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User's Manual for the Graphics Package ORGRAPH

C. W. Nestor, Jr.
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COMPUTER SCIENCES DIVISION

USER'S MANUAL FOR THE GRAPHICS PACKAGE ORGRAPH

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NOVEMBER 1974

This work was begun originally by the authors
and M. Feliciano, Jr. and M. M. Perardi.

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ABSTRACT

A package of subroutines has been prepared to facilitate the use of the plotting equipment available at the ORNL-site Computing Center. A wide variety of data plotting, function plotting and labeling options is available for any of the plotters.

INTRODUCTION

This report is intended for those who wish to use computers and automatic plotters for the production of graphs. It is a user's manual for the ORNL Graphics Package ORGRAPH.

Scattered through the report are samples of graphs and pictures produced with ORGRAPH. In some cases, the corresponding FORTRAN program is given.

The user who is new to this subject should begin at the beginning, namely Chapter 1, which contains mainly introductory material.

The user who is going to write a FORTRAN program to draw graphs should look at Chapter 2, Combination Subroutines. Many kinds of graphs can be drawn with the Combination Subroutines. However, Chapters 3 and 4 are intended to provide a much wider range of options.

When the time comes for putting the program in the computer and trying to get a graph, the necessary control statements can be found in Chapter 5.

ORGRAPH will be extended according to user needs. Constructive comments and suggestions are welcome.

1. GRAPHICS AND ORGRAPH

1.1 Introduction to Computer Graphics

When large amounts of data or symbols are to be plotted, the use of computers and automated graphics equipment offers some advantages. Electromechanical plotters do not have the versatility and artistry of skilled draftsmen but are generally faster. Instructions are given to the plotter in the form of a computer program and must be quite specific. You do not say, "Please put a few trees in the background," to a Calcomp plotter. The plotters at the ORNL-site are incremental plotters; that is, they recognize only a few commands, such as, "Move one step to the right," or "Put the pen on the paper." A complete picture requires thousands of such commands. Fortunately, the user need not issue each command individually; special computer programs are used to translate the user's request into plotter commands and to write these commands on a magnetic tape. The tape is later used to drive the plotter.

Many computer programs exist for computing plotter commands. Some simply draw a line from (x_1, y_1) to (x_2, y_2), while others draw a complete picture. A group of related subroutines which can be used to draw a variety of graphs is called a plotting package. One plotting package, ORGRAPH, is described in this report.

Plotting packages can be used either to obtain a picture quickly with minimum effort or to obtain finished graphs with detailed labels and titles. Finally, if a plotting program for a particular application is properly written, it can be used over and over again with different data and different parameters.

1.2 Introduction to ORGRAPH

ORGRAPH (or Oak Ridge Graphics Package) is a family of subroutines for use in computer graphics. Some examples of graphs drawn with ORGRAPH are given in the following chapters.

Some properties of ORGRAPH are:

1. It is mainly for graphs of data and functions.

2. ORGRAPH can make graphs on the CALCOMP pen-and-ink plotter, the CALCOMP CRT plotter, or the line printer. It is easy to switch from one to another.

3. Most of ORGRAPH is plotter-independent. Capability for driving other plotting equipment may be added later.

4. Simple graphs can be obtained without having to specify lots of details. However, a wide variety of options and special effects can be invoked, if needed.

5. A variety of styles for data presentation can be used: with or without symbols; with or without lines or with dashed lines; or with or without error bars.

6. A variety of graph styles can be used; linear, logarithmic, and semi-logarithmic.

7. Several subroutines for drawing labels, titles, arrows, and legends are available.

8. ORGRAPH imposes no limit on the amount of data that can be put on each graph or on the number of graphs that can be made in one computer run.

9. ORGRAPH is part of the ORNL-site computer system. The user does not need to include ORGRAPH card decks with his program.

10. Additions to ORGRAPH are made from time to time in response to user needs.

A typical sequence of events involving ORGRAPH is:

1) The user writes a FORTRAN program which reads or computes data to be graphed.

2) He includes in the program one or more CALL statements to subroutines in ORGRAPH.

3) He submits this program with appropriate control cards and job cards to the computer center.

4) The execution of the program causes plot commands to be written on a magnetic tape, except for the case of line printer plots, which do not require a magnetic tape.

5) The tape is removed from the computer and attached to either the mechanical plotter or the Cathode Ray Tube plotter.

6) The paper or 35mm. film is sent to the user.

7) In the case of film, the user can also obtain TTEK prints at standard magnification of 14.7.

1.3 Outline of ORGRAPH

There are two kinds of ORGRAPH subroutines, the Combination subroutines (Chapter 2) and the Building Block subroutines (Chapter 4). One of the subroutines, QWIKPI, can draw a complete graph. In other cases a sequence of

calls is used to obtain a complete graph. In this way, the user has more options available. Data points and curves may be plotted on the same graph. Any or all points may be labeled. Scales can be on any or all sides or even inside the graph.

A fairly wide range of options is available with just the Combination subroutines. However, the Building Block subroutines are still more versatile. Each Building Block subroutine performs one small part of making a graph such as computing a scale factor or labeling a point.

There is a COMMON area available to all ORGRAPH subroutines called the Common Parameter Area, or CPA. Descriptive information, such as graph size, margin size, scale factors, is put into the CPA by ORGRAPH subroutines or by the user directly. For many kinds of graphs the user does not need to enter data into the CPA directly. However, a variety of special effects can be obtained by direct use of the CPA and for this reason an entire chapter (Chapter 3) is devoted to it.

As with any computer program, special control cards are needed for plotting with ORGRAPH. These are described in Chapter 5.

1.4 Computer Graphics Equipment

Equipment currently in use at ORNL for automatic graph-making is described in the ORNL Programmer's Manual:

Plotters, Section 1.1.4

Printers, Sections 1.1.1, 1.1.2, 20

Graph Paper, Sections 1.1.4

Film and Glossy Prints, Sections 1.1.4, 13

Computers, Sections 1.1.1, 1.1.2, 1.1.5

1.5 Computer Graphics Services

1.5.1 Plotting Services

The plotting equipment is maintained by the Computer Sciences Division. A request for plotting can be made when a card deck is submitted for a computer run (see Chapter 5, Control Cards). The user can specify which plotter, paper type, number of graphs, etc.

