PLOT: A MULTIPURPOSE FORTRAN SUBROUTINE FOR TWO-DIMENSIONAL PLOTTING ON A LINE PRINTER

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TABLE OF CONTENTS

I. INTRODUCTION

This is a versatile FORTRAN subroutine for performing two-dimensional plotting operations on a line printer. The subroutine explicitly provides for X-Y plotting, histograms, frequency distributions, and cumulative frequency distributions. Plotting of specified functions, preparation of contingency table matrices from numerical codes, and several other operations are also available depending upon the user's knowledge of programming. Although several programs are available for each of these operations, we feel that there is an advantage in having a single subroutine which can perform all of these with only minor modifications in the control cards and calling procedures. This uniformity is especially advantageous for users with a limited knowledge of programming.

All testing and example runs were performed under the Version II disk monitor system on an IBM 1130 computer with 8K, 16-bit words of core storage, IBM 1442 card read punch, IBM 1132 printer, and a single magnetic disk; however, the subroutine does not require the auxiliary storage capacity of the disk.

The senior author is responsible for the systems analysis and initial programming, while the junior author did extensive debugging and testing of the program.

II. PURPOSE

This subroutine subprogram is designed to make a line printer, attached as an output device to a computer, serve as a versatile two-dimensional plotter. This is possible because of the approximate correspondence between one vertical space and two horizontal spaces on such a printer. The horizontal scale is actually a little larger than the vertical scale, and this should be kept in mind when interpreting plots produced by this program.

The program provides for the construction of X-Y plots, histograms, frequency distributions, cumulative frequency distributions, and contingency table matrices for numerical data. It can also be used for plotting functions. The only restriction is that the horizontal scale must increase from left to right, and the vertical scale must increase from bottom to top. An observed value is plotted at the nearest intersection of grid lines. A limited control over the treatment of boundary values is provided via a control card parameter. The user is free to select the symbols to be plotted. For X-Y plotting, the program can easily be made to plot the number of observations falling at each intersection of grid lines (up to and including a frequency of 99).

The horizontal axis of the graph is the first row of plotted characters above the column marks, and the vertical axis of the graph is the first double column of characters to the right of the line marks. Every fifth value on each scale is printed. Since these scale values are printed under a fixed point format, some scaling of the data may be necessary or desirable when dealing with very large or very small values. The grid lines are omitted from the graph to improve readability.

The number of observations plotted on the graph is printed in the lower left-hand corner of the page containing the graph. The number of observations which could not be plotted because they were beyond the scale limits is printed (if any) on the page immediately following the graph. Two sizes of graphs are available. The smaller size, having a resolution of 1 in 40, fits on an $8\frac{1}{2}$ X 11-inch page when the margins are trimmed. The larger size, having a resolution of 1 in 50, is 10 by 12 inches in size. An option is available for multiple copies.

III. PROCEDURE

The user must supply the following items:

A. A short FORTRAN main program which specifies the form of the input data and invokes the necessary calls to SUBRØUTINE PLØT.

B. The monitor cards necessary for compilation and execution of the main program and subprogram.

C. Seven control cards. The first three control cards are used to specify the desired plotting symbols. For convenient reference, we refer to these as the SYMBOLA, SYMBOLB, and SYMBOLC control cards, respectively. The fourth, or XTITLE, control card contains title information to be printed below the horizontal axis of the graph. The fifth, or YTITLE, control card contains title information to be printed at the top of the graph. The sixth, or OPTION, control card is used to set program parameters. These first six control cards are placed in front of the data deck. The seventh control card, called the STOP card, is placed immediately behind the data deck. It contains a flag number which indicates the end of the input data for the current run.

D. The deck of data cards.

An assembled input deck is shown schematically in Figure 1. The main program, monitor cards, and control cards are explained more fully in subsequent sections.

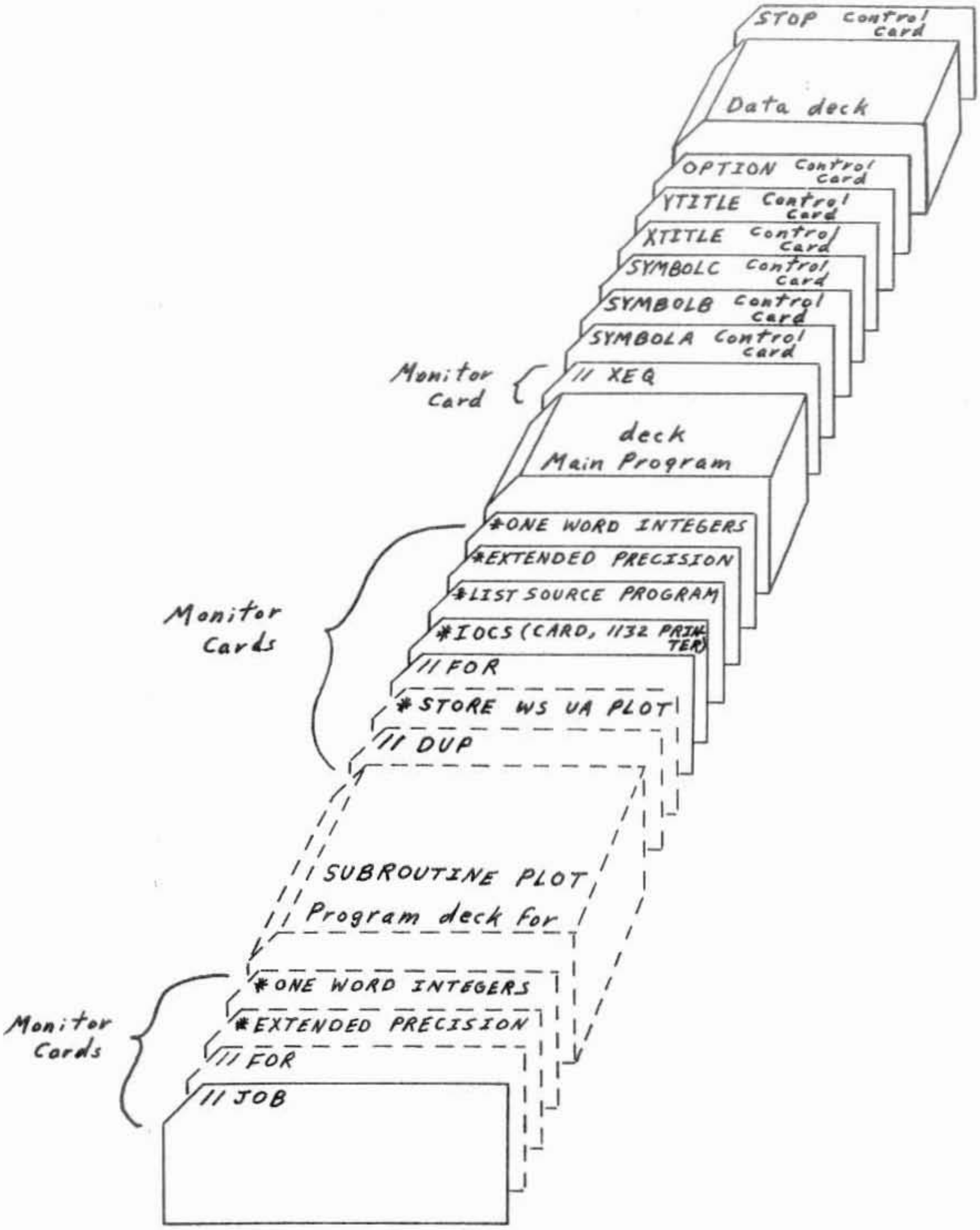

Figure 1. Diagram of input deck, including monitor cards for the IBM 1130 disk monitor system. Broken outline indicates that item should be omitted if SUBROUTINE PLOT has been stored previously on magnetic disk.

IV. MAIN PROGRAM

The general form of the mainline program for X-Y plots, histograms, frequency distributions, cumulative frequency distributions, and contingency table matrices is shown in Figure 2. In all cases, the user must alter the FØRMAT statement to suit his input data. Also note the number 2 in column 12 of the READ statement. This is appropriate for an IBM 1130 computer having an IBM 1442 card read punch. If the computing system is not of this type, replace the number 2 with the appropriate reference number for the card reader.

For X-Y plotting and constructing the matrices of contingency tables, the letter X in column 17 of the READ statement refers to the variable to be plotted on the horizontal axis, and the letter Y in column 22 refers to the variable to be plotted on the vertical axis. If the X-value for a given observation precedes the Y-value on the data card(s), it is only necessary to revise the FØRMAT card. If the Y-value precedes the X-value, it is also necessary to interchange the positions of X and Y in the READ statement.

For histograms, frequency distributions, and cumulative frequency distributions, the "Y(I)," portion of the READ statement is irrelevant. If the READ statement is left as shown, a dummy field description must be provided for Y in the FØRMAT statement. Alternatively, the user can delete "Y(I)," from the READ statement and the corresponding field description from the FØRMAT statement.

The mainline program for plotting functions is somewhat different. The general form for this purpose is shown in Figure 3. The user must rewrite the statement which begins Y(I)= so that it defines Y(I) in terms of X(I) for the particular function being plotted. The corresponding statement in Figure 3 is included only for illustrative purposes and is the version that is appropriate to example #5. Obviously, this use depends on the ability of the user to express the desired function as a FORTRAN program statement.

