CHAR. PICK UP REGISTER
LOC    LDQ **,4                   PICK UP 6 CHARACTERS.
       LGL 42,2                   SHIFT CHARS.
VAR    TXI *+1,0,0                NOP FOR NORMAL CHAR.
       ANA 63B35                  GET SINGLE 6 BIT CHAR.
       COM                        SKIPED FOR SPECIAL CHAR.
       SXD 1X,1                   SAVE INDEX REGISTERS
REENT  SXD 2X,2                   FOR NEXT TIME THRU.
       SXD COM,4
       REM
FWD    PAX -1,1
       CLA TABLE-1,1              PICK LOC OF OFFSET DATA
       STA DLOC
       STA OLOC
       ARS 6
63B35  PDX 63,1                   PICK UP SHIFT COUNT
       ARS 12
       ANA 63B35                  SAVE ONLY OFFSET COUNT
       STO NO
       TZE CLAP
       CLA XXK                    TEST FOR SPECIAL CHAR.
       TPL DLOC-1                 TRANSFER ON NORMAL CHAR.
       REM
       CLA INCS                   MOVE REFERENCE POINT
       FSB INCC                   FOR SPECIAL SYMBOLS
       ACL TWICE                  MULTIPLY BY 2
       FAD X0                     SO THAT ORIGINAL X0,Y0
       STO X0                     CORRESPONDS TO CENTER
       CLS INCC                   MOVE REFERENCE POINT
       FSB INCS
       ACL TWICE                  MULTIPLY BY 2
```

```
       FAD YO
       STO YO
       REM
       LXA ZERO,2                    INITIAL SETTING FOR PICK UP OFFSET
DLOC   LDQ **,2                      PICK OFFSET DATA
       LGL 39,1                      SHIFT OFFSET CHAR INTO ACCUM
       ANA 7B35                      SAVE ONLY 3 BITS FOR X
       PAX 0,4                       X4=X OFFSET COUNT
       REM
       TXL *+3,4,6
       CLA L3
X4     TXI STD,0,**
       REM
       CLA XO                        PICK UP XO FOR USE IN
       STO XX                        COMPUTING INTERMEDIATEX
       CLA YO                        SAME FOR YO.
       STO YY
       REM
       TXL OLOC,4,0                  SKIP X CALCUCATION IF 0
       REM
EN     CLA XX
       FAD INCC                      COS COMPONENT OF OFFSET
       STO XX
       CLA YY
       FAD INCS                      SIN COMPONENT OF OFFSET
       STO YY
       TIX EN,4,1
       REM
OLOC   LDQ **,2                      PICK UP OFFSET DATA
       LGL 42,1
       ANA 7B35                      SAVE ONLY 3 BITS FOR X
25N    PAX 24,4
       TXL JEN,4,0                   SKIP IF NO Y OFFSET COUNT
       REM
NEJ    CLA YY                        ADD COS COMPONENT TO
       FAD INCC                      Y VALUE
       STO YY
       CLA XX                        ADD SIN COMPONENT TO
       FSB INCS                      X VALUE
       STO XX
       TIX NEJ,4,1
       REM
JEN    TSX $PLOT,4                   CALL PLOT ROUTINE TO
       PZE XX                        MOVE TO COMPUTED POINT.
       PZE YY
       PZE VL
       REM
       CLA L2                        RESET LINKAGE TO
STD    STD VL                        LOWER PEN
       REM
       REM
       CLA NO                        PICK UP OFFSET COUNT
       SUB ONE                       DECREMENT BY ONE
       TZE CLAP                      EXIT WHEN FULFILLED
       STO NO
       TIX DLOC,1,6                  DECREMENT SHIFT COUNT BY 6
       LXA 36N,1                     RESET SHIFT COUNT TO 36
       TXI DLOC,2,-1                 MOVE TO NEXT OFFSET WORD
       REM
CLAP   CLA L3                        RESET LINKAGE TO LIFT PEN
       STD VL
       CLA XO                        CALCULATE X AND Y FOR
       FAD XT                        NEXT CHARACTER IN SERIES
       STO XO
       CLA YO
```

```
        FAD YT
        STO YO
        REM
        LXD 1X,1                      RESET INDEX REGISTERS
        LXD 2X,2                      FOR NEXT CHARACTER
        LXD COM,4                     PICK UP.
        REM
        TIX *+3,2,6                   CHANGE SHIFT COUNT FOR NEW CHAR.
        REM
        LXA 36N,2                     RESET NEW CHARACTER SHIFT
FF      TXI *+1,4,**                  MOVE TO NEXT BCD WORD
        TXL EXIT,1,1                  END OF STRING OF CHARS.