If the user requests a Cathode Ray Tube plot, he receives a roll of developed film negatives. He can also request ITEK prints at magnification 14.7, corresponding to a graph size of 11 inches by 17 inches. Although ITEK prints are easy to make and inexpensive, they turn brown in a few months. One way to get a permanent record is to Xerox the ITEK print.

Frequently, graphs for publication are finished by the Graphic Arts Department. In this mode of operation the data points are plotted on blank paper with a very coarse grid or no grid. Graphic Arts adds titles and labels. In some cases, graphs done with ORGRAPH are ready for publication without further work.

1.5.2 Programming Services

The Computing Applications Department of the Computer Sciences Division performs programming services, including graphics programming. The ORGRAPH package, described herein, is maintained by the Computer Sciences Division and will be extended to meet user needs.

1.6 Conventions Used in the Report

1.6.1 Graph Production

It is often convenient to say that a subroutine produces a graph or part of a graph. This is an abbreviated version of a more involved process. Actually, the subroutine, if properly invoked, will call other subroutines which call other subroutines which eventually cause plotting commands to be written on a magnetic tape. Later, the magnetic tape will be attached to a tape reader which is in turn attached to a plotter.

1.6.2 FORTRAN

In this report, some FORTRAN conventions are used. It is assumed that the user is writing or modifying a FORTRAN program to include graphics options. Sample Fortran statements are written with capital letters. Example:

```
CALL QWIKPL(X,Y,3,'LOG','NAME$')
```

This statement may be keypunched and added to the user's program. The items inside the parentheses refer to information that is to be sent to the subroutine or returned from the subroutine and may be varied to suit the user's need. The FORTRAN-type conventions are used; in the above example the first two names, X and Y, refer to REAL variables, the third could be replaced by a variable of type INTEGER, and the last two are literals, as indicated by the apostrophes. Usually, the REAL and INTEGER variables can be chosen to fit the user's calling program while the literal variables should be selected from a small list of literals given with the description of the subroutine.

1.6.3 Data

ORGRAPH plots four-byte data values. If eight-byte numbers are given, only the first four bytes will be used. (In nearly every case the 32 low-order bits would not make a noticeable difference in the plotted position.) In Chapter 3, a method for skipping alternate numbers is described. This can be used to plot arrays of data stored in REAL*8 form; ORGRAPH will treat the data as REAL*4 values stored in alternate locations.

1.6.4 Scaling

Scale factors are set up so that ORGRAPH will convert the given data into plotting positions. This is normally done by the Setup Routines (Section 2.3). For example, if the user requests a 10-inch graph with x-axis going from 40. to 90., then each x-value in the user's array should be scaled and offset (x-value is taken to be in user's units):

x-value in inches = 10.0(x-value - 40.0)/(90.0 - 40.0)

or more generally:

x-value in inches = (graph length)(x-value - x-min)/(x-max - x-min)

for linear scales

x-value in inches = (graph length)(log(x-value) - log(x-min))/(log(x-max) - log(x-min))

for log scales with analogous equations for y-values.

The quantities x_{min}, x_{max}, Y_{min}, Y_{max}, graph length, and graph height are stored within ORGRAPH. They can easily be changed by the user.

In the routines which prepare for plotting, such as the Setup Routines in Section 2.3, the phrase "in user's units" means that the data will be used to help determine x_{min}, x_{max}, Y_{min}, and Y_{max}. In the data plotting routines the phrase "in user's units" means that the above transformation will be performed on the data before it is plotted.

1.6.5 Some Definitions

Advance	Move the paper or film to a new position beyond the present graph area.
Building Block Subroutines	An arbitrary name for a group of subroutines in ORGRAPH. The building block subroutines are described in Chapter 4.
Calling sequence	The manner in which an ORGRAPH Subroutine is called. Typical, or possible, calling sequences are given. Example: CALL RAYPLT(X, Y, 50)
Combination Subroutines	An arbitrary name for a group of subroutines in ORGRAPH. Each combination subroutine performs several functions. The combination subroutines are described in Chapter 2.
CPA	Common Parameter Area. Residence for information describing the current coordinate system and graph style. This is further described in Chapter 3.

CRT	Cathode Ray Tube plotter.
Curve	A line drawn through at least two points on a graph.
Default values	The CPA is completely defined by DATA statements. Values which are not changed are sometimes referred to as default values. The CPA default values are listed in Chapter 3.
Entry	FORTRAN ENTRY statements.
Frame	Usually, this means a box drawn around a graph. Sometimes, it means the section of film presently available for exposure.
Function	A relationship between x-values and y-values described by a FUNCTION subprogram or, in the parametric case, by two FUNCTION subprograms.
Inch	On the mechanical plotters and printers 1 inch = 1 inch. On the CRT plotter 1 inch requested in the program = 1 inch if the film is projected at 14.7x magnification.
Log or Logarithmic	This indicates that logarithmic spacing is to be used for the numbers in the scale and tick marks.
ORGRAPH	The name of the graphics package described in this report. There is, however, no subroutine of that name in the package.
Parameter	This vague term is used for one or both of the following. 1. Information stored in the Common Parameter Area.

2. Information passed to or from ORGRAPH via a calling sequence.

Point	An ordered pair, consisting of an x-value and a y-value. "To plot a point" means to move the pen or beam to the corresponding coordinates, and to draw a symbol there, in the case of LINPLT.
Preset values	In this report, these are the same as default values.
Scale	Numbers along the edge of the graph.
Scale factor	Units per inch. See 1.6.4.
Setup routines	These set up a coordinate system and, optionally, draw scales, axes, and grid. They do not plot data. Examples of set up routines are SETPLT, FIXPLT, RNDPLT, SETFNC, and SETPAR, which are described in Chapter 2.
Tick marks	Small lines drawn perpendicularly to the axes to indicate scale divisions.
Title	Descriptive information at the top of the graph plotted with subroutine TITLE.
User's units	The CPA contains scale factors and other information which describes the user's current coordinate system. The user's calling program may set up or change this coordinate system at any time. The default coordinate system is in inches with 1:1 scaling. The setup routines (SETPLT, FIXPLT, etc.) are normally used to match the user's coordinate systems to the user's data arrays.

