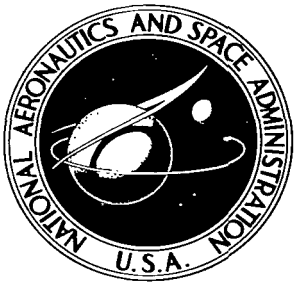
NASA TECHNICAL NOTE

NASA TN D-2174



NASA TN D-2174

AN OPTIMIZED PRINTER PLOTTING SYSTEM CONSISTING OF COMPLEMENTARY 7090 (FORTRAN) AND 1401 (SPS) SUBROUTINES

PART I - INSTRUCTIONS FOR USERS

by Lois T. Dellner and Betty Jo Moore

Lewis Research Center
Cleveland, Ohio

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1964

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SUMMARY

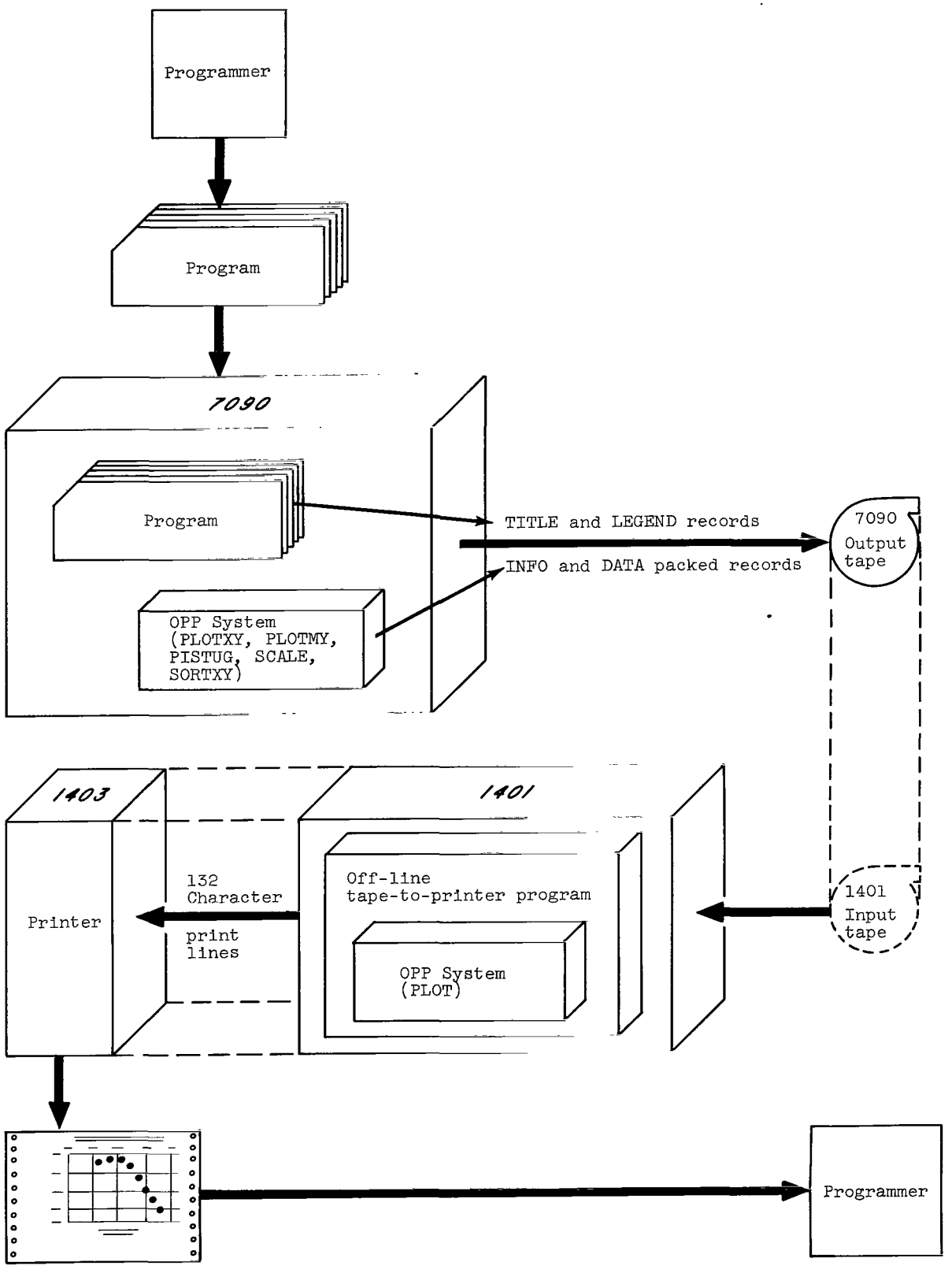
Complementary subroutines for the IBM 7090 and 1401, easy for the FORTRAN programmer to use, provide printed plots as part of the normal off-line output. These subroutines are simplified so that no choices must be made and generalized so that choices may be made, by the programmer, of the plotting characters, the scales, the appearance of the grid, the number of curves, and other options. The 7090 routines write information-packed records that are decoded and used by the 1401 routine to produce the plot at full printer speed (6 sec/page). Part I contains a general description of the system and is intended as a manual for the user. Part II (Technical Note D-2175) is a manual for the systems programmer.

INTRODUCTION

With the increased use of digital data computing systems for engineering calculations, a fast, efficient method of plotting computer output has become a necessity. An inexpensive way of obtaining printed plots from a 7090-1401 computer system is described herein. This method makes use of the printer attached to the 1401 computer as the plotter. Also contained in this report are 12 figures as examples of the plots obtainable using the OPP system (Optimized Printer Plotting).

This system, a set of complementary subroutines for the IBM 7090 and 1401, is a simple-to-use system that requires minimum storage, reduces 7090 execution time (by a factor of more than 10 from that required by presently available machine plotting methods), and produces printed plots at full printer speed (6 sec/page) as part of normal off-line output. This optimization is achieved by combining three techniques: (1) performing most of the requisite arithmetic on the 7090, (2) packing the results on the output tape, (3) having the 1401 generate the grid and the grid labels, as well as position the points in a subroutine of the standard tape-to-printer program. (See flow chart on p. 2)

The system permits, but does not require, the programmer to choose the plotting characters, the scales, the grid-line spacing, etc. It handles single


Programmer
Program
7090
Program
OPP System
(PLOTXY, PLOTMY,
PISTUG, SCALE,
SORTXY)
TITLE and LEGEND records
INFO and DATA packed records
7090
Output
tape
1403
1401
Printer
132
Character
print
lines
Off-line
tape-to-printer program
OPP System
(PLOT)
1401
Input
tape
Programmer

or multiple curves, prints true scales, and prints titles either above or below the plot.

The chief advantages of OPP-system plotting over manual plotting are the complete elimination of elapsed time and the reduction of the cost per plot by a factor of at least 50. Even when the limitations of the printer - 10 characters per inch horizontally (to a maximum of 100) and 6 characters per inch vertically - make a printed plot inadequate for a particular application, a printed plot aids the manual plotter by supplying a guide to the scales and the minimum number of points required to define the curve.

More than 150 programmers are now using this system effectively, and more than 500 plots are printed weekly. The entire plotting system has been in use at this Center on the 7090-1401 since April 1962. The 1401 routine, PLOT, is written for a 4K machine.

GENERAL DESCRIPTION

The OPP system offers the programmer plotted output with a minimum of effort. After writing a title for his plot on the output tape, he writes CALL PLOTXY (for single curve) or CALL PLOTMY (for multiple curves). The arguments, or call list, include the names of the arrays to be plotted and specify the number of points per curve and the number of curves. The programmer then writes a legend to be printed at the bottom of the plot.

The plot or plots are printed as part of the regular output listing with no delay. No changes in his card-handling procedures nor special instructions for the operators are required.

If he is using PLOTXY, the values of the variable to be plotted in the x-direction must be in sequence. If they are not, the subroutine SORTXY (which makes the necessary rearrangement) is supplied to be used before calling PLOTXY. For either PLOTXY or PLOTMY, if the size of the elements in (or the total range of) any array is not known to be within certain limits, the programmer calls the subroutine SCALE for each array before calling the plotting subroutine. SCALE will transform the array to suit PLOTXY and PLOTMY only if it is necessary.

In addition to the minimum-effort use just described, the programmer may choose to use one or more of several options that permit him to control, for example, the appearance of the grid (by specifying the frequency of the grid-lines in either direction), the scale for either variable (by specifying the scale-factor and a starting-value), the plotting character, etc.

This presentation of the OPP system is in two sections, Parts I and II. Part I (this report) provides detailed instructions for the use of PLOTXY and PLOTMY and brief descriptions of the auxiliary routines SCALE and SORTXY. A section on debugging incorporates some of the knowledge gained from a year's experience with the system. Figures 1 to 12 illustrate some of the possibilities of the system.

Part II (ref. 1) is a manual for the systems programmer who implements and possibly modifies the system and then must help debug the users' programs.

USING THE SYSTEM

I. PLOTXY

To get plotted output using PLOTXY, the corresponding pairs of ordinates to be plotted must be in two arrays. For an example, let us name the arrays XDOWN and YACROS and assume each is NPTS elements long. These names are chosen specifically to call the user's attention to the fact that the "x-direction" is down the page.