        TXI LOC,1,-1                  GO VACK FOR ANOTHER CHAR.
        REM
EXIT    LXD X1,1                      RESTORE INDEX REGISTERS
        LXD X2,2                      TO VALUES AT ENTRY TO
        LXD X4,4                      ROUTINE.
7B35    TRA 7,4                       RETURN
        REM
OUT     SSP                           SET HEIGHT PLUS
        LXA ONE,2                     SETX2 FOR BKWD STACK DATA
X1      TXI BACK,0,**                 RETURN
        REM
SPECL   LXA ONE,1                     COUNT=1
        LXA 25N,2                     SET CHIFT COUNT TO PICK UP DECP.
        LDQ FACT                      RECOMPUTE FACTOR
        FMP F7TH                      FACTOR=HEIGHT/4
        STO FACT                      (ADD SPECIAL CHARACTER HANDLING)
        CLA 1X
        STO VAR
        LXD XXK,4                     PICK UP N VALUE FOR PEN LIFT DECISIO
        TXL LRTN,4,1                  IF N=-1 SET PEN TO LIFT
        CLA L2                        N=-2SET PEN TO LOWER.
X2      TXI RTN,0,**                  RETURN
        REM
F7      DEC 7.0                       FACTOR=HEIGHT/7.0
F7TH    DEC 1.75                      FACTOR=HEIGHT/4.0
CONST   DEC 0.0174533                 3.1416/1800.0
FACT    PZE 0                         LETTER FACTOR
INCC    PZE 0                         FACTOR * COS THETA
INCS    PZE 0                         FACTOR * SIN THETA
X0      PZE 0                         X COORDINATE OF FIRST CHAR.
Y0      PZE 0                         YCOORDINATE OF FIRST CHAR.
COM     TXI VAR+1,0,**                VARIABLE INSTRUCTION NORMAL
1X      TXI MORE,0,**                 VARIABLE INSTRUCTION SPECIAL
MORE    SXD 1X,1
        PAX 0,1                       PICK UP NUMBER FOR SPECIAL
        TXL REENT,1,16                IF GREATER THAN THE TOTAL
        TXI *+1,1,-17                 NUMBER OF SPECIAL CHARACTERS
        STZ XXK
36N     PXA 36,1
        LXD 1X,1
2X      TXI VAR+1,0,**                THEN REDUCE BY 17 AND
        REM                           GO INTO HOLLER7TH TABLE
VL      PZE 0,0,**
TWICE   OCT 001000000000
L3      PZE 0,0,3
L2      PZE 0,0,2
ONE     PZE 1
NO      PZE 0
XXK     PZE 0                         CONSTANT FOR SPECIAL CHARACTER IND.
XX      PZE 0
YY      PZE 0
XT      PZE 0
YT      PZE 0
```

```
F6      DEC 6.0
        PZE VECTOR,0,64*12+2         -171
        PZE VECTOR,0,64*24+2         -16-
        PZE S15,0,64*24+6            -UK
        PZE S4,0,64*12+4             -14
        PZE S13,0,64*24+6            -13
        PZE S4,0,64*30+13            -12
        PZE S11,0,64*30+14           -11
        PZE S10,0,64*30+7            -10
        PZE S9,0,64*36+8             -9
        PZE S8,0,64*30+6             -8
        PZE S7,0,64*36+7             -7
        PZE S6,0,64*36+7             -6
        PZE S5,0,64*30+7             -5
        PZE S4,0,64*30+7             -4
        PZE S3,0,64*24+6             -3
        PZE S2,0,64*18+12            -2
        PZE S1,0,64*24+8             -1
TABLE   PZE 0,0,64*24+9              00
        PZE N1,0,64*18+5             01
        PZE N2,0,64*24+8             02
        PZE N3,0,64*24+13            03
        PZE N4,0,64*30+9             04
        PZE N5,0,64*6+9              05
        PZE N6,0,64*24+11            06
        PZE N7,0,64*36+6             07
        PZE N3,0,64*24+17            10
        PZE N9,0,64*18+12            11
        PZE COLON,0,64*24+11         12
        PZE MINUS,0,64*12+5          13
        PZE MINUS,0,64*12+8          14
        PZE LF,0,64*24+6             15
        PZE N7,0,64*12+8             16
        PZE N2+1,0,64*12+4           17
        PZE PLUS,0,64*12+5           20
        PZE A,0,64*36+10             21
        PZE D+1,0,64*30+12           22
        PZE O,0,64*24+8              23
        PZE D,0,64*6+7               24