When used with an IBM 1130 computer having 8K words of core storage, the main program must necessarily be short since SUBRØUTINE PLØT requires most of the available storage capacity. When more core storage is available, the main programs shown can be incorporated into larger programs. The CALL LINK feature of the IBM 1130 disk monitor system can also be used to extend the size of the main program; however, the CØMMØN area available for passing information will be severely limited for 8K systems.

```
Col. 7
    '

     DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
     IC(1)=1
     GØ TØ 4
   1 IF(IC(7)-1)2,5,2
   2 NI=IC(2)
     READ(2,3)(X(I),Y(I),I=1,NI)
   3 FØRMAT(F10.4,10X,F10.4)
   4 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
     IC(1)=2
     GØ TØ 1
   5 CALL EXIT
     END
```

Figure 2. Generalized main program for X-Y plots, histograms, frequency distributions, and contingency table matrices. Monitor cards are not included.

```
Col. 7
      '

      DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
      IC(1)=1
      N=0
    1 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
      IC(1)=2
      IF(IC(7)-1)2,6,2
    2 DØ 3 I=1,10
      X(I)=C+N*D
      Y(I)=.005454154*X(I)*X(I)
    3 N=N+1
      IF(N-IC(5))5,5,4
    4 X(1)=G
    5 GØ TØ 1
    6 CALL EXIT
      END
```

Figure 3. General form of main program for plotting functions. Monitor cards are not included.

V. CONTROL CARDS

The general purposes and positioning of the control cards are described in section III and Figure 1. Detailed instructions for completing the control cards are given in Table 1.

Table 1.

Card name	Columns	Information
SYMBOLA	1 through 2	This set of two symbols is used to plot distribution curves and functions and to mark the upper edge of the bars in a histogram. For simple X-Y plotting and contingency table matrices, this set of symbols is plotted at any grid intersection containing a single observation.
"	3 through 4	This set of two symbols is used to shade areas of histogram bars and the area beneath distribution curves. If these two columns are blank, there will be no shading. For simple X-Y plotting and contingency table matrices, this set of symbols is printed at any intersection containing two observations. For plotting functions, these two columns should be blank.
"	5 through 80	For histograms, distributions, and functions, these columns should be blank. For simple X-Y plotting and contingency table matrices, the set of symbols in columns 5 and 6 is plotted at any grid intersection having three observations, the set of symbols in columns 7 and 8 is plotted at any intersection having four observations, ..., the set of symbols in columns 79 and 80 is plotted at any intersection having 40 observations.

Table 1. (continuation)

Card name	Columns	Information
SYMBOLB	1 through 80	For histograms, distributions, and functions, the entire SYMBOLB card should be blank. However, the blank card cannot be omitted. For simple X-Y plotting and contingency table matrices, the set of symbols in columns 1 and 2 is plotted at any grid intersection having 41 observations, the set of symbols in columns 3 and 4 is plotted at any intersection having 42 observations, ..., the set of symbols in columns 79 and 80 is plotted at any intersection having 80 observations.
SYMBOLC	1 through 38	For histograms, distributions, and functions, the entire SYMBOLC card should be blank. Again, the blank card cannot be omitted. For simple X-Y plotting and contingency table matrices, the set of symbols in columns 1 and 2 is plotted at any grid intersection having 81 observations, the set of symbols in columns 3 and 4 is plotted at any intersection having 82 observations, ..., the set of symbols in columns 37 and 38 is plotted at any intersection having 99 observations.
"	39 through 40	These two columns should always be blank because this is the set of symbols plotted at any grid intersection containing no observations.

Table 1. (continuation)

Card name	Columns	Information
SYMBOLC	41 through 42	For histograms, distributions, and functions, these two columns should be blank. For simple X-Y plotting and contingency table matrices, this set of symbols is plotted at any intersection having more than 99 observations.
"	43 through 80	Any information in these columns is ignored by the computer.
XTITLE	1 through 72	The information in these columns is reproduced starting in column 21 at the bottom of the graph. Any information on the remainder of the card is ignored.
YTITLE	1 through 72	The information in these columns is reproduced in the corresponding columns at the top of the graph. Any information on the remainder of the card is ignored.
OPTION	1 through 10	For all purposes except the plotting of cumulative distributions, this is the midpoint of the lowest scale interval on the horizontal axis. For cumulative distributions, this is the upper limit of the lowest scale interval. This number should be right justified, and the decimal point should be punched. If, however, the decimal point is omitted, columns 7 through 10 will be interpreted as decimal places.
"	11 through 20	The size (width) of the scale interval on the horizontal axis should be specified in these columns. This number should be right justified, and the decimal point should be punched. If, however, the decimal is omitted, columns 17 through 20 will be interpreted as decimal places.

Table 1. (continuation)

Card name	Columns	Information
OPTION	21 through 30	In all cases, this is the midpoint of the lowest scale interval on the vertical axis. This number should be right justified, and the decimal point should be punched. In the absence of a decimal point, columns 27 through 30 will be interpreted as decimal places.
"	31 through 40	The size of the scale interval on the vertical axis should be specified in these columns. This number should be right justified, and the decimal point should be punched. In the absence of a decimal point, columns 37 through 40 will be interpreted as decimal places.
"	41 through 50	Place here a number which is not found among the values to be plotted on the horizontal axis. This number should be right justified and the decimal point should be punched. In the absence of a decimal point, columns 47 through 50 will be interpreted as decimal places. This number must appear again on the STOP control card (at the end of the data deck). It serves as a flag to indicate when the last data card has been read. The only other restriction on its value is that the number of digits plus the decimal point cannot exceed the number of columns allotted to a field of the variable to be plotted on the horizontal axis.
"	53	Normally this column is left blank, in which case any given plotting interval will include its upper boundary but not its lower boundary. If the number 1

Table 1. (continuation)

Card name	Columns	Information
OPTION	53 (cont'd)	is placed in this column, the lower boundary will be included in the interval but not the upper boundary.
"	55 through 56	This is an integer number (right justified with no decimal) specifying the number of observations per data card. For simple X-Y plotting and contingency table matrices, a set of horizontal and vertical coordinates is counted as a single observation. This number must be less than or equal to 20 . For plotting functions, this column can be blank.
"	59	If the purpose is to construct a histogram or simple frequency distribution, place the number 1 in this column. If the purpose is to construct a cumulative frequency distribution, place the number 2 in this column. For any other purpose, place the number 3 in this column.
"	62	This is the device code number (symbolic unit number or data set reference number) assigned to the printer on which the graph is to appear. The code number for the IBM 1132 printer is 3 .
"	65	This column is used to specify the size of the graph. If the number 1 is placed in this column, the graph will have a resolution of 1 in 40 and will fit on an $8\frac{1}{2}$ X 11-inch page when the margins are trimmed. If the number 2 is placed in this column, the graph will have a

Table 1. (conclusion)

Card name	Columns	Information
OPTION	65 (cont'd)	resolution of 1 in 50 and will be approximately 10 by 12 inches in size.
"	68	This column is used to specify the number of copies desired, including the original. If this column is left blank, it will be assumed that a single copy is desired.
STOP	varies	The number placed in columns 41 through 50 of the OPTION card is repeated on this last control card, but not necessarily in the same columns. Its positioning here depends on the positioning of information on the data cards. The number should be positioned on this card exactly as if it was the horizontal coordinate of an extra observation. With several observations per data card, the STOP card and the last data card will often coincide. As mentioned above, this number serves as a flag to indicate the end of the data deck.

Any questions regarding preparation or use of control cards should be clarified by reference to the examples.

VI. IBM 1130 DISK MONITOR CARDS

The monitor cards necessary for processing this program under the IBM 1130 disk monitor system are indicated in Figure 1 and Figure 4. The positions of these cards in the input deck are shown in Figure 1, and their formats are shown in Figure 4. For a different monitor system, the appropriate manuals should be consulted.

Column number

02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

```
// JØB

// FØR

*EXTENDED PRECISIØN

*ØNE WØRD INTEGERS

// DUP

*STØRE      WS  UA  PLØT

*IOCS(CARD,1132 PRINTER)

*LIST SØURCE PRØGRAM

// XEQ
```

Figure 4. Positioning of information on IBM 1130 disk monitor cards.

VII. SUBRØUTINE PLØT SOURCE PROGRAM

The meanings of the FORTRAN labels used in SUBRØUTINE PLØT are explained in Table 2.

Table 2.

FORTRAN label	Meaning
DEL	This is the difference between XMIN and the upper limit of the first scale interval on the horizontal axis. It determines whether the plotting will be over midpoints or upper limits of scale intervals on this axis.
FI	This is working storage.
I	This is an iteration variable.
IC	This array is used to pass program parameters between main program and subroutine.
ICHAR	This array contains the 101 sets of two characters used in plotting.
IDIF	This is working storage.
IDRØP	The value 0 means include upper boundary but not lower in scale interval. The value 1 means include lower boundary but not upper in scale interval.
IGØ	The value 1 means enter the subroutine at statement number 5000. The value 2 means enter the subroutine at statement number 50 .
IGRID	This is the 50 x 50 array representing the intersections of grid lines.
IØ	This is the reference number of the printer on which output is to appear.
IQ	This is working storage.

Table 2. (continuation)

FORTRAN label	Meaning
IS	This is working storage
ISIZE	The value 1 for this variable means smaller version of graph. The value 2 for this variable means larger version of graph. Subsequently, ISIZE indicates the number of scale intervals on an axis.
ISTØP	This variable is set equal to 1 when the reading of data is complete.
ITØP	This variable is used only for frequency distributions and histograms. It indicates the highest frequency which can be represented on the vertical axis.
ITYPE	The value 1 for this variable means operation is construction of histogram or simple frequency distribution. The value 2 for this variable means operation is construction of a cumulative frequency distribution. The value 3 for this variable means operation is anything not covered by the previous two codes.
IZ	This is the subscript index of the zero point on the vertical scale of histograms and frequency distributions.
J	This is an iteration variable.
K	This is an iteration variable.
KØUNT	This is the number of observations plotted on the graph.
L	This is an iteration variable.
LØCX	This is the horizontal coordinate of an observation in terms of scale intervals.