X-direction	Direction along the paper or film. In the mechanical plotters, pen motion in the x-direction is actually accomplished by rotating the drum under the pen. In the CRT plotter, motion in either direction is accomplished by deflecting the electron beam; the film is not moved until the film advance command is encountered.
Y-direction	Direction across the paper or film.
X-value	Coordinate in the x-direction.
Y-value	Coordinate in the y-direction. For some subroutines, these are in the user's units; in others they are in inches.

2. COMBINATION SUBROUTINES

2.1 Introduction

In ORGRAPH there are subroutines (called building blocks) each of which performs a specialized operation. At times it is convenient to use a subroutine that combines several of the building blocks. Subroutines of this kind are called combination subroutines. Those presently available in ORGRAPH are described in this chapter.

One of the combination subroutines is complete in the sense that it can produce a complete graph. The subroutine is QWIKPL and is described in Section 2.2.

The remaining combination subroutines are themselves used in combination. The plotting of a complete graph is decomposed into the following steps:

a. set up the scales and draw the frame

b. draw the titles and labels

c. draw the set of points or curve

d. advance the film or paper.

Figure 2.1 shows the flow of steps that will produce a set of graphs.

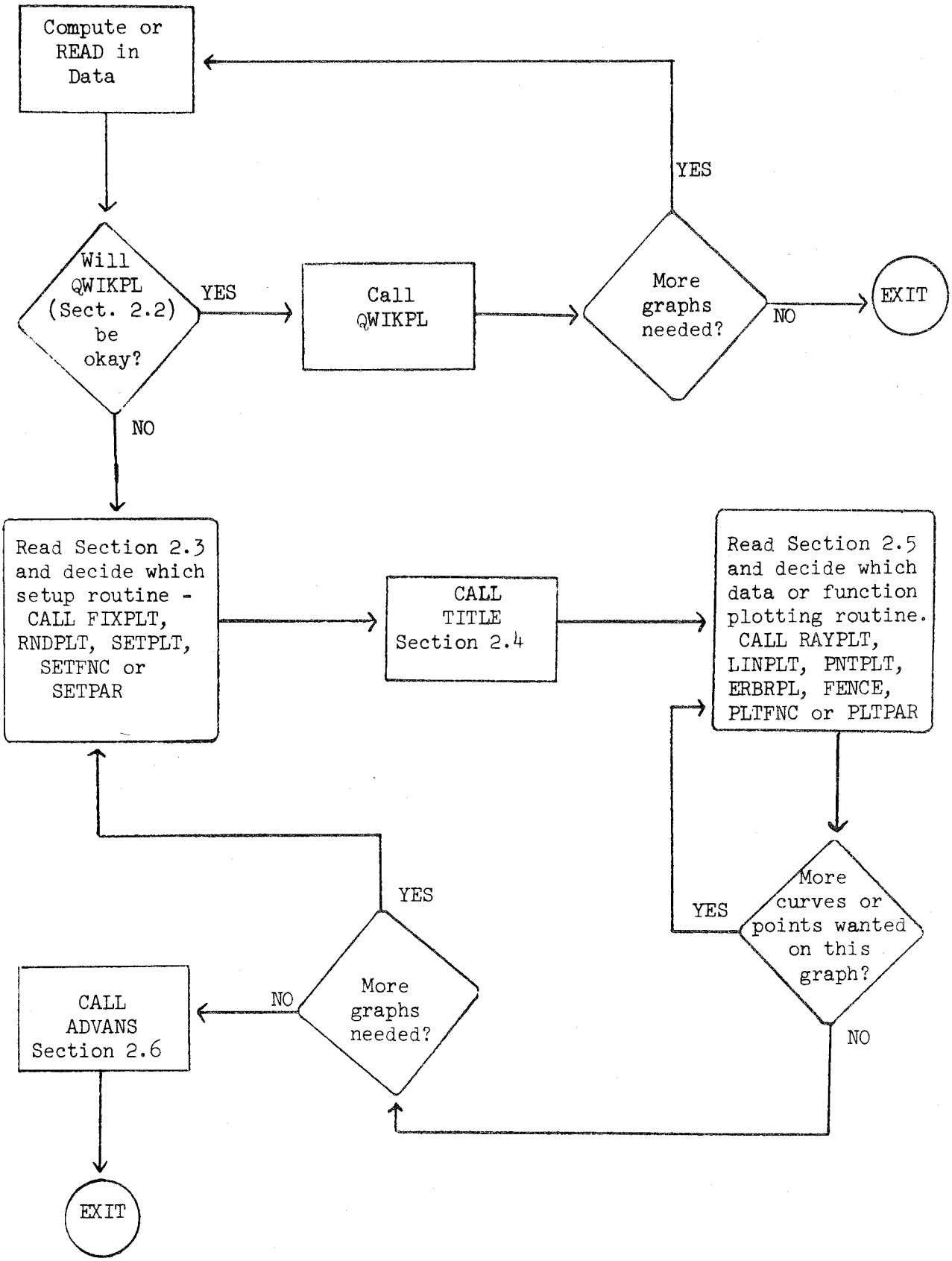


Fig. 2.1 Production of a Set of Graphs

It should be noted that the setup subroutine (step a.) will advance the film or paper in any call after the first one. Therefore, a special call to advance the film or paper should not be made until after the last picture is drawn. Any number of sets of points or curves can be drawn in the same picture.

The setup is described in Section 2.3, titles and labels in Section 2.4, plotting points or curves in Section 2.5, and advance of film or paper in Section 2.6.

A fairly wide range of options is available with the combination subroutines. An even wider range of options can be obtained by direct use of the Common Parameter Area (Chapter 3) or the building block subroutines (Chapter 4).