        PZE L,0,64*30+7              25
        PZE L,0,64*24+6              26
        PZE G,0,64*18+12             27
        PZE H,0,64*36+6              30
        PZE RP,0,64*12+6             31
        PZE N2+1,0,64*24+4           32
        PZE N7,0,64*12+5             33
        PZE RP,0,64*30+4             34
        PZE AR,0,64*18+5             35
        PZE MINUS,0,64*30+8          36
        PZE AST,0,64*24+3            37
        PZE MINUS,0,64*30+2          40
        PZE U,0,64*12+5              41
        PZE M,0,64*18+7              42
        PZE L,0,64*30+3              43
        PZE M,0,64*36+5              44
        PZE N,0,64*18+4              45
        PZE O,0,64*36+11             46
        PZE W,0,64*18+7              47
        PZE O,0,64*24+11             50
        PZE W,0,64*18+10             51
        PZE PER,0,64*36+14           52
        PZE N7+1,0,64*6+11           53
        PZE AST,0,64*12+11           54
        PZE N1,0,64*30+5             55
        PZE T,0,64*12+5              56
```

```
        FAD YT
        STO YO
        REM
        LXD 1X,1                       RESET INDEX REGISTERS
        LXD 2X,2                       FOR NEXT CHARACTER
        LXD COM,4                      PICK UP.
        REM
        TIX *+3,2,6                    CHANGE SHIFT COUNT FOR NEW CHAR.
        REM
        LXA 36N,2                      RESET NEW CHARACTER SHIFT
FF      TXI *+1,4,**                   MOVE TO NEXT BCD WORD
        TXL EXIT,1,1                   END OF STRING OF CHARS.
        TXI LOC,1,-1                   GO VACK FOR ANOTHER CHAR.
        REM
EXIT    LXD X1,1                       RESTORE INDEX REGISTERS
        LXD X2,2                       TO VALUES AT ENTRY TO
        LXD X4,4                       ROUTINE.
7B35    TRA 7,4                        RETURN
        REM
OUT     SSP                            SET HEIGHT PLUS
        LXA ONE,2                      SETX2 FOR BKWD STACK DATA
X1      TXI BACK,0,**                  RETURN
        REM
SPECL   LXA ONE,1                      COUNT=1
        LXA 25N,2                      SET CHIFT COUNT TO PICK UP DECP.
        LDQ FACT                       RECOMPUTE FACTOR
        FMP F7TH                       FACTOR=HEIGHT/4
        STO FACT                       (ADD SPECIAL CHARACTER HANDLING)
        CLA 1X
        STO VAR
        LXD XXK,4                      PICK UP N VALUE FOR PEN LIFT DECISIO
        TXL LRTN,4,1                   IF N=-1 SET PEN TO LIFT
        CLA L2                         N=-2SET PEN TO LOWER.
X2      TXI RTN,0,**                   RETURN
        REM
F7      DEC 7.0                        FACTOR=HEIGHT/7.0
F7TH    DEC 1.75                       FACTOR=HEIGHT/4.0
CONST   DEC 0.0174533                  3.1416/1800.0
FACT    PZE 0                          LETTER FACTOR
INCC    PZE 0                          FACTOR * COS THETA
INCS    PZE 0                          FACTOR * SIN THETA
X0      PZE 0                          X COORDINATE OF FIRST CHAR.
Y0      PZE 0                          YCOORDINATE OF FIRST CHAR.
COM     TXI VAR+1,0,**                 VARIABLE INSTRUCTION NORMAL
1X      TXI MORE,0,**                  VARIABLE INSTRUCTION SPECIAL
MORE    SXD 1X,1
        PAX 0,1                        PICK UP NUMBER FOR SPECIAL
        TXL REENT,1,16                 IF GREATER THAN THE TOTAL
        TXI *+1,1,-17                  NUMBER OF SPECIAL CHARACTERS
        STZ XXK
36N     PXA 36,1
        LXD 1X,1
2X      TXI VAR+1,0,**                 THEN REDUCE BY 17 AND
        REM                            GO INTO HOLLER7TH TABLE
VL      PZE 0,0,**
TWICE   OCT 001000000000
L3      PZE 0,0,3
L2      PZE 0,0,2
ONE     PZE 1
NO      PZE 0
XXK     PZE 0                          CONSTANT FOR SPECIAL CHARACTER IND.