Table 2. (continuation)

FORTRAN label	Meaning
LØCY	This is the vertical coordinate of an observation in terms of scale intervals.
M	This is the reference number of the card reader.
NCØPY	This is the number of copies of the graph to be printed.
NI	This is the number of observations per data card.
SAVE	This is working storage.
NØUT	This is the number of observations falling outside the scale limits.
NPRNT	This is an iteration variable.
SAV	This is working storage.
STØB	This is the flag number which indicates the end of the data deck.
X	This is a buffer array which holds the horizontal coordinates of NI points while they are being processed.
XMIN	This is either the midpoint or the upper limit of the lowest scale interval on the horizontal axis, depending upon the purpose.
XSTEP	This is the scale interval on the horizontal axis.
XTITL	This array contains title information to be printed at the bottom of the graph.
Y	This is a buffer array which holds the vertical coordinates of NI points while they are being processed.

Table 2. (conclusion)

FORTRAN label	Meaning
YMIN	This is the midpoint of the lowest scale interval on the vertical axis.
YSTEP	This is the scale interval on the vertical axis.
YTITL	This is an array containing title information for the top of the graph.

The FORTRAN source program for SUBRØUTINE PLØT appears on the pages immediately following. The position of column 7 is marked at the top of each page. The cards are numbered sequentially in columns 78 through 80.

Col. 7

```
      SUBRØUTINE PLØT(YTITL,XTITL,X,Y,XMIN,XSTEP,YMIN,YSTEP,STØB,DEL,
     1IGRID,ICHAR,IC)
      DIMENSIØN IGRID(50,50),ICHAR(101),YTITL(18),XTITL(18),X(20),Y(20),
     1IC(10)
      IGØ=IC(1)
      NI=IC(2)
      ITYPE=IC(3)
      IØ=IC(4)
      ISIZE=IC(5)
      NCØPY=IC(6)
      ISTØP=IC(7)
      IDRØP=IC(8)
      NØUT=IC(9)
      KØUNT=IC(10)
C ....DETERMINE ENTRY PØINT.
      GØ TØ(5000,50),IGØ
 5000 M=2
      READ(M,1)ICHAR,XTITL,YTITL,XMIN,XSTEP,YMIN,YSTEP,STØB,IDRØP,NI,
     1ITYPE,IØ,ISIZE,NCØPY
    1 FØRMAT(40A2/40A2/21A2/,2(18A4,/),5F10.4,6(1X,I2))
C ....ADJUST GRID TØ SPECIFIED SIZE.
      GØ TØ (601,602),ISIZE
  601 ISIZE=40
      GØ TØ 603
  602 ISIZE=50
C ....ASSUME SINGLE CØPY ØF GRAPH IF NØT SPECIFIED ØTHERWISE.
  603 IF (NCØPY)610,609,610
  609 NCØPY=1
C ... EXCEPT FOR CUMULATIVE, PLØT ØVER MIDPØINTS ØN THE ABSCISSA.
  610 IF(ITYPE-2)102,101,102
```

Col. 7

```
  101 DEL=0.0
      GØ TØ 103
  102 DEL=.5*XSTEP
C ....INITIALIZE AS NECESSARY
  103 ISTØP=0
      DØ 4 I=1,ISIZE
      DØ 4 J=1,ISIZE
    4 IGRID(I,J)=0
      NØUT=0
      KØUNT=0
      GØ TØ 39
C ....BEGIN PLØTTING SETS ØF NI PØINTS IN THE MEMØRY GRAPH, IGRID.
C ....IN THIS FIRST STAGE, THE GRAPH IS IN TERMS ØF FREQUENCIES.
C ....FOR FREQUENCY DISTRIBUTIØNS, TABULATE IN 1ST INTERVAL ØN ØRDINATE.
   50 GØ TØ(1001,1001,1003),ITYPE
 1001 DØ 1002 I=1,NI
 1002 Y(I)=YMIN
C ....SET ISTØP TØ 1 IF STØP NUMBER HAS BEEN READ.
 1003 DØ 500 I=1,NI
      IF(X(I)-STØB)500,499,500
  499 IS=I-1
      ISTØP=1
      IF(IS)501,62,501
  500 IS=NI
  501 NI=IS
C ....REJECT PØINT IF IT IS ØUTSIDE LIMITS ØF GRAPH.
      DØ 6 I=1,NI
      IF(IDRØP-1)71,72,71
   71 IF(((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP)-Y(I))7,8,8
   72 IF(((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP)-Y(I))7,7,8
```

Col. 7

```
      7 NØUT=NØUT+1
        GØ TØ 6
      8 IF(IDRØP-1)91,92,91
     91 IF((YMIN-.5*YSTEP)-Y(I))10,9,9
     92 IF((YMIN-.5*YSTEP)-Y(I))10,10,9
      9 NØUT=NØUT+1
        GØ TØ 6
     10 IF(ITYPE-2)210,220,210
    210 IF(IDRØP-1)211,213,211
    211 IF((XMIN-DEL)-X(I))212,13,13
    212 IF(((XMIN+(ISIZE-1)*XSTEP)+DEL)-X(I))13,14,14
    213 IF((XMIN-DEL)-X(I))214,214,13
    214 IF(((XMIN+(ISIZE-1)*XSTEP)+DEL)-X(I))13,13,14
    220 IF(IDRØP-1)221,223,221
    221 IF((XMIN-XSTEP)-X(I))222,13,13
    222 IF((XMIN+(ISIZE-1)*XSTEP)-X(I))13,14,14
    223 IF((XMIN-XSTEP)-X(I))224,224,13
    224 IF((XMIN+(ISIZE-1)*XSTEP)-X(I))13,13,14
     13 NØUT=NØUT+1
        GØ TØ 6
C ....LØCATE NEAREST HØRIZØNTAL CØØRDINATE.
     14 LØCX=1
        LØCY=1
        DØ 16 J=1,ISIZE
        IF(X(I)-((XMIN+(J-1)*XSTEP)+DEL))16,17,9917
     17 IF(IDRØP-1)16,9917,16
   9917 LØCX=LØCX+1
     16 CØNTINUE
C ....INCREMENT KØUNT.
        KØUNT=KØUNT+1
```

Col. 7

```
C ....LØCATE NEAREST VERTICAL CØØRDINATE.
      DØ 18 J=1,ISIZE
      IF(Y(I)-((YMIN+(J-1)*YSTEP)+.5*YSTEP))18,19,9919
   19 IF(IDRØP-1)18,9919,18
 9919 LØCY=LØCY+1
   18 CØNTINUE
C ....INCREMENT FREQUENCY ØF NEAREST GRID INTERSECTIØN.
      IF(IGRID(LØCY,LØCX)-32767)1004,341,341
 1004 IGRID(LØCY,LØCX)=IGRID(LØCY,LØCX)+1
    6 CØNTINUE
C ....IF ALL PØINTS NØT PRØCESSED, RETURN TO MAIN PRØGRAM FØR NEXT SET.
      IF(ISTØP)62,5011,62
 5011 CØNTINUE
      GØ TØ 39
C ....BEGIN REPLACING FREQUENCIES BY PLØTTING SYMBØLS
C ....FREQUENCY DISTRIBUTIONS AND HISTØGRAMS REQUIRE A SPECIAL PRØCEDURE.
   62 GØ TØ (1009,1009,1300),ITYPE
C ....THIS PRØCEDURE IS FØR FREQUENCY DISTRIBUTIØNS AND HISTØGRAMS
 1009 SAV=0.0
C ....LØCATE ZERØ PØINT ØN THE VERTICAL SCALE, IF INCLUDED.
      IZ=1
      DØ 9991 I=1,ISIZE
      IF(IDRØP-1)1014,1015,1014
 1014 IF(YMIN+.5*YSTEP)9990,9991,9991
 1015 IF(YMIN+.5*YSTEP)9990,9990,9991
 9990 IZ=IZ+1
 9991 CØNTINUE
      IQ=0
C ....DETERMINE HIGHEST FREQUENCY INCLUDED IN THE VERTICAL SCALE.
      I=1
```

Col. 7

```
      IF((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP)39,39,2101
 2101 FI=I
      IF(IDRØP-1)1016,1017,1016
 1016 IF(FI-((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP))2102,2102,2103
 1017 IF(FI-((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP))2102,2103,2103
 2102 ITØP=I
      I=I+1
      GØ TØ 2101
C ....BEGIN MAIN LØØP FØR FREQUENCY DISTRIBUTIØNS AND HISTØGRAMS.
 2103 SAVE=0.0
      DØ 1115 J=1,ISIZE
C ....ACCUMULATE FREQUENCIES ØR NØT, ACCØRDING TØ THE PURPØSE.
      IF(ITYPE-2)1100,1010,1100
 1010 SAV=IGRID(1,J)
      SAVE=SAVE+SAV
      GØ TØ 1101
 1100 SAVE=IGRID(1,J)
C ....IS FREQUENCY ABØVE RANGE ØF VERTICAL SCALE.
 1101 IF(IDRØP-1)1901,1902,1901
 1901 IF(((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP)-SAVE)1102,1103,1103
 1902 IF(((YMIN+(ISIZE-1)*YSTEP)+.5*YSTEP)-SAVE)1102,1102,1103
 1102 GØ TØ(1202,1212),ITYPE
 1202 IDIF=IGRID(1,J)-ITØP
      KØUNT=KØUNT-IDIF
      NØUT=NØUT+IDIF
      GØ TØ 1203
 1212 IF(IQ)1203,1213,1203
 1213 NØUT=KØUNT-ITØP
      KØUNT=ITØP
      IQ=1
```