A. Title

The call for PLOTXY must be preceded by writing at least one TITLE (PT) record. The minimum requirement is:

```
      WRITE OUTPUT TAPE 6, 500
  500 FORMAT(2HPT)
```

A more representative example is:

```
      WRITE OUTPUT TAPE 6, 500
  500 FORMAT (2HPT, 73X, 14HSAMPLE EXAMPLE/2HPT, 72X,
     16H OPP SYSTEM PLOT)
```

The result is shown on the plot on the facing page.

B. Legend

The call for PLOTXY must be followed by writing at least one LEGEND (PL) record. The minimum requirement is:

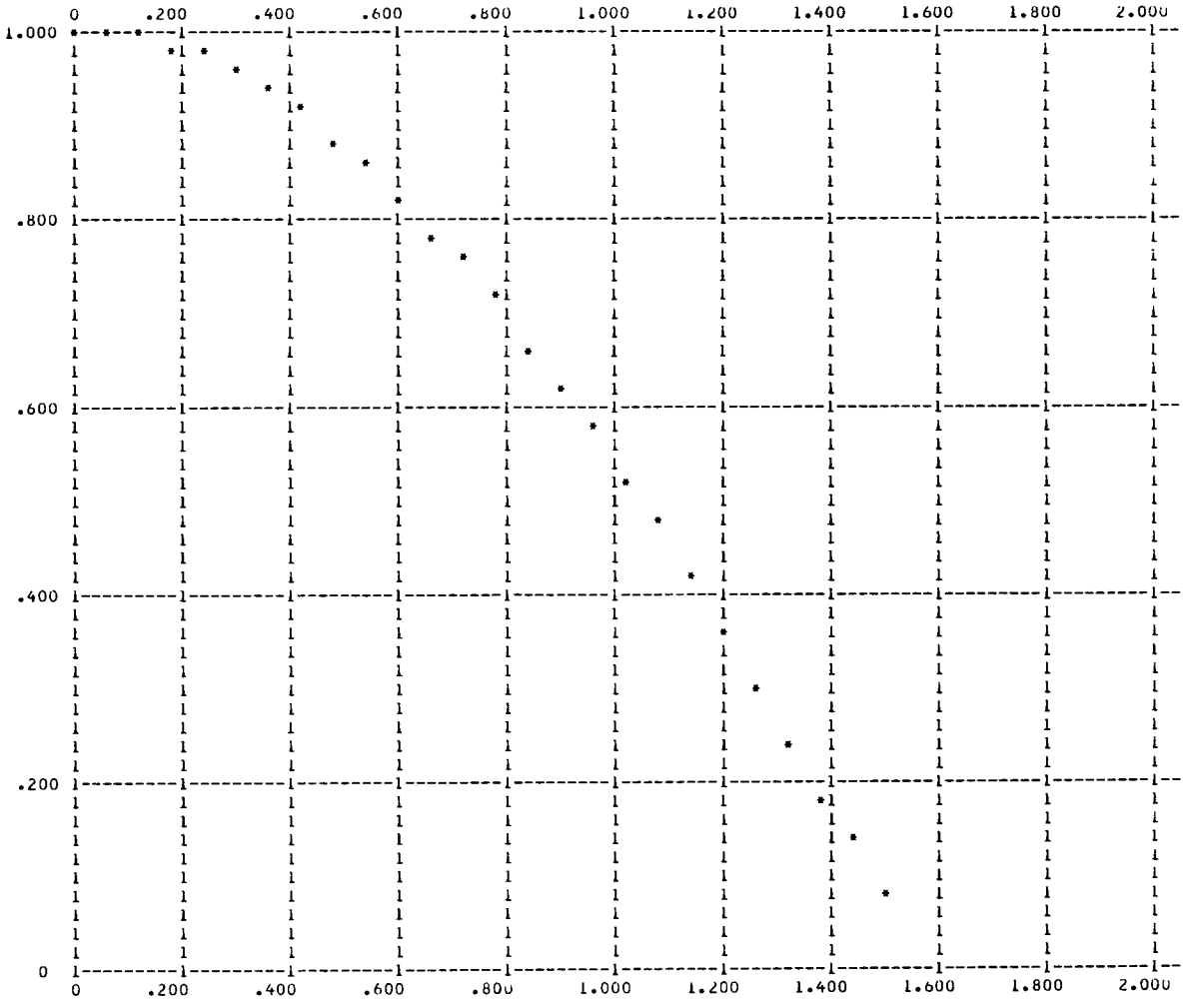
```
      WRITE OUTPUT TAPE 6, 502
  502 FORMAT(2HPL)
```

A more representative example is:

```
      WRITE OUTPUT TAPE 6, 502
  502 FORMAT (2HPL, 72X, 16HF SUB2 VS. THETA/2HPL, 72X,
     16H(---)      (RAD))
```

The result is shown on the plot on the facing page.

SAMPLE EXAMPLE
OPP SYSTEM PLOT



F SUB2 VS. THETA
(---) (RAD)

C. Call

Between writing the TITLE and LEGEND records, you write

CALL PLOTXY (XDOWN, YACROS, KODE, P)

XDOWN is the name of the array containing the values of the variable to be plotted on the x scale (down the page). The elements in the array are restricted as follows:

1. They must be in floating point.

2. The absolute value of each element must[1] be within permissible limits (approx. $10^{-6} \leq e \leq 10^{6}$).

3. They must[2] be in order, either increasing or decreasing.

YACROS is the name of the variable to be plotted on the y scale (across the page). The elements of the array are restricted exactly as in 1. and 2. above.

KODE is the name of an integer. Many options are provided for the user of PLOTXY. Each has a number associated with it. The sum of the numbers representing the options being used is KODE ($0 \leq$ KODE ≤ 127). For your first plot, use KODE = 0. When KODE = 0, the starting-values and scale-factors in both directions are computed by PLOTXY. The other effects of KODE = 0 are shown in the example plot:

1. The plotting character is an asterisk.

2. The grid-line frequency is 10 × 10.

3. Nothing is printed to the left of the plot.

P is an array.

P(1) must contain NPTS (the number of points to be plotted) in floating point.

If KODE = 0 or 64, there are no other requirements for P.

For all other values of KODE, the requirements for the P array are displayed in Section D. - Using the Options.

---

[1]If the element size of any array is unknown or out of range, write CALL SCALE (NPTS, A, KA) before calling PLOTXY. (See p. 12.)

[2]If the array to be plotted on the x scale is not in order, write CALL SORTXY (XDOWN, YACROS, NPTS) before calling PLOTXY. (See p. 12.)

D. - Using the Options

Each option has a number associated with it. The sum of the numbers representing the options chosen is KODE, the third argument in the call.

TO CHOOSE:	TO KODE ADD	AND SUPPLY	IN	(FORMAT)	KODE 0 USES
The plotting character. θ represents any acceptable FORTRAN character except the minus sign.	1	Desired character	P(2)	1Hθ	*
The frequency of x grid-lines. They are printed every m line-spaces below the first. If m = 0, only two will be printed, one above and one below the plot.	2	m	P(3)	Floating point	10
The frequency of y grid-lines. They are printed every n positions to the right of the first. If n = 0, only one is printed, at the left of the plot.	4	n	P(4)	Floating point	10
The x scale. The scaling parameters, FX, representing the starting-value, and DX, representing the scale-factor for one line space, must be whole numbers of magnitude less than 10^6. ($0 \leq KSX \leq 6$) See I.-E. - Scaling.	16	Three scaling parameters, KSX, FX, and DX	P(6), P(7), P(8)	Floating point	Scale computed by plotting routine
The y scale. The scaling parameters, FY, representing the starting-value, and DY, representing the scale-factor for one print position, must be whole numbers of magnitude less than 10^6. ($0 \leq KSY \leq 6$) See I.-E. - Scaling.	32	Three scaling parameters, KSY, FY, and DY	P(9), P(10), P(11)	Floating point	Scale computed by plotting routine
To print P array. The 6 BCD characters in P(I+11) will be printed at the left of the plot on the line on which the point (x_1, y_1) is plotted. (If desired material is numeric, write it out using format F6.n, and read it back into P array using A6.)	8	6. and array to be printed	P(5) and P(I+11) through P(NPTS+11)	Floating point; BCD	No print-out
To print coordinates. The coordinates of each point will be printed on the line on which the point is plotted.	64	No requirements			No print-out

E. Scaling

When the user wishes to specify his own scale in either direction, in addition to increasing KODE by 16 or 32, he must:

1. Choose his desired starting-value, F.

2. Choose his desired scale-factor, D; for one line-space if he is specifying the x scale, for one print position if he is specifying the y scale.

3. Determine a value of N such that:

   a. $F \times 10^N$ is a whole number.

   b. $D \times 10^N$ is a whole number.

   c. $0 \leq N \leq 6$.

4. Compute 6 - N.

The integer calculated in step 4. is the first of three scaling parameters that must be available in the P array (in P(6) if scaling x, P(9) if scaling y) when the plotting subroutine is called. $F \times 10^N$ is the second scaling parameter, to be placed in P(7) or P(10). F may be zero. $D \times 10^N$ is the third, and is placed in P(8) or P(11). Note that D may never be zero, and when scaling x for PLOTMY, D must be positive.