The Combination subroutines are

Name	Purpose	Section
QWIKPL	Draw a complete graph	2.2
FIXPLT	setup for data plotting, fixed limits	2.3.2
RNDPLT	setup for data plotting, rounded limits	2.3.3
SETFLT	setup for data plotting, limits from data	2.3.4
SETFNC	setup for data plotting, limits from F(X)	2.3.5
SETPAR	setup for data plotting, limits from F1(T), F2(T)	2.3.6
TITLE	graph title and axis labels	2.4
RAYPLT	plot data points	2.5.2
LINPLT	plot data points	2.5.3
PNTPLT	plot a data point	2.5.4
ERBRPL	plot data with error bars	2.5.5
FENCE	plot data with vertical lines	2.5.6
PLTFNC	plot a function	2.5.7

PLTPAR	plot a parametric function	2.5.8
ADVANS	move to next frame	2.6

2.2 QWIKPL, Plot a Complete Graph

2.2.1 Introduction to QWIKPL

The graph in Figure 2.2.1b was produced by the program in Figure 2.2.1a. QWIKPL is used when you want a complete graph with a minimum effort.

If you want to plot a set of points described by (x,y) pairs, see Section 2.2.2.

If you want to plot a set of y-values with constant spacing in the x-direction, see Section 2.2.3.

If you wish to do either of the above, but with more than one set of points per graph, read Section 2.2.4.

With QWIKPL your range of options is rather limited. If QWIKPL does not produce what you want, look elsewhere in the report.

```
      DIMENSION Y(31)
      READ 1, Y
    1 FORMAT (7E10.0)
      CALL QWIKPL (2., Y, -31, 'LINE', 10., 'CWN$')
      STOP
      END
```

Fig. 2.2.1a Program Using QWIKPL

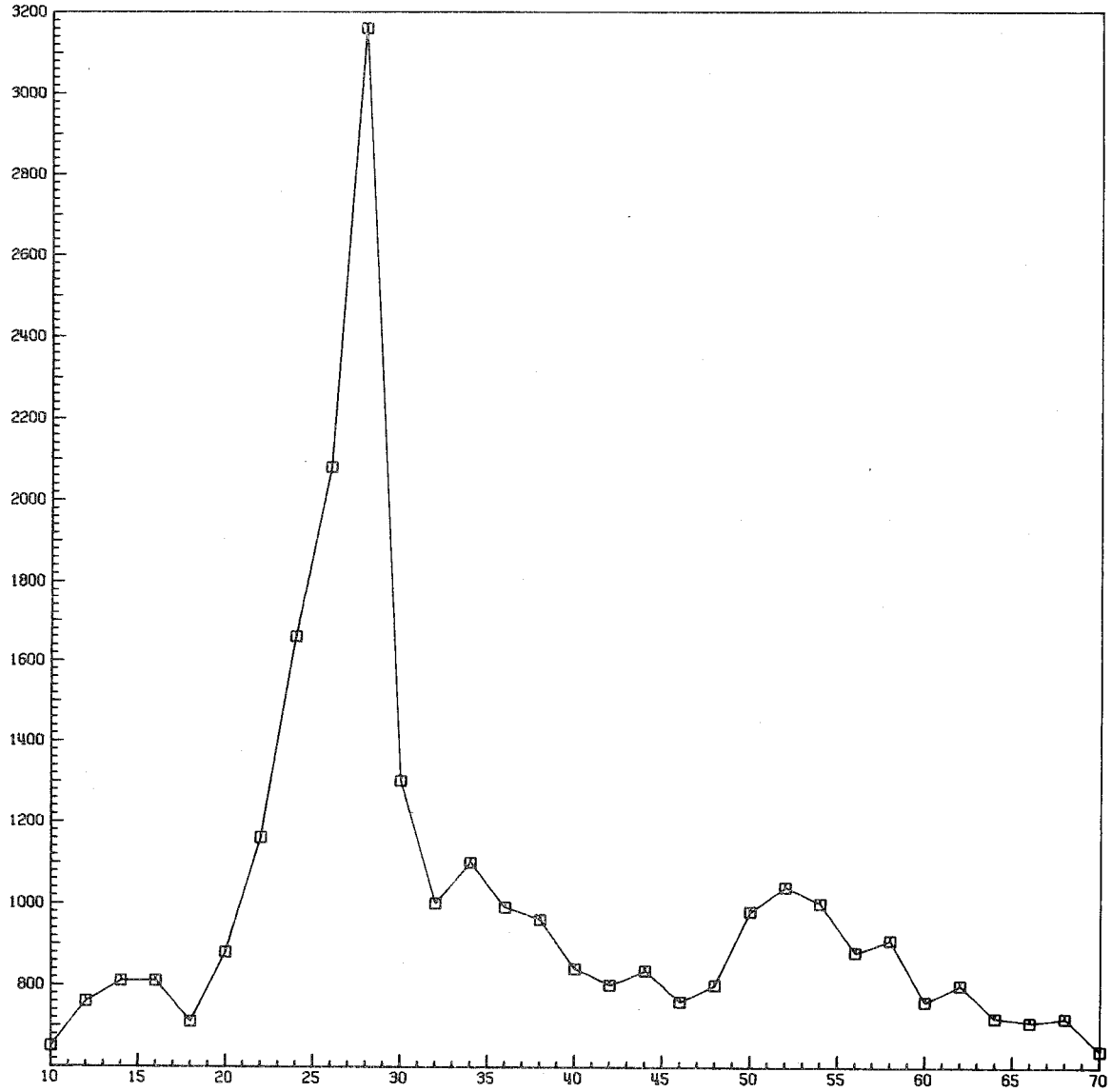


Fig. 2.2.1b Plot Produced by QWIKPL

2.2.2 One Set of Points (x , y)

It is assumed that the user's program has read in, or computed, some x-values and some corresponding y-values. To get a graph of (x,y) points, a statement like the following should be added to the FORTRAN program:

```
CALL QWIKPL(XARRAY, YARRAY, N, TYPE, NAME)
```

XARRAY	Array of x-values
YARRAY	Array of y-values
N	Number of elements to be plotted in XARRAY (also the number of elements to be plotted in YARRAY)
TYPE	Use one of the following:
'LINE'	Linear plot, mechanical plotter
'YLOG'	Log scale for y, linear for x, mechanical plotter
'XLOG'	Log scale for x, linear for y, mechanical plotter
'LOG'	Log scales for x and y, mechanical plotter
'CLINE'	Linear plot, CRT plotter
'CYLOG'	Log scale for y, linear for x, CRT plotter
'CXLOG'	Log scale for x, linear for y, CRT plotter
'CLOG'	Log scale for x and y, CRT plotter
'PLINE'	Linear plot, line printer
'PYLOG'	Log scale for y, linear for x, line printer
'PXLOG'	Log scale for x, linear for y, line printer
'PLOG'	Log scale for x and y, line printer
NAME	User's name, followed by $, within apostrophes; for example, 'JOHN Q. DOE $'. The first 12 characters will be used.