Col. 7

```
 1203 K=ISIZE-1
      IGRID(ISIZE,J)=ICHAR(1)
      TØ TØ 1111
C ....IS FREQUENCY BELØW THE RANGE ØF THE VERTICAL SCALE.
 1103 IF(IDRØP-1)1903,1904,1903
 1903 IF((YMIN-.5*YSTEP)-SAVE)1106,1104,1104
 1904 IF((YMIN-.5*YSTEP)-SAVE)1106,1106,1104
 1104 GØ TØ(1220,1240),ITYPE
 1220 NØUT=NØUT+IGRID(1,J)
      KØUNT=KØUNT-IGRID(1,J)
      GØ TØ 1250
 1240 IF(J-ISIZE)1250,1241,1250
 1241 NØUT=NØUT+KØUNT
      KØUNT=0
 1250 DØ 1105 I=1,ISIZE
 1105 IGRID(I,J)=ICHAR(100)
      GØ TØ 1115
C ....DETERMINE CØØRDINATE ØN VERTICAL SCALE.
 1106 K=1
      DØ 1108 I=1,ISIZE
      IF(IDRØP-1)1905,1906,1905
 1905 IF(SAVE-((YMIN+(I-1)*YSTEP)+.5*YSTEP))1108,1108,1107
 1906 IF(SAVE-((YMIN+(I-1)*YSTEP)+.5*YSTEP))1108,1107,1107
 1107 K=K+1
 1108 CØNTINUE
C ....PLACE APPRØPRIATE SYMBØLS IN CØLUMN.
      IF(SAVE)39,9993,1109
 9993 IGRID(K,J)=ICHAR(100)
      IF(ITYPE-2)9994,1109,9994
 1109 IGRID(K,J)=ICHAR(1)
```

Col. 7

```
9994 K=K+1
     IF(K-ISIZE)9992,9992,1908
9992 DØ 1110 I=K,ISIZE
1110 IGRID(I,J)=ICHAR(100)
1908 K=K-2
1111 IF(K-IZ)1115,1909,1909
1909 DØ 1112 I=IZ,K
1112 IGRID(I,J)=ICHAR(2)
     IF(IZ-1)1115,1115,1911
1911 K=IZ-1
     DØ 1912 I=1,K
1912 IGRID(I,J)=ICHAR(100)
1115 CØNTINUE
     GØ TØ 1500
C ....THIS PRØCEDURE IS FØR ITYPE NUMBER 3.
1300 IQ=0
     DØ 20 I=1,ISIZE
     DØ 20 J=1,ISIZE
     K=IGRID(I,J)
     IF(K)22,21,22
  21 IGRID(I,J)=ICHAR(100)
     GØ TØ 20
  22 IF(K-100)24,23,23
  23 IGRID(I,J)=ICHAR(101)
C ....PRINT THE EXACT FREQUENCY WHEN ØVER 99.
     IF(IQ)100,34,100
  34 WRITE(IØ,36)ICHAR(101)
  36 FØRMAT(1H1,59HIN THE GRAPH BELØW, FREQUENCIES ØVER 99 ARE REPRESEN
    1TED BY ,A2,1H.,/,38H A LIST ØF THESE FREQUENCIES FØLLØWS. ,//,25X,
    21HX,20X,1HY,15X,9HFREQUENCY //)
```

Col. 7

```
      IQ=1
  100 XSCAL=XMIN+(J-1)*XSTEP
      YSCAL=YMIN+(J-1)*YSTEP
      WRITE(IØ,37)XSCAL,YSCAL,K
   37 FØRMAT(1H ,20X,2(F10.4,10X),I5)
      GØ TØ 20
   24 IGRID(I,J)=ICHAR(K)
   20 CØNTINUE
C ....BEGIN PRINTING GRAPH(S).
 1500 DØ 390 NPRNT=1,NCØPY
C ....PRINT GRAPH.
      WRITE(IØ,25)YTITL
   25 FØRMAT(1H1,//,1X,18A4)
      L=4
      DØ 26 K=1,ISIZE
      I=(ISIZE+1)-K
      IF(L)28,27,28
   27 YSCAL=YMIN+(I-1)*YSTEP
      WRITE(IØ,29)YSCAL,(IGRID(I,J),J=1,ISIZE)
      L=5
      GØ TØ 26
   28 WRITE(IØ,30)(IGRID(I,J),J=1,ISIZE)
   26 L=L-1
   29 FØRMAT(1H ,7X,F10.4,2H +,50A2)
   30 FØRMAT(1H ,17X,2H +,50A2)
      IF(ISIZE-50)605,604,605
  604 WRITE(IØ,31)
   31 FØRMAT(1H ,18X,101H+ + - - - - + - - - - + - - - - + - - - - + - -
     1 - - + - - - - + - - - - + - - - - + - - - - + - - - - -)
      GØ TØ 606
```

```
Col. 7
      '

  605 WRITE(IØ,311)
  311 FØRMAT(1H ,18X, 81H+ + - - - - + - - - - + - - - - + - - - - + - -
     1 - - + - - - - + - - - - + - - - -)
  606 IQ=(ISIZE/5)-1
      DØ 5 I=1,IQ
    5 X(I)=XMIN+I*5*XSTEP
      WRITE(IØ,32)KØUNT,XMIN,(X(I),I=1,IQ)
   32 FØRMAT(1H ,I5,10X,10F10.4)
      WRITE(IØ,33)XTITL
   33 FØRMAT(1H ,7HENTRIES,//,21X,18A4)
      IF(NØUT)390,390,38
C ....ERRØR MESSAGE FØR THE UNLIKELY EVENT ØF A FREQUENCY ØVER 32766.
  341 WRITE(IØ,3401)
 3401 FØRMAT(1HO,65HFREQUENCY ØF AN INTERSECTIØN EXCEEDS 32766, EXECUTIØ
     1N TERMINATED.)
      GØ TØ 39
C ....PRINT NUMBER ØF PØINTS REJECTED DUE TØ BEING BEYØND SCALE LIMITS.
   38 WRITE(IØ,40)NØUT
   40 FØRMAT(1H1,//,I5,34H PØINT(S) BEYØND THE SCALE LIMITS,/,51H AND TH
     1EREFØRE TRUNCATED ØR ØMITTED FRØM THE GRAPH.)
  390 CØNTINUE
   39 IC(1)=IGØ
      IC(2)=NI
      IC(3)=ITYPE
      IC(4)=IØ
      IC(5)=ISIZE
      IC(6)=NCØPY
      IC(7)=ISTØP
      IC(8)=IDRØP
      IC(9)=NØUT
      IC(10)=KØUNT
      RETURN
      END
```

VIII. EXAMPLE #1: X-Y PLOTTING

Following is the first of five complete examples which should aid the user in applying the program to his data. Each example illustrates a different type of application.

Assumed data

Suppose that we have 22 observed pairs of values, the first member of a pair being the value of a variable X and the second member the value of a variable Y. Each observed pair of values is punched on a data card, with the X-value in columns 5 through 10 and the Y-value in columns 26 through 30. Although no decimal points are actually punched on the cards, columns 10 and 30 of each card are implied decimal places. Thus, the digits 25 punched in columns 9 and 10 of a card represent an X-value of 2.5 . The observed values and their positioning on the cards are shown in Figure 5.

Purpose

Our purpose in this example is to obtain a simple X-Y plot of the data, with the variable X on the horizontal scale and the variable Y on the vertical scale. The symbol plotted at an intersection of grid lines should be the number of points for which this is the nearest intersection. If the number of points falling at an intersection exceeds 99 (which is an impossibility in this case since we only have 22 points), an asterisk should be placed at that intersection.

We choose zero as the midpoint of the lowest scale interval on both axes. We choose .5 as the scale interval on the horizontal axis and 1.0 as the scale interval on the vertical axis. We wish the resulting graph to fit on an $8\frac{1}{2}$ x 11-inch page, so we choose the smaller size. Our example is now constructed so that the first data point and the last three data points fall outside the scale limits and, therefore, will be omitted from the graph. The code number of the printer is 3 since this example is to be run on an IBM 1130 system with an IBM 1132 printer. Finally, we do not require any additional copies of the graph.

Main program

The main program appropriate for this example is shown in Figure 6. With respect to the READ card, note that the code number of the IBM 1442 card read punch is 2 .

Control cards

The completed control cards for this example are shown in Figure 7. We use 9999.9 as the flag number since this number does not occur among our observed values for the variable X.

Column number

02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

10 ↓	30 ↓
250	500
0	0
5	10
10	20
10	20
20	40
40	80
50	100
50	100
50	100
70	140
80	160
100	200
100	200
110	220
120	240
130	260
135	270
145	290
200	400
210	420
200	900
↑	↑

Figure 5. Assumed data for example #1. Arrows at bottom and top of figure show the location of the implied decimal points.

Results

The results of running example #1 are shown in Figures 8a and 8b. The first page contains the graph, and the second page contains supporting information regarding the number of points which were omitted because they were beyond the scale limits.

```
Column
number   02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

      DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
      IC(1)=1
      GØ TØ 4
    1 IF(IC(7)-1)2,5,2
    2 NI=IC(2)
      READ(2,3)(X(I),Y(I),I=1,NI)
    3 FORMAT(5X,F5.1,15X,F5.1)
    4 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
      IC(1)=2
      GØ TØ 1
    5 CALL EXIT
      END
```

Figure 6. Main program for example #1.