II. PLOTMY

Although more than one curve can be plotted on the same grid with PLOTXY, only one plotting character will be used for all curves. PLOTMY provides a different plotting character for each curve. Options, similar to those in PLOTXY, are available but not required, except that option 1 must be used if there are more than six curves. However, a selection must be made from three Variations; DUPX - when more than one set of y values corresponds to the same set of x values; DUPY - when more than one set of x values corresponds to the same set of y values (this offers complete control of which variable is to be plotted in which direction); and NO DUP - when each set of x values has a corresponding set of y values.

A. Title

A TITLE record must be written before calling PLOTMY, exactly as for PLOTXY.

B. Legend

A LEGEND record must be written after calling PLOTMY, exactly as for PLOTXY.

C. Call

Between writing the TITLE and LEGEND records, you write:

```
CALL PLOTMY (XDOWN, YACROS, KKK, P)
```

XDOWN is the name of the array containing the values of the variable to be plotted on the x scale (down the page). The minimum DIMENSION of this array depends on the Variation selected. (See E. - Variation Layout.) The elements of this array are destroyed by PLOTMY. The elements are restricted as follows:

1. They must be in floating point.

2. They must be within permissible range. (See I. - PLOTXY.)

YACROS is the name of the array containing the values of the variable to be plotted on the y scale (across the page). The minimum DIMENSION of this array depends on the Variation selected. (See E. - Variation Layout.) The elements of this array are restricted exactly as in 1. and 2. above.

KKK is the name of an array. The first element must be KODE (as in PLOTXY, this is the sum of the option numbers), and the second element must be KN (the number of curves). The third element must be:

1. The number of points in one curve for DUPX and DUPY.

2. The number of points in the first curve for NO DUP.

The remaining odd-numbered elements are only required for NO DUP, and the remaining even-numbered elements are only required for option 1. (See E. - Variation Layout.) The minimum DIMENSION of KKK is 2*KN+2 or 14, whichever is greater.

P is the name of an array. The first element must specify the Variation selected:

P(1) = 1. for DUPX

P(1) = 3. for DUPY

P(1) = 5. for NO DUP

The remaining elements and the minimum DIMENSION of P are functions only of the options being used. (See E. - Variation Layout.)

D. Using the Options

The use of the options is exactly the same as for PLOTXY (see I.-D. - Using the Options) with the following exceptions:

1. If option 16 is used, DX must be positive.

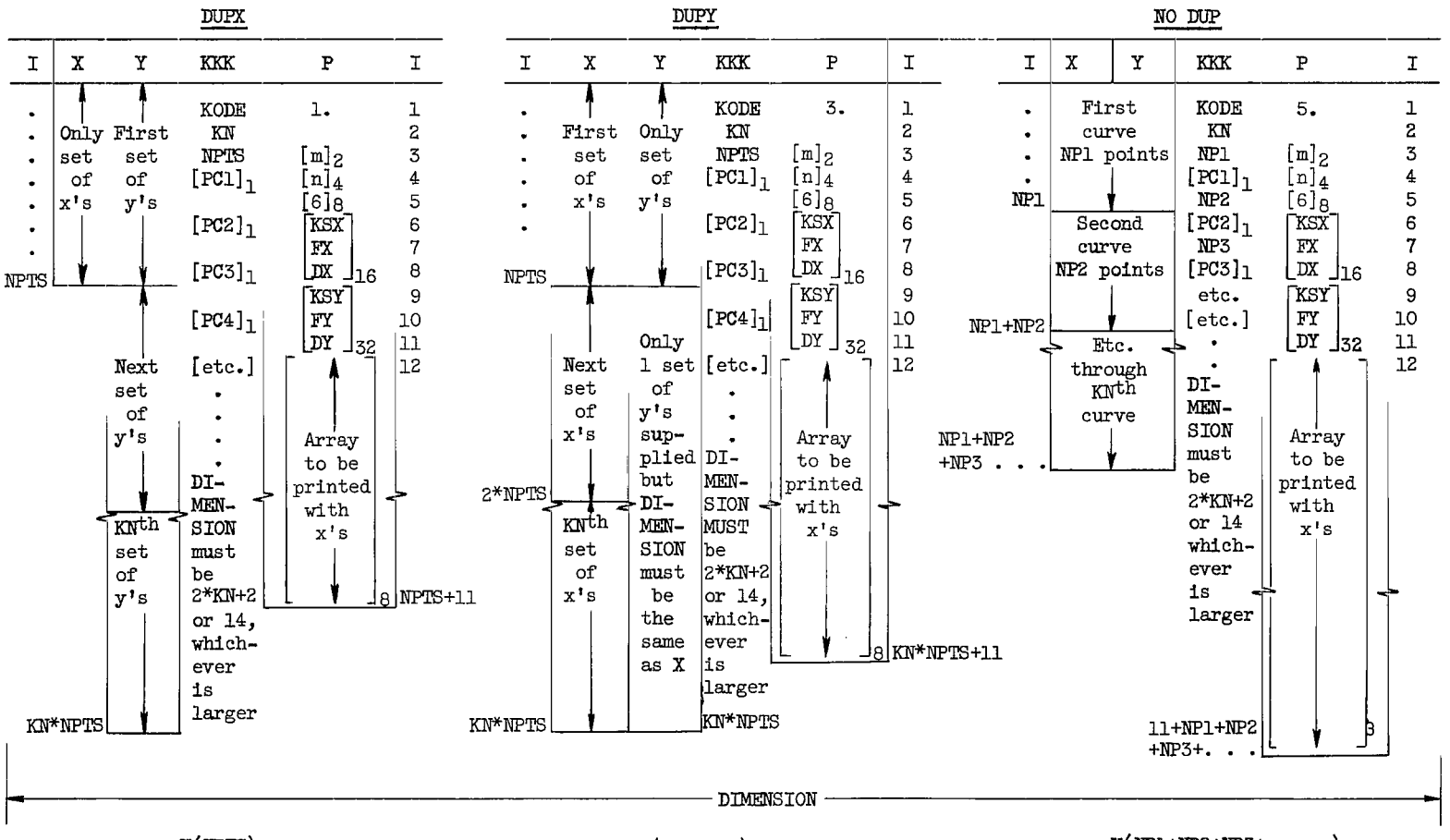
2. When option 64 is used, only the ordinate in the x-direction will be printed.

3. Unless option 1 is chosen, the plotting characters *, +, 0, ×, =, 0, will be used for the first six curves. To use others, use option 1 and supply the desired plotting character for the first curve in KKK(4), for the second curve in KKK(6), ... If more than six curves are to be plotted, option 1 must be used, and all plotting characters supplied. To put a plotting character, for example, $, in KKK(4), write:

```
EQUIVALENCE (PC, KKK(4))
PC = 1H$
```

E. Variation Layout

$[\ ]_N$ means supply item in brackets if option N is being used.



KKK=(2*KN+2) or (14), whichever is greater, for all Variations.

If option 8 is not used, P($\leq$11), depending on use of options 2, 4, 16, and 32.
If option 8 is used:

P(NPTS+11) P(KN*NPTS+11) P(11+NP1+NP2+NP3+ . .)

III. SCALE

CALL SCALE (NPTS, A, KRSTR)

This subroutine finds the largest absolute value of the NPTS elements of A and computes the characteristic of its $\log_{10}$. If the characteristic K is $-2 \leq K \leq 4$, KRSTR is set to zero and control returns to the calling program. If $K > 4$ or < -2, each element of A is multiplied by a power (KRSTR) of 10 to transform the array to suit PLOTXY and PLOTMY. KRSTR is output to permit the user to ReSToRe the array or to record how it has been altered.

IV. SORTXY

CALL SORTXY (V, W, NPTS)

This subroutine rearranges the NPTS elements of the V array in order of increasing size. The elements of the W array are moved to maintain the original pair-relation; that is, if the fifth element of the V array is moved to the first position of V, the fifth element of W is moved to the first position of W.

V. ERROR DIAGNOSIS

A. Error Messages

1. PLOTMY will write an error message

NPTS IS MISSING OR WRONG IN THE KARRAY. IMIN = nnn

if the search for the plotting character is unsuccessful. Information missing or misplaced in the KKK array, or "dimensioning" the KKK array less than 14, may cause this write-out to occur.

2. PISTUG (a FORTRAN subroutine called by both PLOTXY and PLOTMY) will write an error message

PLOT HALTED BY ARRAY NUMBER n VALUES OUT OF RANGE. KCD = nnnn

if the array being scaled does not meet the "range test." The absolute value of the range - maximum element minus minimum element - must be greater than 10^{-3}, and the larger of the absolute values of these two elements must fall between 10^{-3} and 10^{7}. If the programmer uses option 16 or option 32, the range test is not made, and an error message will not be written even if the array is "out of range." In such a case, although the plot may be printed, the grid-labels may be incorrect.

3. PLOT (the 1401 subroutine that prints the plot when output is listed) may write an error message:

X OUT OF ORDER mmmnnn

This may mean that PLOTXY was called with the elements of the x array out of sequence. With PLOTMY, it may mean a DIMENSION in the calling program is wrong, or that the programmer has chosen his own scale and has supplied points that cannot be plotted. (See C.-5. and 6. in this section.) The mmmnnn is a message to the systems programmer.