This call produces a scaled graph, 10 inches by 10 inches, on the mechanical plotter, the line printer, or the CRT plotter. The frame will have scales and tick marks. The scale factors will be chosen so that all the data points will be inside of the frame. A symbol will be drawn at each point and the points will be connected by straight lines.

After the graph is finished, the frame or page will be advanced so that another call to QWIKPL would produce a new graph.

QWIKPL does not produce labels or titles. On the mechanical plotter, QWIKPL works best with blank (ungridded) paper, type 0.

2.2.3 One Set of Points, y

The x-values are to have constant spacing, Δx, starting from some minimum x-value, x_{min}:

$$x_i = x_{min} + (i - 1)\,\Delta x$$

The calling sequence is:

```
CALL QWIKPL(XINC, YARRAY, MN, TYPE, XMIN, NAME)
```

XINC	Increment for x-value, Δx
YARRAY	Array of y-values
MN	A negative integer whose absolute value is the number of points to be plotted
TYPE	Defined as in Section 2.2.2.

XMIN	Starting value for x
NAME	User's name followed by $, all in quotes; e.g., 'I.M.A.PLOT$'. The first 12 characters will be used.

2.2.4 QWIKPL with Multiple Data Lists

Several data sets can be plotted on one graph by inserting an integer from 2 to 9 in front of any of the type options listed in Section 2.2.2.

For example, TYPE='3LOG' means that this is the first of three sets of data that are to be plotted on one graph. For the next two calls to QWIKPL the TYPE parameter will be ignored and may be omitted. Thus a typical sequence is:

```
CALL QWIKPL (X1, Y1, N1, '3LOG', NAME)
CALL QWIKPL (X2, Y2, N2)
CALL QWIKPL (X3, Y3, N3)
```

After the third data list is plotted, the paper is advanced, so that another call to QWIKPL will begin a new graph. Since the second and third calls refer to the graph already set up, any parameters after the third are ignored. Any points outside the graph limits (set by the first call to QWIKPL) are not plotted.

2.3 Setup Subroutines

2.3.1 Introduction

The setup routines do a number of things to prepare for data plotting. Scale factors are set. The graph size request and the margin size are picked up from the Common Parameter Area (see Chapter 3). A frame with scales and tick marks is drawn. A grid is drawn, if requested.

No data or curves are plotted by the setup routines. The data and curve plotting routines of Section 2.5 are intended for use with the setup routines. This combination gives the user more versatility than is available with QWIKPL.

The setup routines described in this section are very similar. The only differences are in the way the scale limits are chosen.

If you know exactly what the limits should be, use FIXPLT. If the limits are computed by your program and may have to be rounded, use RNDPLT. If you want the scale limits chosen to include all the data, use SETPLT. If you want the scale limits chosen to include a function over a given range, use SETFNC or SETPAR.

Mainly for purposes of drawing axis scales, tick marks, and grids, the setup routines will divide the data range for

each axis into what will be referred to as major scale divisions or, simply, major divisions. For a linear scale each major division will correspond to 1., 2., or 5. units times some power of 10. For a logarithmic scale, each major division will correspond to one decade. Normally, scale numbers will be written only at major divisions. Each major division may be further subdivided for drawing tick marks or grids. With the exact data limits as passed to or computed by the setup routines the axis scales will not necessarily begin and end on major divisions. RNDPLT, SETFNC, and SETPAR will extend the data limits, if necessary, to reach major scale divisions. SETPLT will optionally do so. FIXPLT will always use the exact limits as specified in the calling sequence.

Normally, a 10 inch by 10-inch graph is set up. However, these dimensions can easily be changed by putting the desired values in the Common Parameter Area as described in Chapter 3.

Each time one of the setup routines is called a new graph is set up. After the first call, the paper or film is advanced with each call to any setup routine.

Data-plotting, function-plotting, or labeling subroutines may be called as often as desired to add to the present graph.

After all plotting calls have been made, ADVANS, described in Section 2.6, should be called to make sure all plotting information stored in the computer is moved to the tape.

2.3.2 FIXPLT, Set Up Graph with Fixed Limits

This subroutine is used to set up a graph when the exact scale limits to be used are known in advance.

The calling sequence is

```
CALL FIXPLT (XMIN,XMAX,YMIN,YMAX,TYPE,
MACHIN,XPAPER,YPAPER,BUFFER,LENGTH,NAME)
```

XMIN	Lower limit of x-axis, in user's units
XMAX	Upper limit of x-axis, in user's units
YMIN	Lower limit of y-axis, in user's units
YMAX	Upper limit of y-axis, in user's units
TYPE	Use one of the following:
'LINE'	Linear plot
'YLOG'	Log scale for y-axis, linear scale for x-axis
'XLOG'	Log scale for x-axis, linear scale for y-axis
'LOG'	Log scale for both axes
MACHIN	Use one of the following:
'MECH'	Pen-and-ink mechanical plotter
'CRT'	Cathode Ray Tube plotter
'PRNT'	Line printer
XPAPER,YPAPER	For CRT plots, line printer plots, or pen-and-ink plots on blank paper, use 0., 0. if you want a grid drawn; use -1., -1. if you do not want a grid drawn. For pen-and-ink plots on linear gridded paper, put the number of lines per inch, usually 20. or 25. For

pen-and-ink plots on log-gridded paper, put the number of cycles in the graph, usually 3. or 4.

BUFFER — Name of an area set aside in the user's program for use by the plotting routines. One way to do this is to include a statement such as DIMENSION BUFFER (4001) in the calling program.

LENGTH — Length, in four-byte words, of BUFFER, (3000 to 8000 suggested). For the example above, LENGTH = 4000.

NAME — User's name followed by a $ and enclosed in apostrophes, e.g., 'I.M.A.PLOT$'. This is used to make a special identification frame.