XX      PZE 0
YY      PZE 0
XT      PZE 0
YT      PZE 0
```

```
F6      DEC 6.0
        PZE VECTOR,0,64*12+2                -171
        PZE VECTOR,0,64*24+2                -16-
        PZE S15,0,64*24+6                   -UK
        PZE S4,0,64*12+4                    -14
        PZE S13,0,64*24+6                   -13
        PZE S4,0,64*30+13                   -12
        PZE S11,0,64*30+14                  -11
        PZE S10,0,64*30+7                   -10
        PZE S9,0,64*36+8                    -9
        PZE S8,0,64*30+6                    -8
        PZE S7,0,64*36+7                    -7
        PZE S6,0,64*36+7                    -6
        PZE S5,0,64*30+7                    -5
        PZE S4,0,64*30+7                    -4
        PZE S3,0,64*24+6                    -3
        PZE S2,0,64*18+12                   -2
        PZE S1,0,64*24+8                    -1
TABLE   PZE 0,0,64*24+9                     00
        PZE N1,0,64*18+5                    01
        PZE N2,0,64*24+8                    02
        PZE N3,0,64*24+13                   03
        PZE N4,0,64*30+9                    04
        PZE N5,0,64*6+9                     05
        PZE N6,0,64*24+11                   06
        PZE N7,0,64*36+6                    07
        PZE N3,0,64*24+17                   10
        PZE N9,0,64*18+12                   11
        PZE COLON,0,64*24+11                12
        PZE MINUS,0,64*12+5                 13
        PZE MINUS,0,64*12+8                 14
        PZE LF,0,64*24+6                    15
        PZE N7,0,64*12+8                    16
        PZE N2+1,0,64*12+4                  17
        PZE PLUS,0,64*12+5                  20
        PZE A,0,64*36+10                    21
        PZE D+1,0,64*30+12                  22
        PZE O,0,64*24+8                     23
        PZE D,0,64*6+7                      24
        PZE L,0,64*30+7                     25
        PZE L,0,64*24+6                     26
        PZE G,0,64*18+12                    27
        PZE H,0,64*36+6                     30
        PZE RP,0,64*12+6                    31
        PZE N2+1,0,64*24+4                  32
        PZE N7,0,64*12+5                    33
        PZE RP,0,64*30+4                    34
        PZE AR,0,64*18+5                    35
        PZE MINUS,0,64*30+8                 36
        PZE AST,0,64*24+3                   37
        PZE MINUS,0,64*30+2                 40
        PZE U,0,64*12+5                     41
        PZE M,0,64*18+7                     42
        PZE L,0,64*30+3                     43
        PZE M,0,64*36+5                     44
        PZE N,0,64*18+4                     45
        PZE O,0,64*36+11                    46
        PZE W,0,64*18+7                     47
        PZE O,0,64*24+11                    50
        PZE W,0,64*18+10                    51
        PZE PER,0,64*36+14                  52
        PZE N7+1,0,64*6+11                  53
        PZE AST,0,64*12+11                  54
        PZE N1,0,64*30+5                    55
        PZE T,0,64*12+5                     56
```

```
 X4     AXT **,4
        TRA 2,4
 END    OCT 076600001206           WRITE SELECT TAPE A-
        RCHA BLOCK
        OCT 077200001206           REWIND TAPE A-6
        TSX $MSG,4                 WRITE MESSAGE ON-LINE PRINTER
        HTR *+1                    HALT WHILE TAPE IS CHANGED
        REWA    6
        AXT     5,4
        WTBA    6
        TIX     *-1,4,1
        SDLA 6                     SET DENSITY LOW ON A-6
        OCT 076600001206           WRITE SELECT TAPE A-6
        RCHA BLOCK                 OUTPUT BLOCK ADDRESS
        CLA     *-1
        STA     TRY
        TRA SPIN                   BACK TO WRITING DATA
 BSR    OCT 076400001206           BACK SPACE TAPE A-6
        OCT 076600001206           WRITE SELECT TO GIVE BLANK 3 INC
        OCT 076600001206           WRITE SELECT TAPE A-6
TRY     RCHA    IO
        TRA SPIN                   NOW TRY TO WRITE CURRENT DATA
 TRWS   CLA 1,4
        STA IO                     THIS PICKS UP LOC OF TAPE WRITE
        REWA    6
        SDLA 6                     SET DENSITY LOW FOR TAPE A-6
        TRA 2,4                    RETURN FROM TRW INITILIZATION
 IO     PZE **,0,**
 BUFER  PZE **
 BLOCK  PZE BLOCK+1,0,7
        BCD 744444444443333333165656513333333444444444
        END
```


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