B. Errors Causing Misuse of Library Subroutines[3]

1. In both PLOTXY and PLOTMY, when the user of option 16 (or 32) specifies both FX (or FY) and DX (or DY) = 0, an attempt to take LOGF(0.0) occurs.

2. In both PLOTXY and PLOTMY, when the user of option 16 (or 32) specifies DX (or DY) = 0, an attempt at division by zero occurs.

3. For both PLOTXY and PLOTMY, when the programmer does <u>not</u> use option 16 (or 32) and commits the programming error of:

a. Supplying all elements in the array equal, or

b. Forgetting to supply the number of points, or

c. Supplying the number of points in fixed point,

an attempt to take the LOGF(0.0) occurs in an internal scaling routine, PISTUG.

C. No Error Message

1. If a programmer uses both options 16 and 32 (specifying his own scaling parameters) and forgets to supply the number of points, there will be no error messages written, but his plot will consist entirely of one horizontal grid-line correctly labeled above and below.

2. PLOTMY assumes the scale-factor in the x-direction is positive, and if the programmer does not use option 16, it will be. If he specifies his own scale and supplies a negative scaling-parameter, DX, the plot will be incorrect. If he really wants a decreasing x scale, he should multiply his x array by -1. before the call and manually inscribe negative signs and change minus signs to plus signs on the x grid-labels of the printed plot.

---

[3]At Lewis, these errors are caught and an error message written by an error package incorporated in the monitor system.

3. The most common programming error to date is the omission of the required 2HPT (or 2HPL) from the FORMAT statement for the second TITLE (or LEGEND) record. Such omission also occurs when slashes (///) are used to get line spaces between or following printed lines. Use 2HPT/2HPT/2HPT etc. to control spacing above the plot.

4. Even when two or more plotting characters should be printed in the same location, only one character is printed. Similarly, when two sets of information to be printed at the left of the plot are supplied for the same value of x, only the last is printed.

5. When option 16 is used and the programmer specifies the scaling parameters for the vertical scale, the OPP system assumes, and does not check, that the elements of the x array will fall on or between the starting-value and the value formed by adding 999 times the scale-factor to the starting-value. If this is <u>not</u> true, because some element in the array should be plotted:

a. From 1 to 9 line-spaces above the first grid-line (the starting-value)	the point will be plotted incorrectly with no error message.
b. More than 9 line-spaces above the first grid-line (the starting-value)	the plot will consist of more than 60 pages of properly labeled grid terminated by the X OUT OF ORDER message described in A.-3. in this section.
c. More than 999 line-spaces below the first grid-line (the starting-value)	the plot will be terminated at 999 lines (about 16 pages) with the X OUT OF ORDER message described in A.-3. in this section.

6. When option 32 is used and the programmer specifies the scaling parameters for the horizontal scale, the OPP system assumes, but does not check, that all the elements in the y array will fall on or between the starting-value and the value formed by adding 102 times the scale-factor to the starting-value. If this is <u>not</u> true because some element in the array should be plotted:

a. From 1 to 9 print positions to the left of the first grid-line (the starting-value)	the point will be plotted incorrectly with no error message.
b. More than 9 print positions to the left of the first grid-line (starting-value)	the point will not be plotted. Also, because this programming error causes program to be overwritten, following plots may be incorrect.
c. More than 102 and less than 999 print positions to the right of the first grid-line (starting-value)	a record mark will be printed at the extreme right of the page.
d. More than 999 print positions to the right of the first grid-line (the starting-value)	the point will be plotted incorrectly with no error message.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, October 1, 1963

REFERENCE

1. Dellner, Lois T., and Moore, Betty Jo: An Optimized Printer Plotting System Consisting of Complementary 7090 (FORTRAN) and 1401 (SPS) Subroutines. II - Systems Programmers Manual, NASA TN D-2175, 1964.

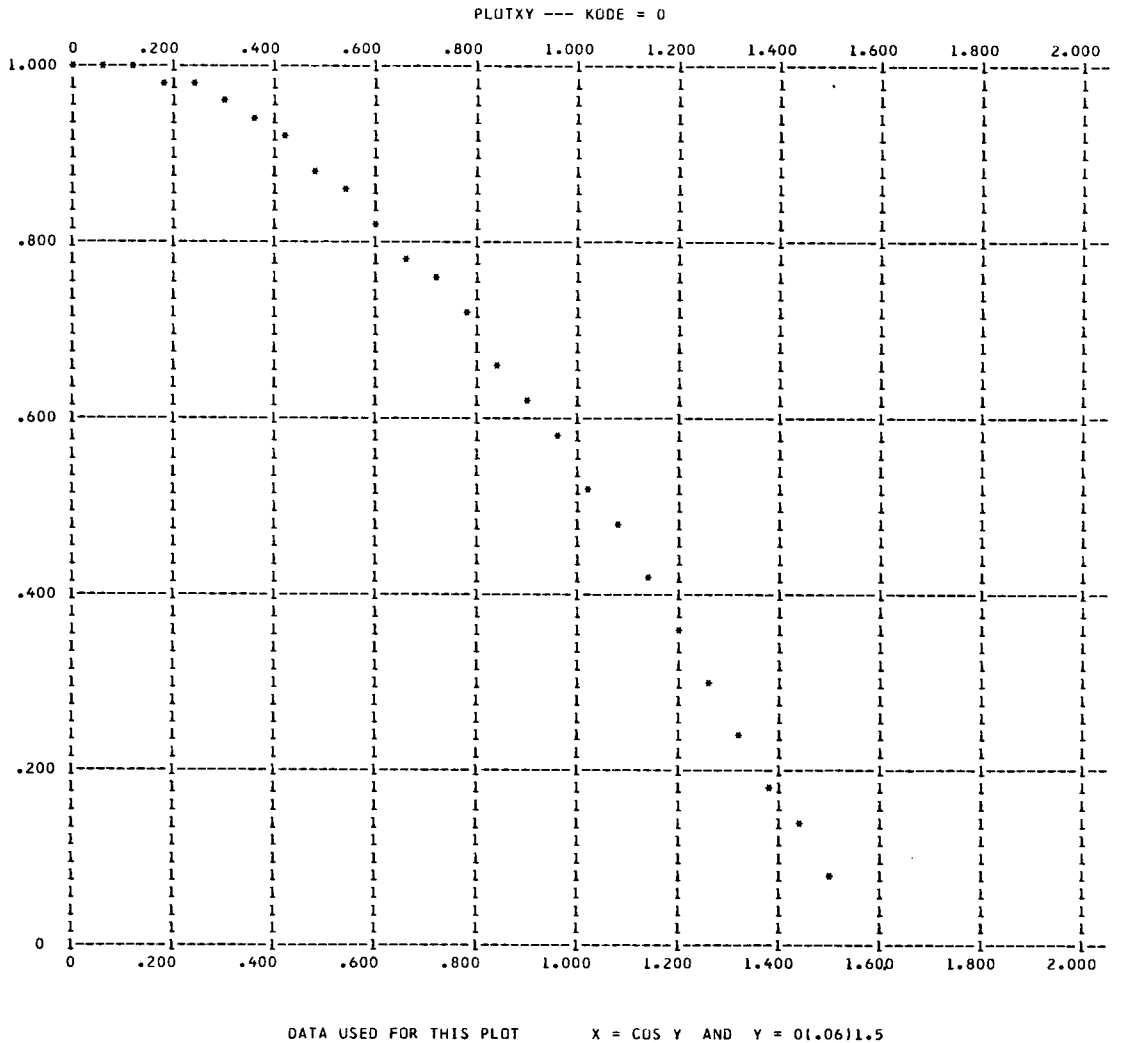


Figure 1. - This plot illustrates using PLOTXY with KODE = 0. The subroutine provides 10 × 10 grid-line spacing, chooses both scales, and uses an asterisk as the plotting character. The number of points (26.) was placed in P(1).