Column number	02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80
Control card	
SYMBOLA	1 2 3 4 5 6 7 8 910111213141516171819202122232425262728293031323334353637383940
SYMBOLB	41424344454647484950515253545556575859606162636465666768697071727374757677787980
SYMBOLC	81828384858687888990919293949596979899 *
XTITLE	X-VALUE
YTITLE	Y-VALUE
OPTION	0.0 0.5 0.0 1.0 9999.9 01 3 3 1 1
STOP	99999

Figure 7. Completed control cards for example #1.

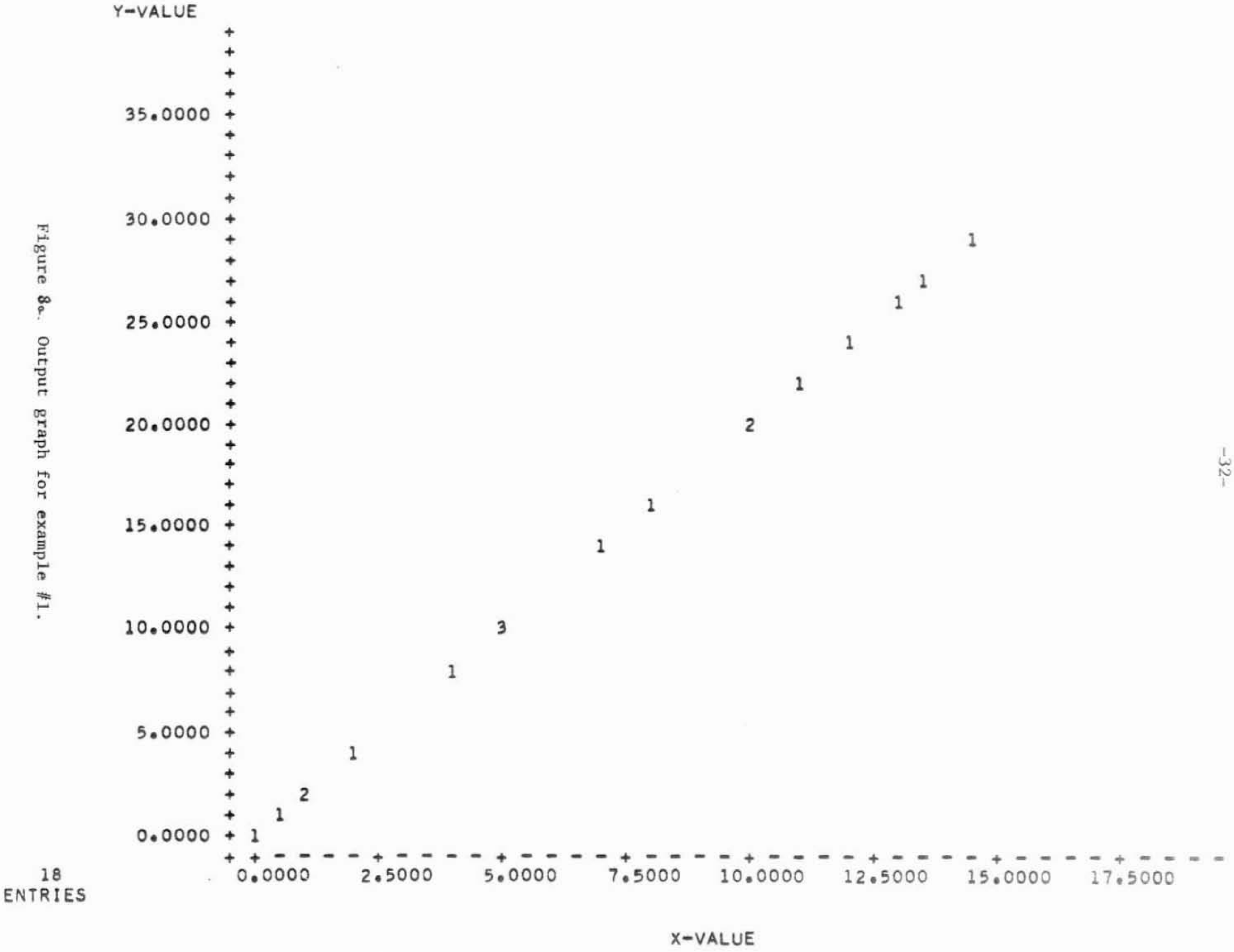

Figure 8a. Output graph for example #1.

4 POINT(S) BEYOND THE SCALE LIMITS,
AND THEREFORE TRUNCATED OR OMITTED FROM THE GRAPH.

Figure 8b. Supporting information printed for example #1.

IX. EXAMPLE #2: HISTOGRAM

Assumed data

Suppose that we have 75 observations on a single variable. The measurements are only to the nearest unit, so that there are no decimal places. Five observed values are punched on each card; each observed value being allotted a field of five columns in which it is right justified. The first value on a card occupies columns 1 through 5, and five blank columns separate adjacent fields. The data and the layout on the cards are shown in Figure 9.

Purpose

Our purpose is to construct a histogram of these data. A set of two dashes (minus signs) should mark the top of a column, and the column should be shaded below with sets of two dots (decimal points or periods). We choose 0. as the midpoint of the lowest interval on both scales, and 1.0 as the scale interval on both scales. Again, we want the smaller size of graph, and do not require any duplicate printouts. As before, the code number of the line printer on the IBM 1130 system is 3 .

Main program

The main program appropriate for this case is shown in Figure 10. It is only necessary for the program to read X-values since we are dealing with a single variable which is to appear on the horizontal axis; however, the "Y(20)" must still appear on the DIMENSION card.

Control cards

The coding for the control cards is illustrated in Figure 11. Blank cards are simply inserted in the places of the SYMBOLB and SYMBOLC control cards.

Results

The histogram produced by the computer for this example run is shown in Figure 12. In this case, the zero line on the vertical axis is superfluous and might better be deleted by using 1.0 as the midpoint of the first interval on the frequency scale. With frequency scale intervals greater than one, it is advisable to include zero in the first interval. A zero frequency (or no observations for a given interval) will then be indicated by a blank at the corresponding position in this first line.

Column number

02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

25	25	25	25	25
25	25	25	25	25
25	25	25	25	25
25	25	25	25	25
10	10	10	10	10
15	15	15	15	15
1	1	2	2	3
3	4	4	5	5
20	20	20	20	20
20	20	20	20	20
30	30	30	30	30
30	30	30	35	35
35	35	35	35	35
35	35	35	35	35
35	35	35	35	35

Figure 9. Assumed data for examples #2 and #3.

Column number

02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

```
      DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
      IC(1)=1
      GØ TØ 4
    1 IF(IC(7)-1)2,5,2
    2 NI=IC(2)
      READ(2,3)(X(I),I=1,NI)
    3 FØRMAT(5(F5.0,5X))
    4 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
      IC(1)=2
      GØ TØ 1
    5 CALL EXIT
      END
```

Figure 10. Main program for examples #2 and #3.

Control card	Column number 02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80
SYMBOLA	--..
SYMBOLB	
SYMBOLC	
XTITLE	ØBSERVED VALUE
YTITLE	FREQUENCY
OPTION	0.0 1.0 0.0 1.0 99999. 05 1 3 1 1
STOP	99999

Figure 11. Control cards for example #2.

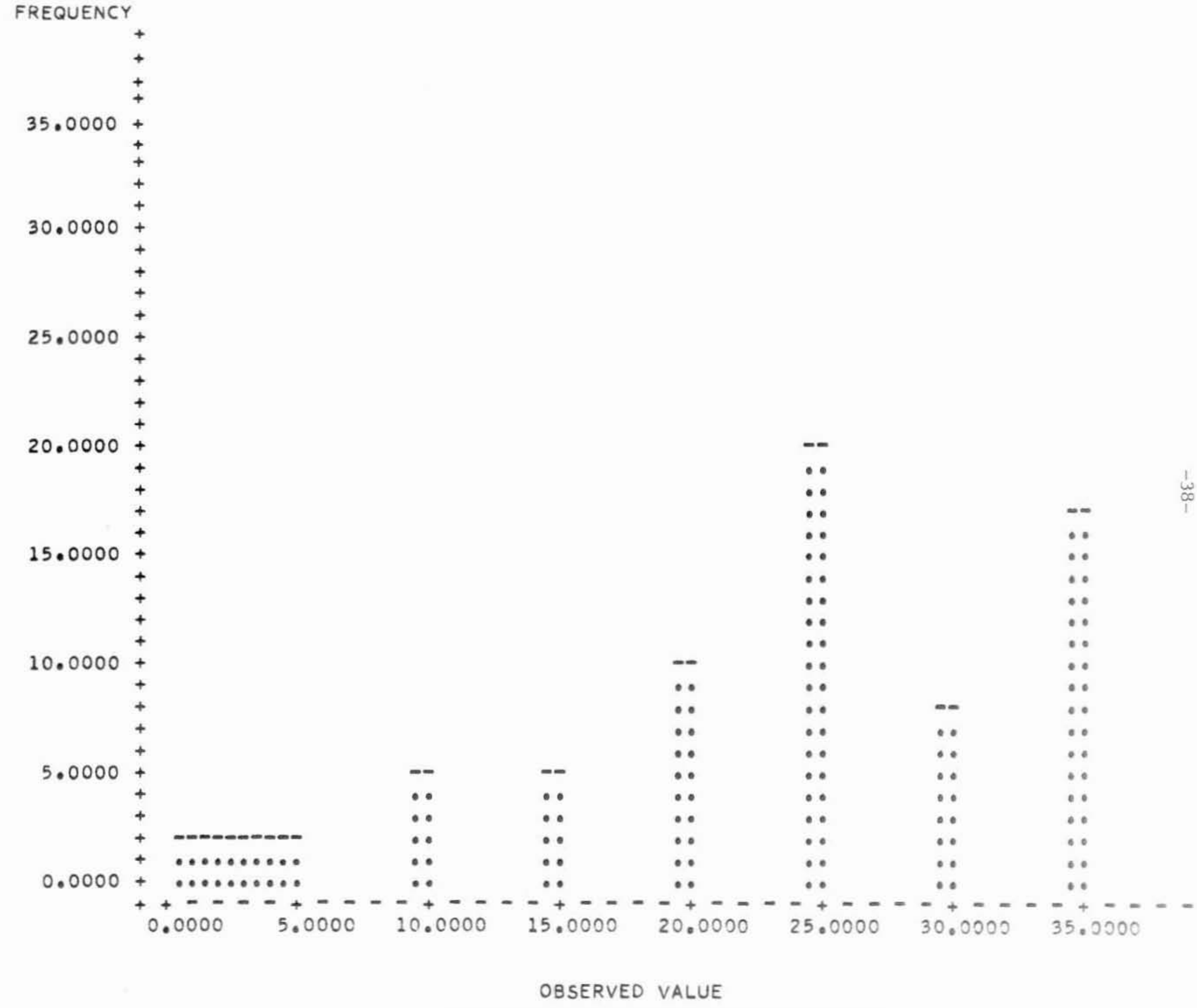

Figure 12. Histogram produced by the computer for example #2.