2.3.3 RNDPLT, Set Up Graph with Rounded Limits

The calling sequence is the same as for FIXPLT, Section 2.3.2. The only difference is that RNDPLT will extend the graph limits outward, if necessary, so that each axis will begin and end on a major scale division.

RNDPLT is appropriate when the graph limits are computed in the user's program but are not rounded.

2.3.4 SETPLT, Set Up Graph with Limits Chosen from Data

SETPLT is appropriate when the graph limits are unknown except that they should be large enough to include all the points in a given set of data. The calling sequence is:

```
CALL SETPLT (XARRAY,YARRAY,N,TYPE,
MACHIN,XPAPER,YPAPER,BUFFER,LENGTH,NAME)
```

XARRAY,YARRAY	Arrays of two or more values which will be searched for maxima and minima.
N	Number of values to be used from the XARRAY. The same number of values will be used from the YARRAY. $N \geq 2$.

The remaining parameters are defined as in FIXPLT, Section 2.3.2.

Normally, SETPLT will round the data limits outward, if necessary, so that each axis scale will begin and end on a major scale division. It is possible to avoid this feature by making N, the third parameter in the calling sequence, a negative number. Then, the limits will not be rounded and

N will be used for the number of points to be tested.

If several sets of data are to be plotted on one graph, it may be possible for SETPLT to test all the data at once. Suppose that $\{x_1, y_1\}$, a set of 50 points, and $\{x_2, y_2\}$, a set of 40 points, are to be plotted on the same graph and the graph should contain all the data:

```
DIMENSION        X1(50), Y1(50), X2(40), Y2(40)

EQUIVALENCE      (X1(51), X2(1)), (Y1(51), Y2(1))

        .
        .
        .
CALL SETPLT      (X1,Y1,90,TYPE,MACHIN,XPAPER,
                 YPAPER,BUFFER,LENGTH,NAME)
        .
        .
        .
```

2.3.5 SETFNC, Set Up Graph with Limits Chosen from Function

This is similar to SETPLT (Section 2.3.4) except that a function is searched rather than data arrays.

The calling sequence is:

```
CALL SETFNC (DIV,XMIN,XMAX,TYPE,MACHIN,XPAPER,YPAPER,BUFFER,LENGTH,NAME)
```

DIV	Maximum distance in inches that may be skipped while scanning F(x). For a very wiggly function, DIV should be small. If DIV = 0, the program uses .2 inch, which is often satisfactory.
XMIN,XMAX	Minimum and maximum x-values
TYPE	Use one of the following:
'LINE'	Linear plot
'YLOG'	Log scale for y-axis, linear scale

	for y-axis
'XLOG'	Log scale for x-axis, linear scale for y-axis
'LOG'	Log scale for both axes
MACHIN	Use of the following:
'MECH'	Pen-and-ink mechanical plotter
'CRT'	Cathode Ray Tube plotter
'PRNT'	Line printer
XPAPER,YPAPER	For CRT plots, line printer plots, or pen-and-ink plots on blank paper, use 0., 0. if you want a grid drawn; use -1., -1. if you do not want a grid drawn. For pen-and-ink plots on linear gridded paper, put the number of lines per inch, usually 20. or 25. For pen-and-ink plots on log-gridded paper, put the number of cycles in the graph, usually 3. or 4.
BUFFER	Name of an area set aside in the user's program for use by the plotting routines.
LENGTH	Length, in four-byte words, of BUFFER, (3000 to 8000 suggested).
NAME	User's name followed by a $ and enclosed in apostrophes. Example: 'I.M.A.PLOT$' This is used to make a special identification frame.

SETFNC examines the FUNCTION F(X), supplied by the user, between the limits XMIN and XMAX, and finds the minimum and maximum values of y = F(x). If no wiggles or peaks or valleys of widths less than DIV exist in the function, SETFNC should successfully find the true YMIN and YMAX.

The function examined must be called FUNCTION F(X) and must be supplied by the user. Other parameters may be

passed via COMMON statements. A computed GO TO may be used if it is needed to make F(X) the name of several different functions, including library functions such as SIN(X). An example is shown in Figure 2.3.5a.

```
Calling prcgram
 COMMON/SW/JGO
        .
        .
        .
    JGO = 1
 CALL SETFNC...
        .
        .
        .
    JGO = 2
 CALL SETFNC...
        .
        .
        .
```

```
      FUNCTION F(X)
      COMMON/SW/JGO
      GO TO (101, 102, 103,...), JGO
101   Y = SIN(X)
      GO TO 200
102   Y = COS(X)
      GO TO 200
103   Y = ATAN(X)
      GO TO 200
        .
        .
        .
200   F = Y
      RETURN
      END
```

Fig. 2.3.5a Use of Computed GO TO in Function Subprogram

Functions with exponent overflow or underflow can be handled by SETFNC but in most cases the scale chosen will obviously not include the entire range of the function. An intermediate range containing part of the function will be used. If this range is unsatisfactory, the user can then change his program to either specify a different XMIN or XMAX or specify his own choice of limits using FIXPLT.

Option: If DIV < 0, the frame will <u>not</u> be drawn. F(X) will be searched for the minimum and maximum values (YMIN and YMAX) of y = F(X). YMIN and YMAX, as well as XMIN and XMAX, will be stored in the appropriate locations within the Common Parameter Area (see Section 3.2: CPA(13), CPA(14), CPA(3) and CPA(4)).

2.3.6 SETPAR, Set Up Graph with Limits Chosen from Parametric Functions

This subroutine is used to scan a function parametrically as

$$x = F1(T)$$

$$y = F2(T)$$

where T is the parameter, and set up a graph that will contain this function. FUNCTION F1(T) and FUNCTION F2(T) must be supplied by the user.

The calling sequence is:

```
CALL SETPAR(DIV,TMIN,TMAX,TYPE,MACHIN,
  XPAPER,YPAPER,BUFFER,LENGTH,NAME)
```

DIV	Maximum step size in T that may be used in scanning. For a very wiggly function DIV should be small. If DIV = 0, the program chooses (TMAX-TMIN)/20, which is often satisfactory.
TMIN,TMAX	Minimum and maximum for the parameter variable T.

The remaining parameters are defined as in SETFNC, Section 2.3.5. Similar comments as made for SETFNC pertaining to overflow and underflow handling, as well as the negative DIV option, are applicable for SETPAR.