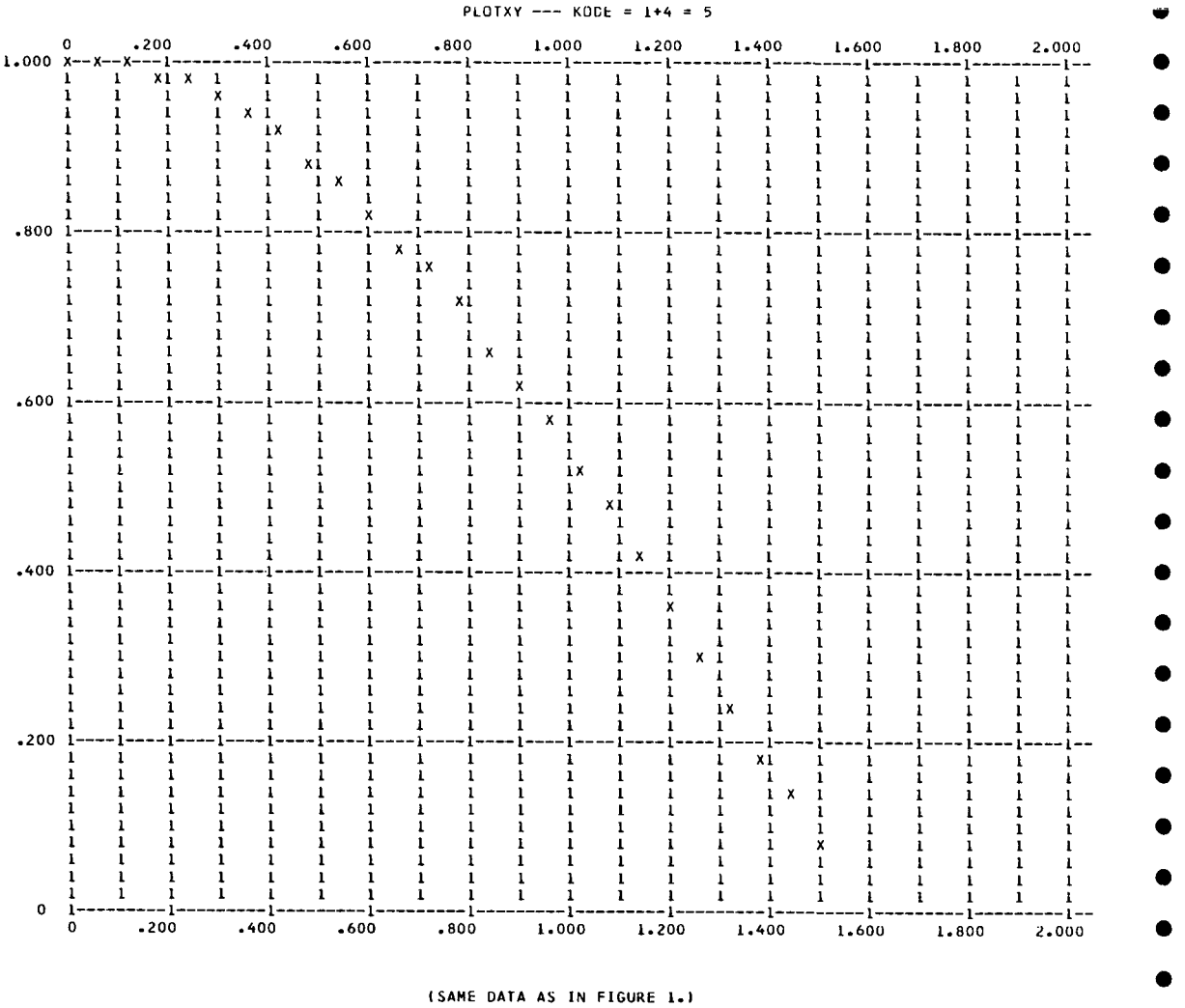


Figure 2. - This plot illustrates using option 1 - choice of plotting character. The desired plotting character, X, was placed in P(2). Option 4 - choice of y grid-line frequency - was also used. The desired frequency (5.) was placed in P(4). Notice that the frequency of y grid-labels is not affected.

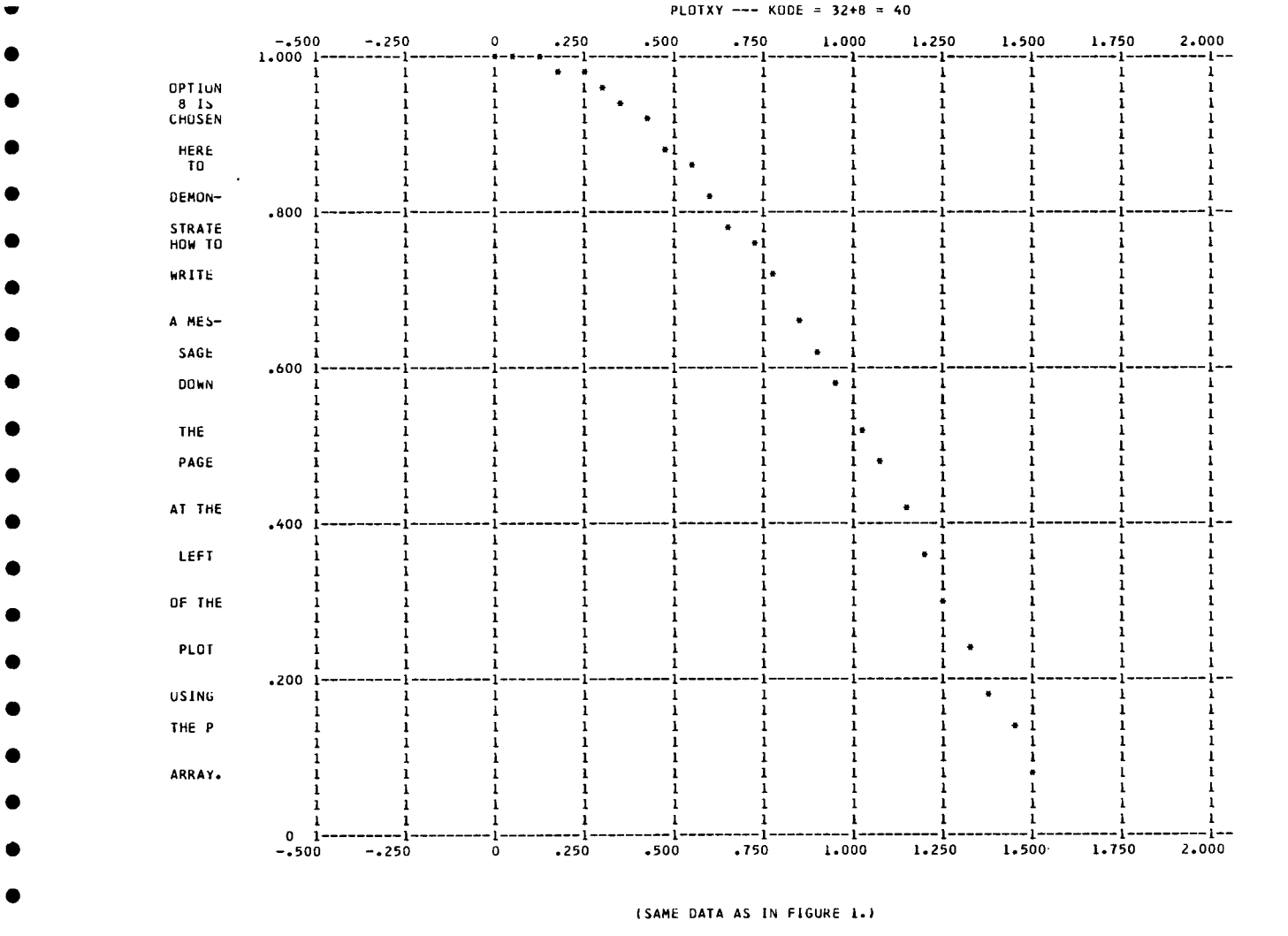


Figure 3. - This plot illustrates using option 32 - choice of y scale. The scale chosen was specified to PLOTXY by placing KSY = 3. in P(9), FY = -500. in P(10), and DY = 25. in P(11). The maximum possible value of KSY was used. (Fig. 4 displays the effect of using a smaller value of KSY.) Also illustrated is the use of option 8 - choice of printing left-side field. The message was placed in the P array; the characters bbbbbb in P(12) through P(15); the characters OPTION in P(16), the characters b8bISb in P(17); etc.