X. EXAMPLE #3: CUMULATIVE FREQUENCY DISTRIBUTION

Assumed data

We use the same data as for example #2 (Figure 9).

Purpose

Our purpose is to construct a cumulative frequency distribution by using the data from example #2. We will use an asterisk (*) as our plotting symbol, and there will be no shading below. Also, we shall use 2.0 as the scale interval on the vertical axis (frequency scale). All other specifications remain the same as for example #2.

Main program

No change is required in the main program (Figure 10).

Control cards

The coding for the control cards is shown in Figure 13. Again, the SYMBOLB and SYMBOLC control cards are blank.

Results

The results of running example #3 on an IBM 1130 computer are shown in Figure 14. We note that using a frequency scale interval of 2.0 and leaving column 53 of the OPTION control card blank effectively makes the numbers printed on this scale lower limits of the frequency classes. This is the result of including the upper limit of the class and excluding the lower limit when the numbers can assume only integral values.

Column number	02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80
Control card	
SYMBOLA	*
SYMBOLB	
SYMBOLC	
XTITLE	ØBSERVED VALUE
YTITLE	CUMULATIVE FREQUENCY
OPTION	0.0 1.0 0.0 2.0 99999. 05 2 3 1 1
STOP	99999

Figure 13. Coding of control cards for example #3.

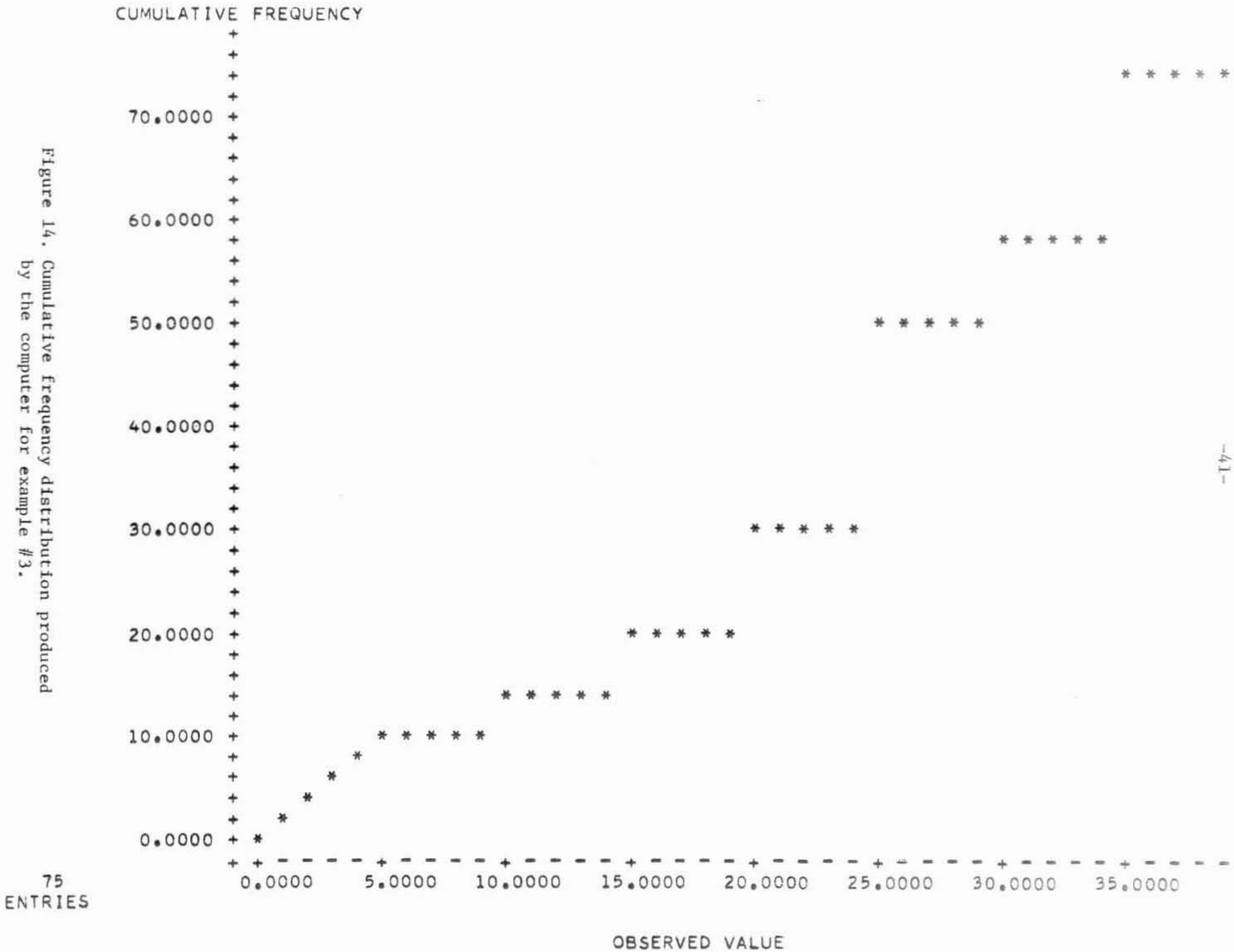

Figure 14. Cumulative frequency distribution produced by the computer for example #3.

XI. EXAMPLE #4: CONTINGENCY TABLE

Assumed data

Assume that 20 subjects have been classified with respect to two attributes, which we call attribute A and attribute B. Assume further that there are two categories for each attribute, coded respectively as 1 and 2 . The classification data for each subject have been punched on a card with the code for attribute B in column 5 and the code for attribute A in column 10. These hypothetical data cards are illustrated in Figure 15.

Purpose

Our purpose is to fill in the cells of a 2 x 2 contingency table corresponding to these data. Attribute A is to be arrayed along the left margin and, therefore, corresponds to an ordinate or Y-value. Attribute B is to be arrayed along the lower margin and, thus, corresponds to an abscissa or X-value. The number 1 is appropriate for the midpoint of the lowest scale interval along both margins, since this is the code for the first category of both attributes. We want the code number 2 to be printed below (or beside) the frequency for the second category of both attributes. Since the program prints only every fifth scale value, we should be able to achieve this by using a scale interval of .2 for both margins. The program will give the cell frequencies and the total frequency, but the other marginal frequencies must be calculated manually from the cell frequencies. Also, frequencies over 99 cannot be printed in the table, but a list of such frequencies (if any) would precede the first copy of the table.

Main program

The main program appropriate for example #4 is shown in Figure 16.

Control cards

The coding for the control cards is illustrated in Figure 17. Note that these control cards would cause any zero frequencies in the table to appear as blanks.

Results

The output of an IBM 1130 computer, for example run #4, is shown in Figure 18.

Column number	02	04	06	08	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80
			1		1																																			
			2		2																																			
			1		2																																			
			1		1																																			
			2		1																																			
			2		1																																			
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			2		1																																			
			1		1																																			
			1		1																																			
			1		2																																			

Figure 15. Assumed data for example #4.

Column number 02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

```
        DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
        IC(1)=1
        GØ TØ 4
      1 IF(IC(7)-1)2,5,2
      2 NI=IC(2)
        READ(2,3)(X(I),Y(I),I=1,NI)
      3 FØRMAT(4X,F1.0,4X,F1.0)
      4 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
        IC(1)=2
        GØ TØ 1
      5 CALL EXIT
        END
```

Figure 16. Main program for example #4.

```
Column
number          02040608101214161820222426283032343638404244464850525456586062646668707274767880

Control
 card

SYMBOLA      1 2 3 4 5 6 7 8 910111213141516171819202122232425262728293031323334353637383940
SYMBOLB     41424344454647484950515253545556575859606162636465666768697071727374757677787980
SYMBOLC     81828384858687888990919293949596979899  ..
XTITLE                         ATTRIBUTE B
YTITLE               ATTRIBUTE A
OPTION            1.0       0.2       1.0       0.2        9.    01   3  3  1  1
STOP            9
```

Figure 17. Coding of control cards for example #4.