2.3.7 Options for Multiple Use of Setup Routines

A second call to SETPLT may look like the first. However, some shorter options are available.

1. CALL SETPLT (XARRAY,YARRAY,0)

   This will set up for a new graph with the same scales as the previous one. XARRAY and YARRAY are not used.

2. CALL SETPLT (XARRAY,YARRAY,N,0)

   New scales will be set by searching XARRAY and YARRAY. The other parameters will be taken from the previous setup call.

3. CALL SETPLT (XARRAY,YARRAY,N,TYPE,0)

   The next graph is to have a different TYPE from the

previous graph. Parameters after TYPE are taken from the previous call. Options analogous to 2 and 3 are also available for the other setup routines, by setting TYPE = 0 and MACHIN = 0, respectively.

2.4 TITLE, Graph Titles and Axis Labels

This is used to add a title, x-axis label, and y-axis label. These are centered.

The calling sequence is:

```
CALL TITLE(HGT,'GRAPH TITLE$','X-AXIS LABEL$','Y-AXIS LABEL$')
```

HGT	Height of top centered graph title. HGT = 0.4 is suggested. Half of HGT is used for the height of the axis labels.

The remainder of the calling sequence consists of three character strings, each terminated by a $, used for the graph title, the x-axis label, and the y-axis label, respectively. If any of these three is to be omitted, put just '$' in the corresponding position.

If you wish to have a dollar sign, $, appear as part of the title, read Chapter 3, Common Parameter Area, especially CPA(20).

Some other labeling subroutines (LABEL, ARROW, LEGEND) are described in Chapter 4. Subroutine LABEL (section 4.10) also plots centered titles and labels and contains several frequently needed options.

2.5 Some Data-Plotting Routines

2.5.1 Introduction

We describe in this section the data-plotting routines that were designed to be used with the setup routines described in Section 2.3.

Any of the data plotting routines can be used after any of the setup routines. Any number of data plotting routines can be used on the same graph.

The data plotting routines are illustrated in Figure 2.5.1. With the exception of the example given for RAYPLT, this figure is incomplete. Each of the other routines has more styles of data presentation than the one shown. For example, a more complete set of illustrations for LINPLT is given in Figure 2.5.3b.

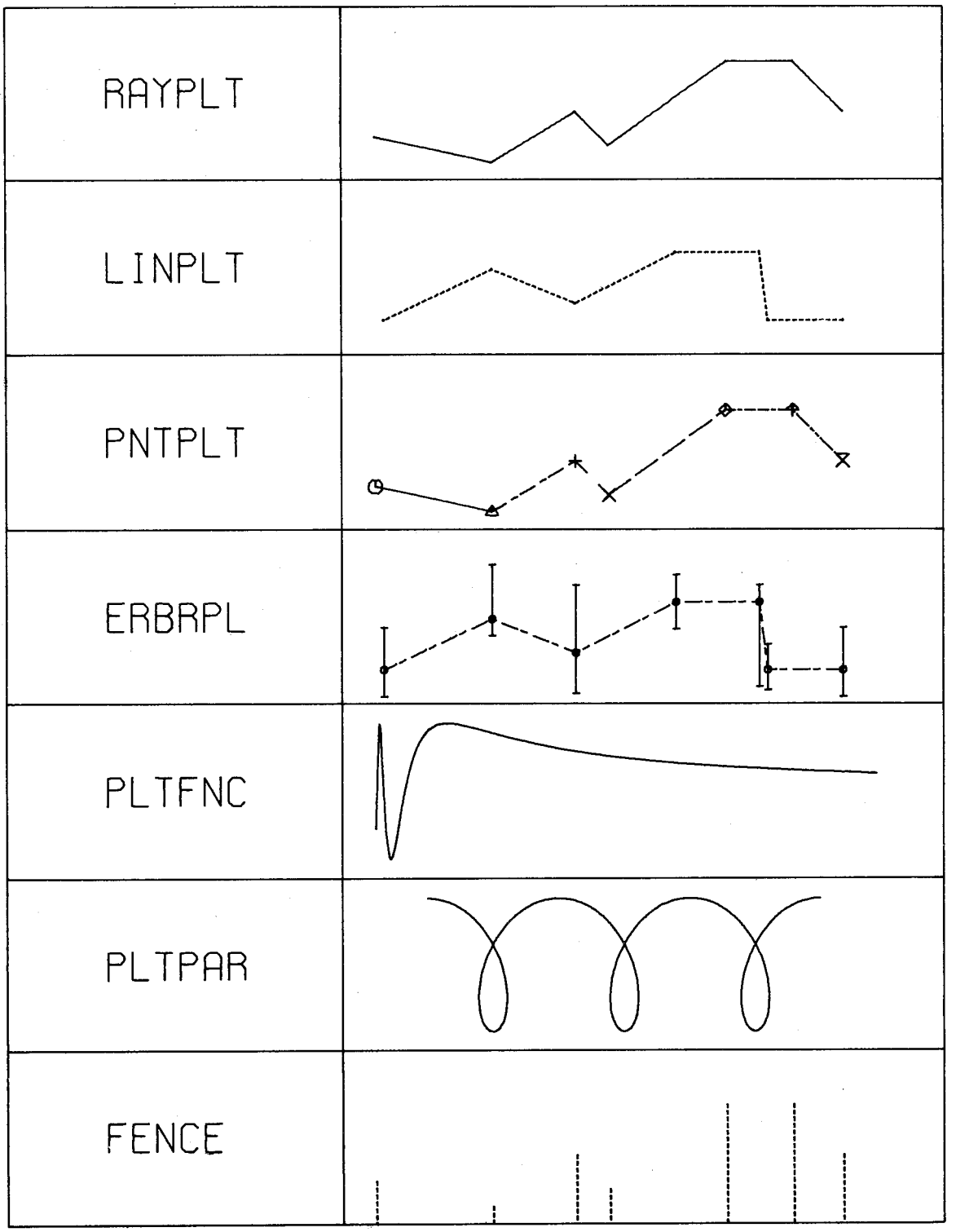


Fig. 2.5.1 Use of Data Plotting Routines

2.5.2 RAYPLT, Plot Data Points

This subroutine plots data points with connecting solid lines according to the scale factors set up in the most recent call to SETPLT, or other setup routine.