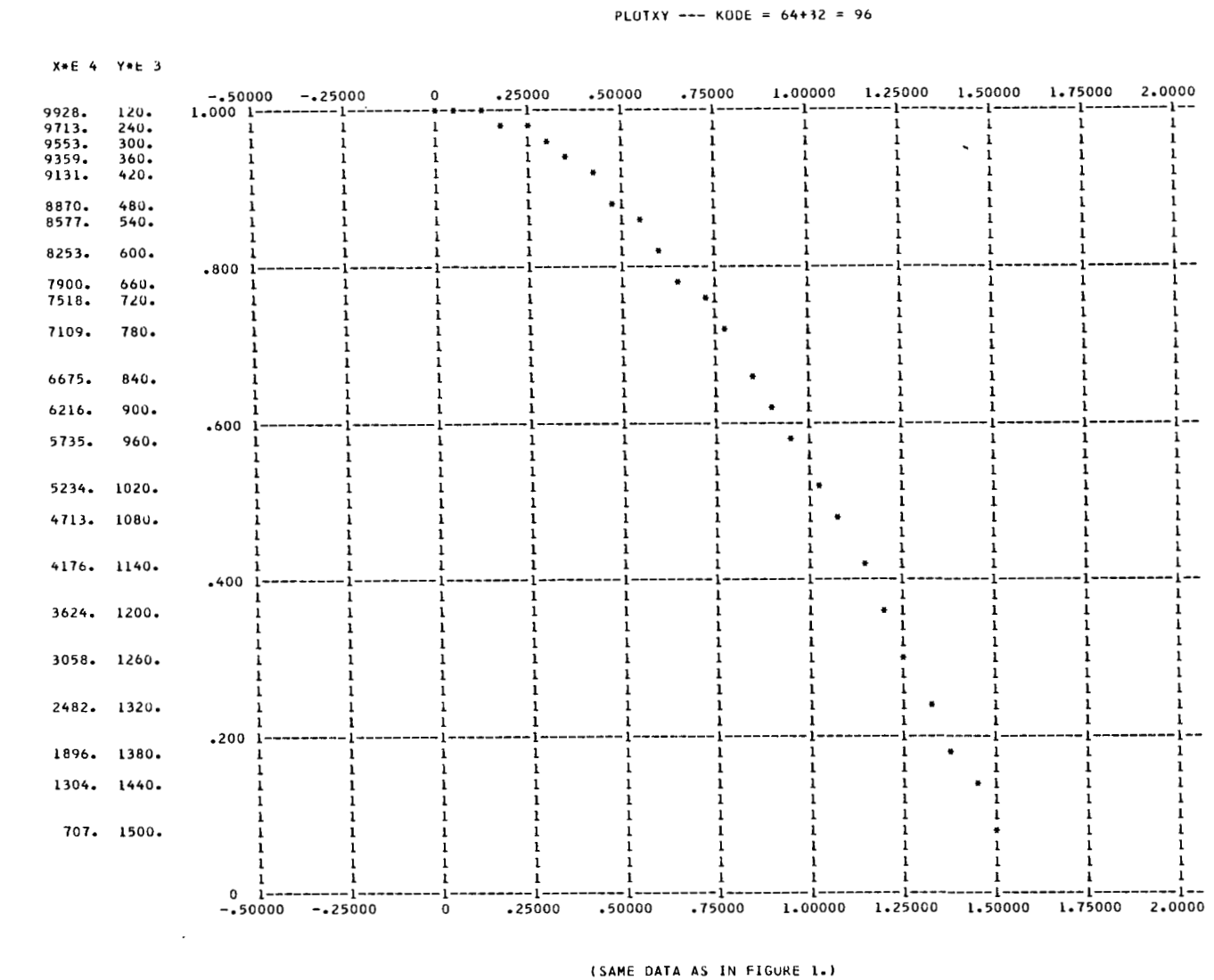


Figure 4. - This plot illustrates using option 64 - choice of printing coordinates at left. Because of the limited field size allotted to this print-out, PLOTXY transforms the coordinates to preserve as many significant figures as possible, and indicates in a special heading what has been done. This plot also illustrates using option 32 - choice of y scale. The same starting-value and scale-factor were wanted as in figure 3, but the values KSY = 1. were placed in P(9), FY = -50000. in P(10), and DY = 2500. in P(11). Notice the corresponding change in the appearance of the y grid-labels.

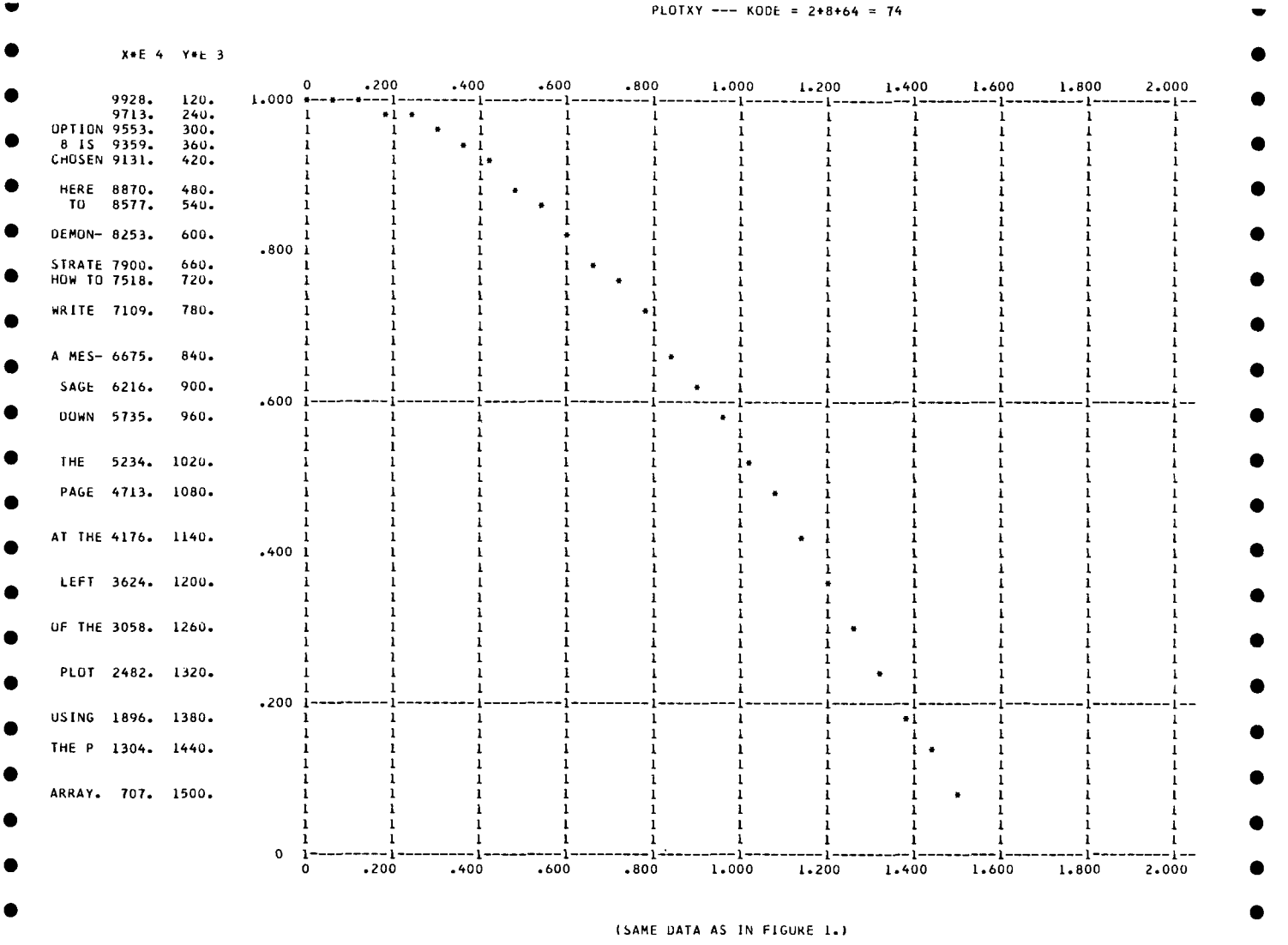


Figure 5. - This plot illustrates using option 2 - choice of x grid-line frequency. The desired frequency (20.) was placed in P(3). Notice that the frequency of the x grid-labels is not affected. This plot also demonstrates that after the last point has been plotted, the grid is only continued to the next grid-label, not to the next grid-line. The result of using options 8 and 64 simultaneously should be compared with figures 3 and 4.