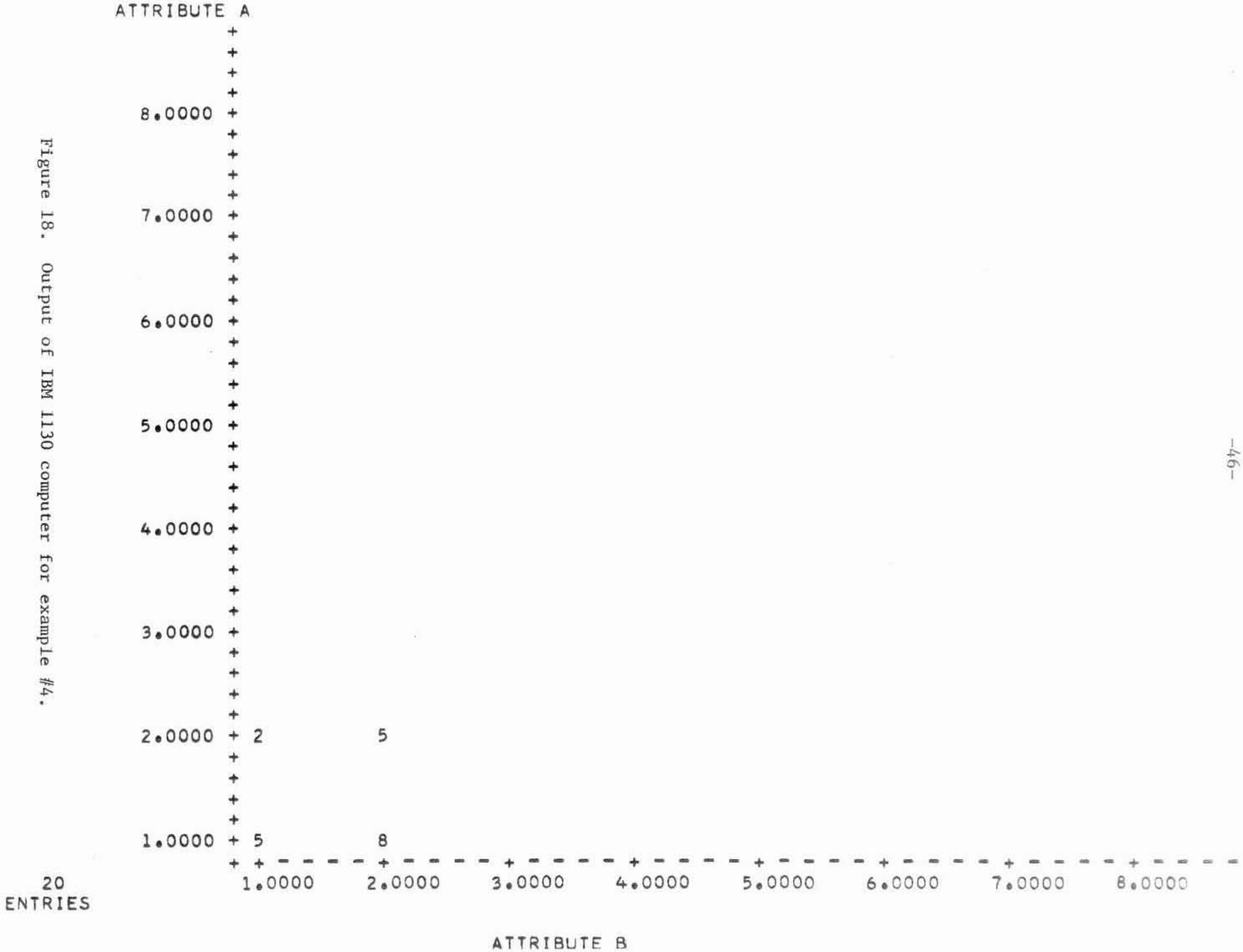

Figure 18. Output of IBM 1130 computer for example #4.

XII. EXAMPLE #5: PLOTTING A FUNCTION

Assumed data

No input data are required.

Purpose

Our purpose is to plot the area of a circle in square feet as a function of the diameter in inches. The midpoint of the first interval on both scales will be 0.0 . The scale interval for diameter will be .5 inch. The scale interval for area will be .1 square foot. An asterisk (*) is the symbol to be used in plotting the function.

Main program

The appropriate main program is shown in Figure 19.

Control cards

The coding for the control cards is shown in Figure 20. The SYMBOLB and SYMBOLC control cards are blank. In this case, the STOP control card is omitted entirely since the number in columns 41 through 50 of the OPTION card is sufficient to signal the end of the operation.

Results

The graph produced by the computer for example #5 is shown in Figure 21. The apparent discontinuities are due to plotting a continuous function in discrete intervals.

Column number

02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

```
      DIMENSIØN A(18),B(18),X(20),Y(20),IA(50,50),IB(101),IC(10)
      IC(1)=1
      N=0
    1 CALL PLØT(A,B,X,Y,C,D,E,F,G,H,IA,IB,IC)
      IC(1)=2
      IF(IC(7)-1)2,6,2
    2 DØ 3 I=1,10
      X(I)=C+N*D
      Y(I)=.005454154*X(I)*X(I)
    3 N=N+1
      IF(N-IC(5))5,5,4
    4 X(1)=G
    5 GØ TØ 1
    6 CALL EXIT
      END
```

Figure 19. Main program for example #5.

Column number	02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80
Control card	
SYMBOLA	*
SYMBOLB	
SYMBOLC	
XTITLE	DIAMETER ØF CIRCLE (INCHES)
YTITLE	AREA (SQ. FT.)
OPTION	0.0 0.5 0.0 0.1 50. 10 3 3 1 1

Figure 20. Coding of control cards for example #5. Note that the STOP control card is omitted.

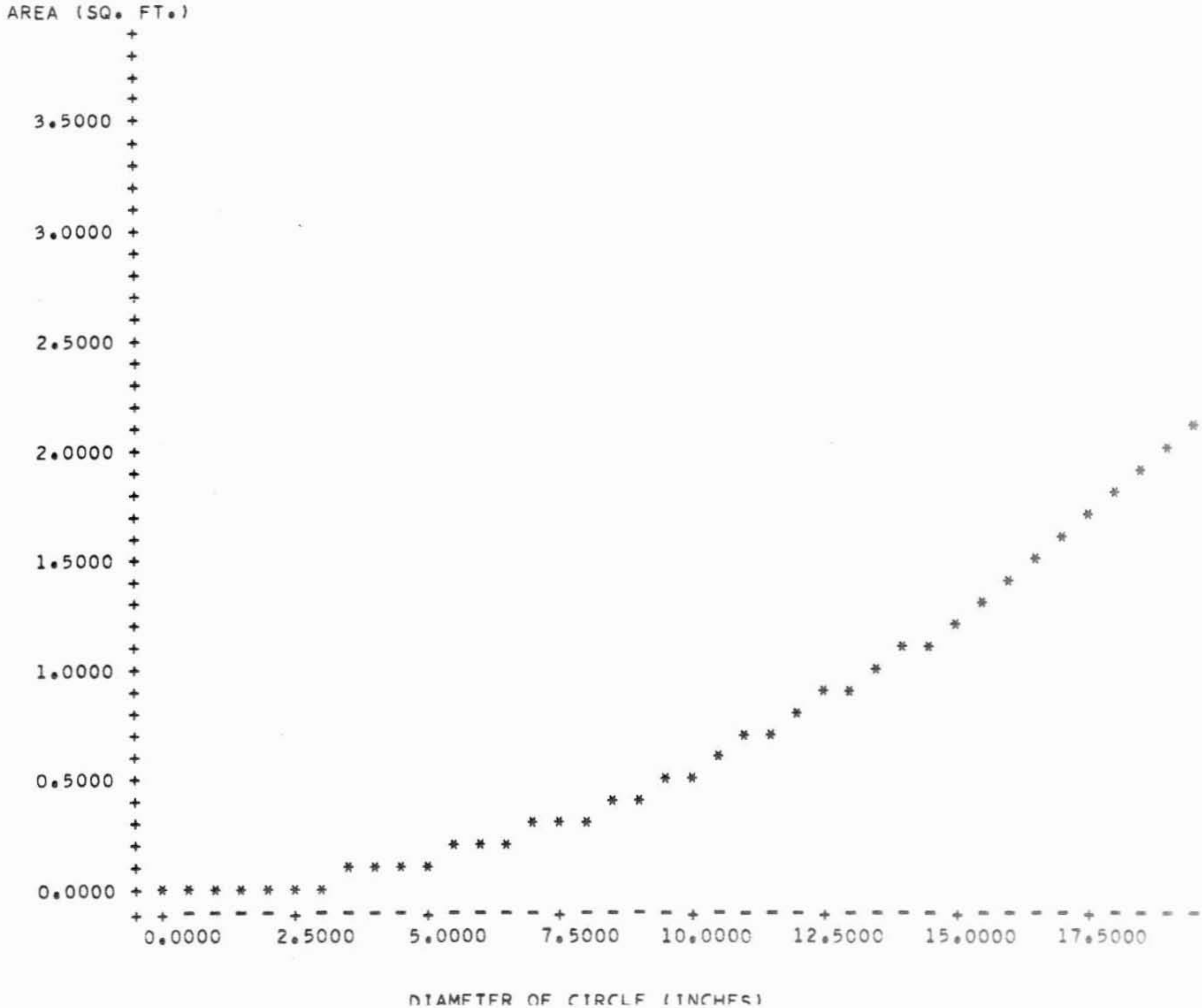

Figure 21. Computer output for example #5.

XIII. STORAGE REQUIREMENTS, TIMING, AND PRECISION

All information given in this section applies to the IBM 1130 version II monitor system using the one word integers and extended precision features of the FORTRAN compiler.

Core storage requirements (in terms of 16-bit words) for SUBRØUTINE PLØT are as follows: variables = 52, program = 2372. All of the example main programs require 2862 words for variables, and 130 words or less for program. Storage requirements for another computing system may differ considerably from these figures because the one word integers feature of the IBM 1130 FORTRAN compiler reduces the storage requirements, whereas the necessity of storing the set of subroutines for real arithmetic increases the requirements.