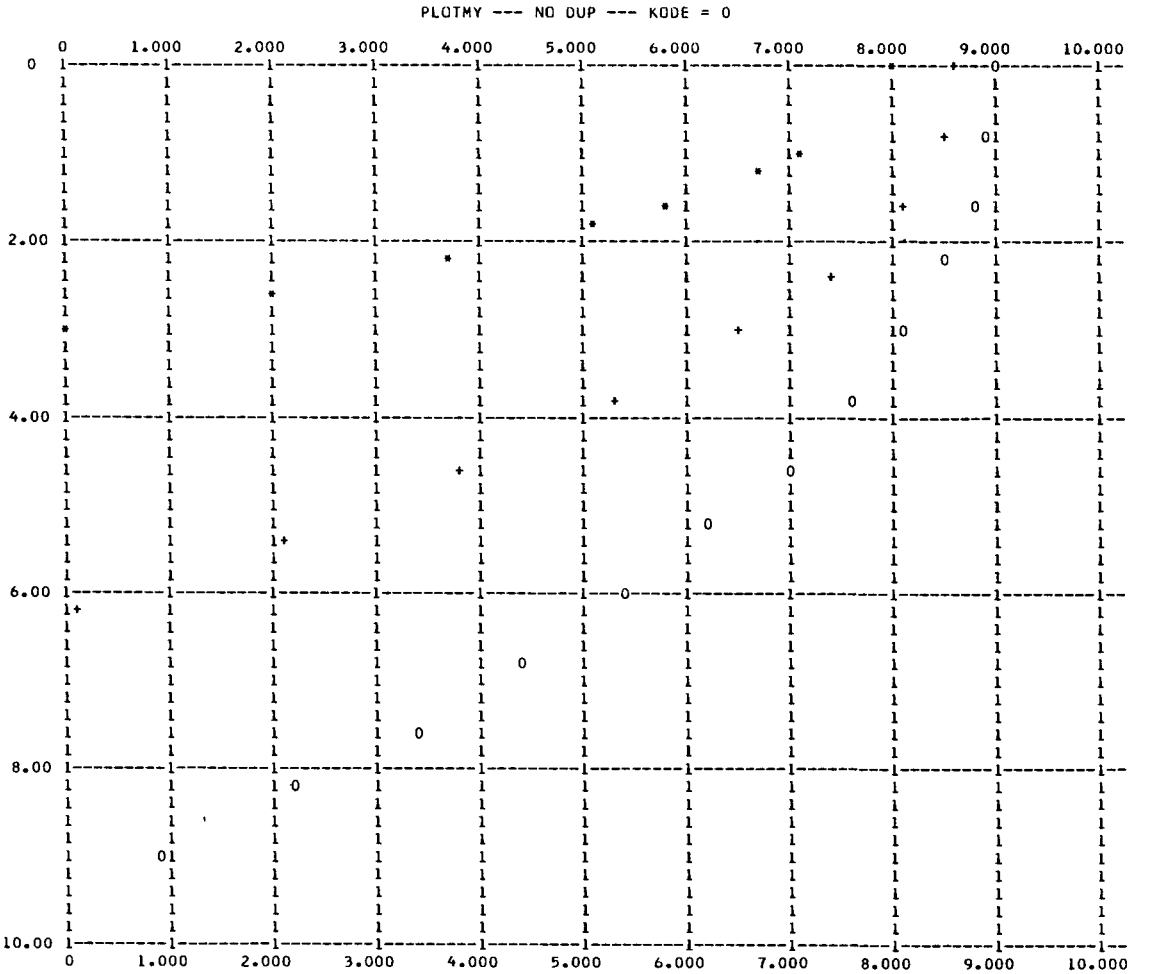


Figure 6. - This plot illustrates using PLOTMY - Variation III - NO DUP with KKK(1) = KODE = 0. As in PLOTXY, the grid-line spacing 10 X 10 is supplied by the routine, as are the scales and the plotting characters. The number of curves (3) was placed in KKK(2), the number of points for the first curve in KKK(3), for the second in KKK(5), and for the third in KKK(7). Variation III was specified by placing 5. in P(1). Notice that several points fall on the grid-lines and compare with figure 7.

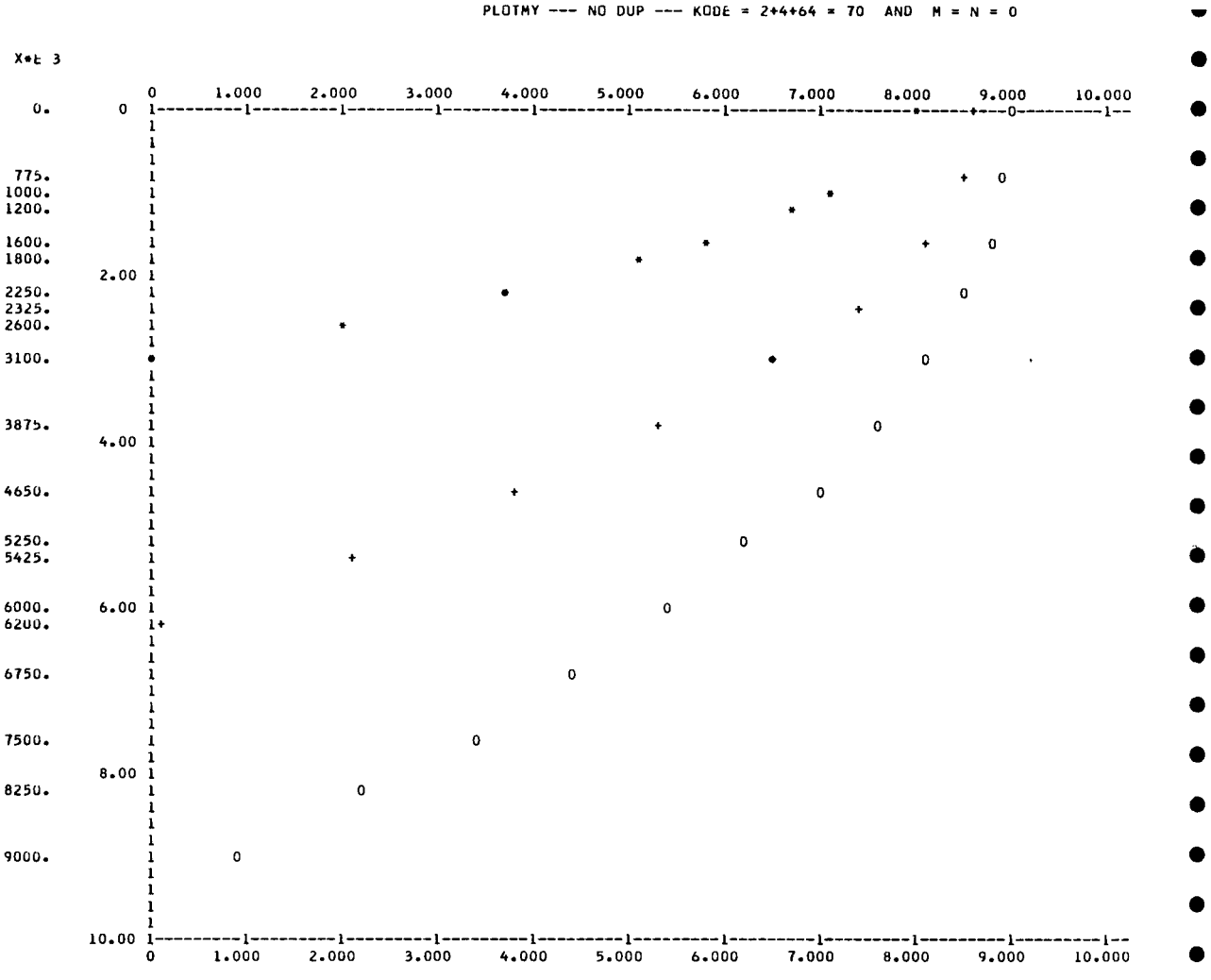


Figure 7. - This plot illustrates using options 2 and 4 to remove all but the first, last, and left-most grid-lines, by supplying the frequencies = 0 in P(3) and P(4). This effect is possible in PLOTXY also. This plot also illustrates the use of option 64 with PLOTMY. The x ordinate only is printed, not both, as in PLOTXY (see fig. 4).

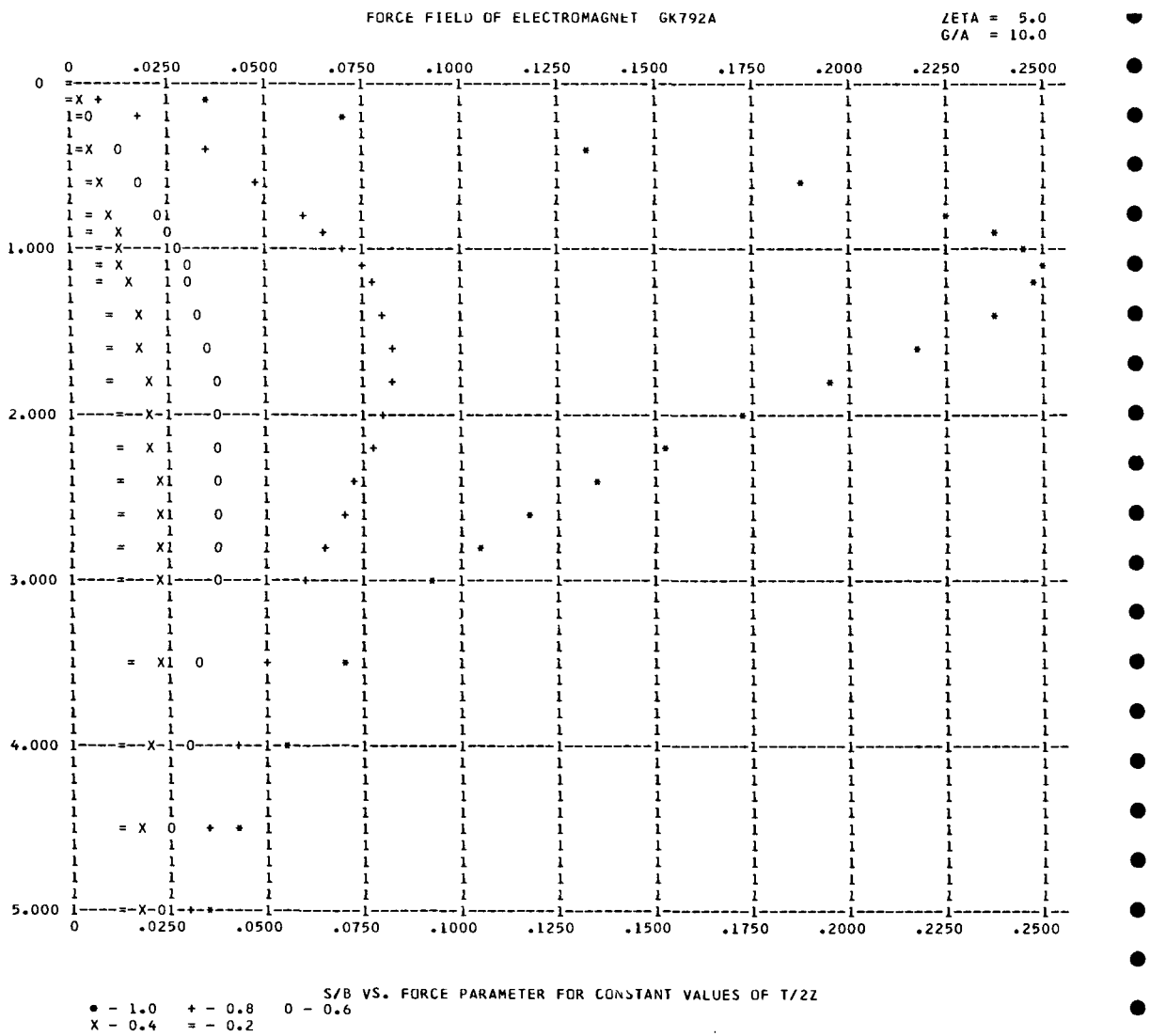


Figure 8. - This plot illustrates using PLOTMY - Variation I - DUP X with KKK(1) = KODE = 0. A single set of x values was placed in the x array, and five sets of y values one after another in the y array. The number of curves was placed in KKK(2) and the number of x values in KKK(3). Variation I was specified by placing 1. in P(1).

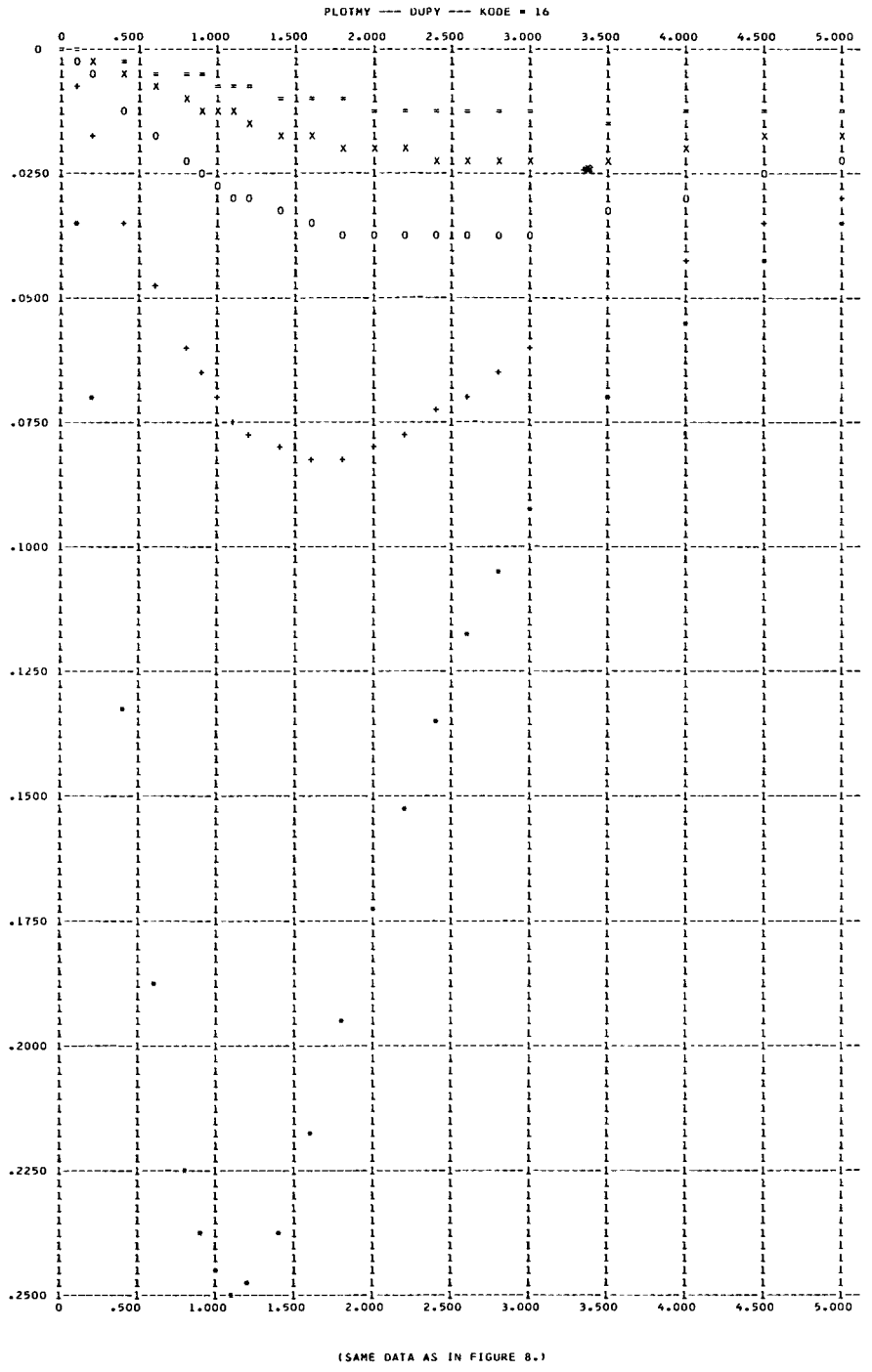


Figure 9. - This plot illustrates using PLOTMY - Variation II - DUP Y with KKK(1) = KODE = 16. The x and y arrays used for figure 8 were interchanged and the x scale specified by placing KSX = 2. in P(6) and DX = 25. in P(8). Otherwise, PLOTMY's choice of scale (which is based on the length of the x array, not on the number of points in the y array supplied in KKK(3)) would have spread the plot over four pages. Variation II was specified by placing 3. in P(1). Compare with figure 8.

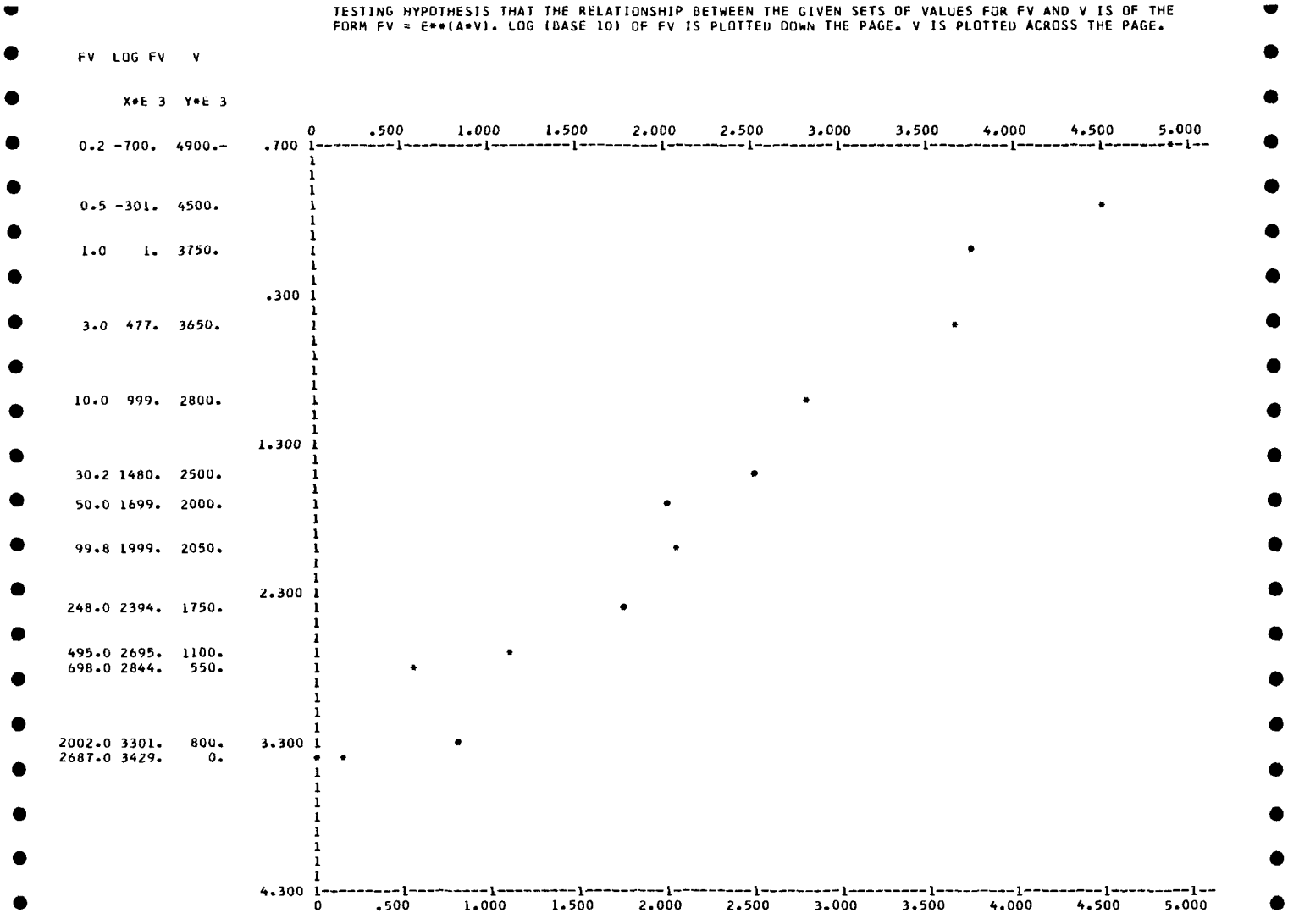


Figure 12. - This plot simulates a plot made on semilog paper. The values in the y array were those that would be plotted on the linear scale, while those in the x array were the logarithms of the values that would be plotted on the logarithmic scale. The original values are displayed using option 8.

2/7/85

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