The IBM 1130 system did not provide a printed record of processing times. Furthermore, with an IBM 1132 printer, compilation time is highly dependent on whether or not a listing is required. After SUBRØUTINE PLØT had been stored in object form on disk, the time required to compile a main program and process an example ranged from 2 to 3 minutes. Approximately 1 minute of this was taken to load the object form of the subroutine into core from the disk. These times may seem long in comparison to IBM 360 system speeds, but the cost of the IBM 1130 is proportionately low.

Especially with an IBM 1130 computing system, it is advisable always to use extended precision for real variables. On such a system, extended precision provides three 16-bit words for each real variable, thus increasing the number of significant digits from 7 to 10.

REFERENCE

Louden, Robert K. 1967. Programming the IBM 1130 and 1800. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 433 p.

APPENDIX: SIMPLE FORTRAN FORMATS

A FØRMAT is a non-executable FORTRAN program statement which describes the type, form, and positioning of data to be read, punched, or printed by a computer. The general layout of a FØRMAT card is as follows:

Columns	Information
1	Leave this first column of the FØRMAT card blank. For the sake of completeness, it should be noted that the FØRMAT identification number described next is allowed to extend into column 1 under most circumstances. To avoid consideration of the special conditions which can arise, however, it is preferable to avoid using this column.
2 through 5	This is an integer number, i.e., no decimal point, which identifies the particular FØRMAT statement. Leading zeros do not have to be punched, and the positioning of the number is not critical. Thus, a two-digit number could occupy columns 2 and 3, 3 and 4, or 4 and 5. However, the neatness and readability will be enhanced if all FØRMAT statements in a program have the last digit of their identifying number in the same column.
6	The number in this column is called a continuation code number. Column 6 of the first card in a FØRMAT statement may either contain a zero or be left blank. Column 6 of any additional cards must contain one of the digits 1 through 9. The order of numbers in column 6 of cards within a FØRMAT statement does not necessarily have to correspond with the position of the cards in the statement; however, interpretation is simplified if this convention is adopted.
7 through 13	FØRMAT(
14 through 72	These columns contain field descriptions, commas, slashes, or parentheses. These are the working elements of the FØRMAT statement. Their uses are explained below. The FØRMAT statement must always end with a right parenthesis in one of these columns.
73 through 80	The computer completely disregards any information which is placed in these columns.

The term "field" designates a set of adjacent columns on the input or output medium, whether it be cards or the printed page. A generalized field description can be represented as follows:

rπc.d

where:

r (meaning "repeat") is the number of times the current field description is to be used before the next one is considered.

π is a code letter designating the type of information which the field contains. This code letter is the primary component of the field description, the other components serving as modifiers. Certain ones of the modifiers are omitted, depending on the code letter; however, a code letter must always be present in a field description.

c (meaning "columns") is the total number of columns in the field, including an allowance for sign and/or decimal point if required.

d (meaning "decimal places") is the number of decimal places in the field, not counting the decimal point itself. Whenever the d modifier is present in a field description, it must be preceded by a decimal point as indicated in the general form above.

The field descriptions are separated from each other by commas. Several code letters for different types of fields are available; however, one can usually operate satisfactorily with the following five: I, F, A, H, and X. The details regarding purposes and uses of these codes are as follows:

Code	Purpose
I	This code signifies that the field contains an integer number. An integer number cannot contain any fractional part or decimal point, therefore, the d modifier and its preceding decimal point are always omitted from an I-field description. In addition, the r modifier may be omitted if the field description is not to be repeated before the next description is considered.
F	This code indicates that the field contains a number which either does or could contain a decimal point. The F-field description requires all modifiers, except that the r modifier may be omitted if the field description is not to be

Code	Purpose
F (cont'n)	repeated before the next one is considered. If data are being printed or punched, one column will be taken up by a decimal point with d decimal places following the decimal point. The decimal places will always appear as far to the right as possible in the field. A number so positioned is said to be right justified. When data are being read from cards, the d modifier covers the case where no decimal point is punched but the last d columns in the field are to be interpreted as decimal places. A decimal point actually punched anywhere in the field on the data card will completely override the d modifier.
A	This code signifies that the field contains alphameric information. Letters, numbers, and punctuation marks are all included under the term alphameric; however, numbers read under this designation cannot be used in arithmetic operations. This code is primarily useful for manipulating names and titles which are to be read from data cards. The d modifier and its preceding decimal point are always omitted from A-field descriptions. Unless one is familiar with the particular computer being used, it is safest to make the c modifier no larger than 2 . This may frequently be wasteful of computer storage, but should avoid the possible omission of some characters. The r modifier may be omitted if the field description is not to be repeated.
H	The H code is used to specify carriage control (explained later) and to transmit alphameric information to or from the FØRMAT statement itself. The H code is basically a single column operator, and, therefore, both c and d modifiers with their intervening decimal point are always omitted. On input, the characters in the next r columns will be inserted into the FØRMAT statement immediately after the H. On output, except for carriage control, the r characters immediately following the H will be punched or printed just as they appear in FØRMAT statement.
X	This code indicates that a column on the input or output medium is to be skipped. The X code is basically a single column operator and, therefore, both the c and d modifiers with their

Code	Purpose
X (cont'n)	intervening decimal point are always omitted. The r modifier indicates the number of columns that are to be skipped before the next field description is considered.

A / is inserted in the FØRMAT statement whenever the computer is to skip the remainder of the current line or card and proceed to the first column of a new line or card. Commas before and after a / are optional. If the FØRMAT controls a printing operation, a carriage control character must be provided for the new line. It also is possible to repeat a group of field descriptions by enclosing the group in parentheses and placing an r modifier before the left parenthesis.

Up to this point, carriage control characters have been mentioned without explanation. If output is the printed page, the computer must know where the line is to be placed in relation to the last line printed. To specify this, an H code with r modifier equal to 1 is placed at the beginning of the FØRMAT statement and after each transfer to a new line. The character following the H is called a "carriage control character" and determines the spacing between lines. If the number 1 follows the H, printing will begin at the top of a new page. The number 0 causes a double space, and a blank causes a single space. Other carriage control characters are available, but usually will not be needed.

In operation, a FØRMAT statement functions as follows. Each input or output statement in the program specifies a list of items to be transmitted and the number of a FØRMAT statement which is to control the transmission of the information. All columns of the cards or lines involved must be accounted for in the FØRMAT statement up to the point where transmission stops. The computer starts at the left of the next available card or line of the input or output medium. The field descriptions in the FØRMAT statement are used in order from left to right until no further items of information remain to be transmitted. If the last field description is used before transmission is completed, the computer goes to a new line or card on the input or output medium and then returns to the nearest left parenthesis in the FØRMAT statement. The field descriptions after this parenthesis are again used in order from left to right until all items in the list have been transmitted or the last field description is again encountered. In the latter case, the above process is again repeated, etc.

A complete understanding of FØRMAT statements requires some knowledge of FORTRAN input/output statements and variable types, which are not discussed here. However, a common problem is to apply an existing program to data which meet all of the requirements of the program except that they are not positioned properly on the data cards.

If the new data occur in the same order on the cards as the original data, it is only necessary to alter the appropriate FØRMAT statements by changing the modifiers of the I- and F- field descriptions and inserting or removing X codes or / 's as required. If the items of data do not occur in the proper order, it also is necessary to reorder their names in the READ statements and their corresponding field descriptions in the FØRMAT statements.

For example, suppose that the relevant statements in the original program are as follows:

```
(Col. 7)
    '

      READ(3,1)(JF(I),Z(I),Y(I),I=1,NI)

    1 FØRMAT(I5,5X,F10.5,10X,F10.5)
```

This set of statements specifies that three items of data are to be read from each data card. The first item, named JF, can never have any fractional part; for example, it might be a frequency. This datum occupies columns 1 through 5 of each card. Columns 6 through 10 of the card do not contain relevant information. The second datum, named Z, occupies columns 11 through 20 of the card. If no decimal point is punched, columns 16 through 20 are to be interpreted as decimal places. Columns 21 through 30 do not contain relevant information. The third datum, named Y, occupies columns 31 through 40 and is similar in form to the second. The READ statement given above also specifies that NI cards will be read each time the statement takes effect. We do not need to worry about the actual value of NI since it is determined elsewhere in the program.

Now suppose that we wish to adapt this program to a new set of data which has the following characteristics. Each value of the variable represented by JF now occupies columns 8 through 10 and is the only item on the card. The values of Z and Y which would have appeared on the card under the original scheme now appear on a second card. The value represented by Z appears in columns 6 through 10, with columns 9 and 10 being decimal places. Columns 11 through 20 do not contain relevant information. Finally, the value of Y appears in columns 21 through 30. This value of Y is recorded only to the nearest unit so that there are no decimal places. Since the items of data occur in the same order as before, the READ statement does not require revision. The appropriate revision of the FØRMAT statement is:

```
(Col. 7)
    '

    1 FØRMAT(7X,I3/5X,F5.2,10X,F5.0)
```

Under this new scheme, NI sets of two cards will be read each time the READ statement takes effect. The value of JF for a given case will be taken from the first card, and the corresponding values of Z and Y will be taken from the second card. Note that the F-field designation is retained for the variable Y even though no decimal places are recorded. The program will not function properly unless the original code letters are retained.

As a further illustration, suppose that the new data set differs from that just described only in having the positions of the Z and Y fields interchanged, so that Y precedes Z on the second card. The corresponding interchanges required in the READ and FØRMAT statements are as follows:

```
(Col. 7)
    '
      READ(3,1)(JF(I),Y(I),Z(I),I=1,NI)

    1 FØRMAT(7X,I3/5X,F5.0,10X,F5.2)
```