The calling sequence is:

	CALL RAYPLT (XARRAY, YARRAY, N)
XARRAY	Array of x-values, $\{x_i\}$
YARRAY	Array of y-values, $\{y_i\}$
N	Number of points to be plotted from $\{x_i, y_i\}$

The points $\{x_i, y_i\}$ will be plotted. A symbol will be plotted at each $\{x_i, y_i\}$ and the symbols will be connected by lines. The first time RAYPLT is called symbol type 0 (shown in Figure 4.10b) will be used. The next call to RAYPLT will use symbol type 1, and so on, until symbol 14 is used or a setup subroutine is called again. Then the next call to RAYPLT will use symbol type 0 again.

The data plotted by RAYPLT need not be the same data used for setting up the scales in the setup subroutines, so there is a possibility that a data point does not lie in the graph. RAYPLT does not plot outside the range set up for it. Instead the line will stop at the edge and a small arrow will be drawn pointing outward. Lines and symbols are discontinued until the data comes back in range.

It is also possible to use RAYPLT to plot a single array of data, $\{y_i\}$ with a constant spacing in the x-direction. The calling sequence is:

CALL RAYPLT (XINC, YARRAY, MN)

XINC	Increment for x-values, $x_{i+1} = x_i$ + XINC
YARRAY	Array of N values to be plotted as $\{y_i\}$
MN	A negative number whose absolute value is the number of values in YARRAY

The one-array call is distinguished from the two-array call by making the third parameter negative. This will plot (x_i, y_i) pairs with x_i = (i-1) * XINC + (the minimum x chosen by the setup subroutine).

2.5.3 LINPLT, Plot Data Points

LINPLT is similar to RAYPLT but allows the user more options. With LINPLT, the user can request a solid line, a dashed line, or no line, and also control which symbol, if any, is used.

The calling sequence is:

CALL LINPLT (XARRAY, YARRAY, N, IS, IDASH)

XARRAY	Array of x-values, $\{x_i\}$
YARRAY	Array of y-values, $\{y_i\}$
N	Number of points to be plotted from $\{x_i, y_i\}$

IS	Symbol number. The symbols available are shown in Figure 4.10b. Symbols 0 - 14 are centered. If IS < 0, no symbols are plotted.
IDASH	The number cf the dash pattern desired, from 0 to 6. The dash patterns are shown in Figure 2.5.3a. If IDASH = -1, no lines are drawn.

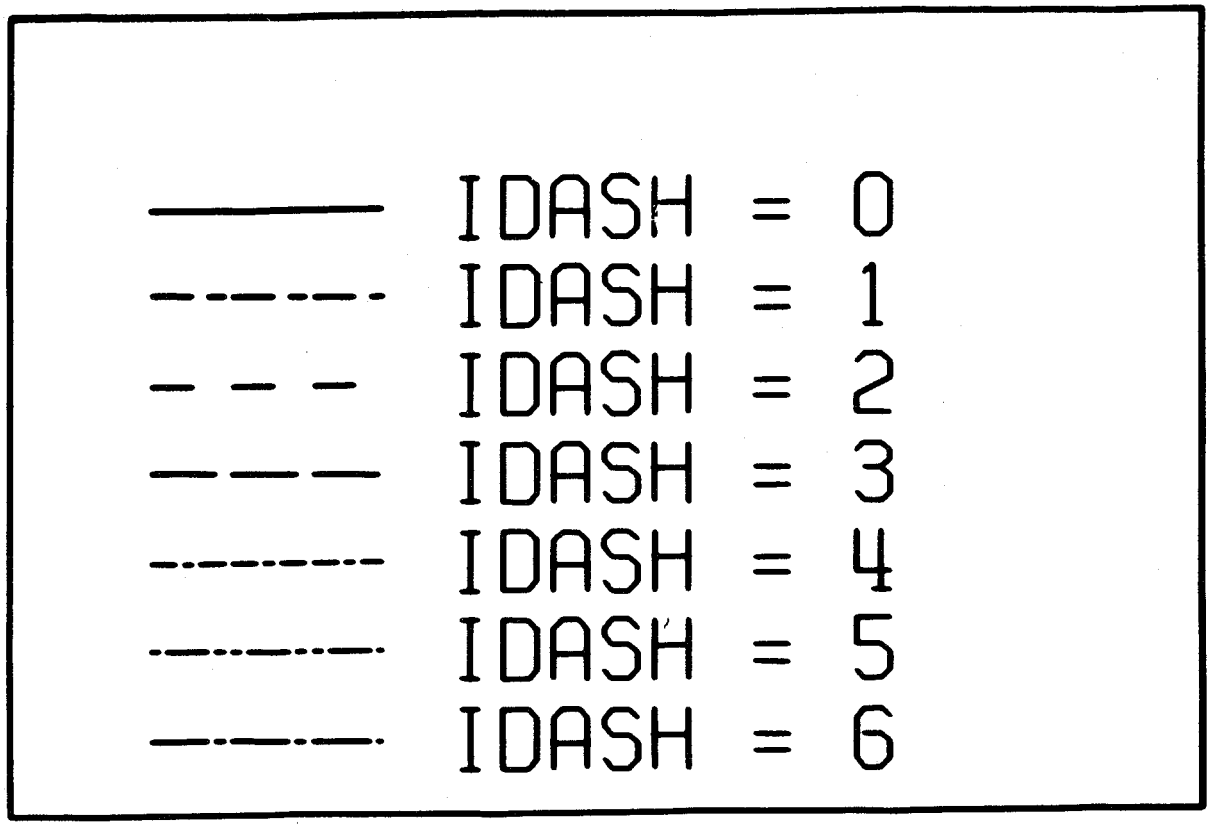


Fig. 2.5.3a Dash Patterns

As with RAYPLT, it is possible to use LINPLT to plot a single array of data, $\{y_i\}$ by setting N negative and using instead of XARRAY, a single value, the x-increment.

LINPLT is further discussed in Chapter 4, where a wide range of options involving direct use of the CPA is described.

See Figure 2.5.3b for some examples of data plotted with LINPLT.

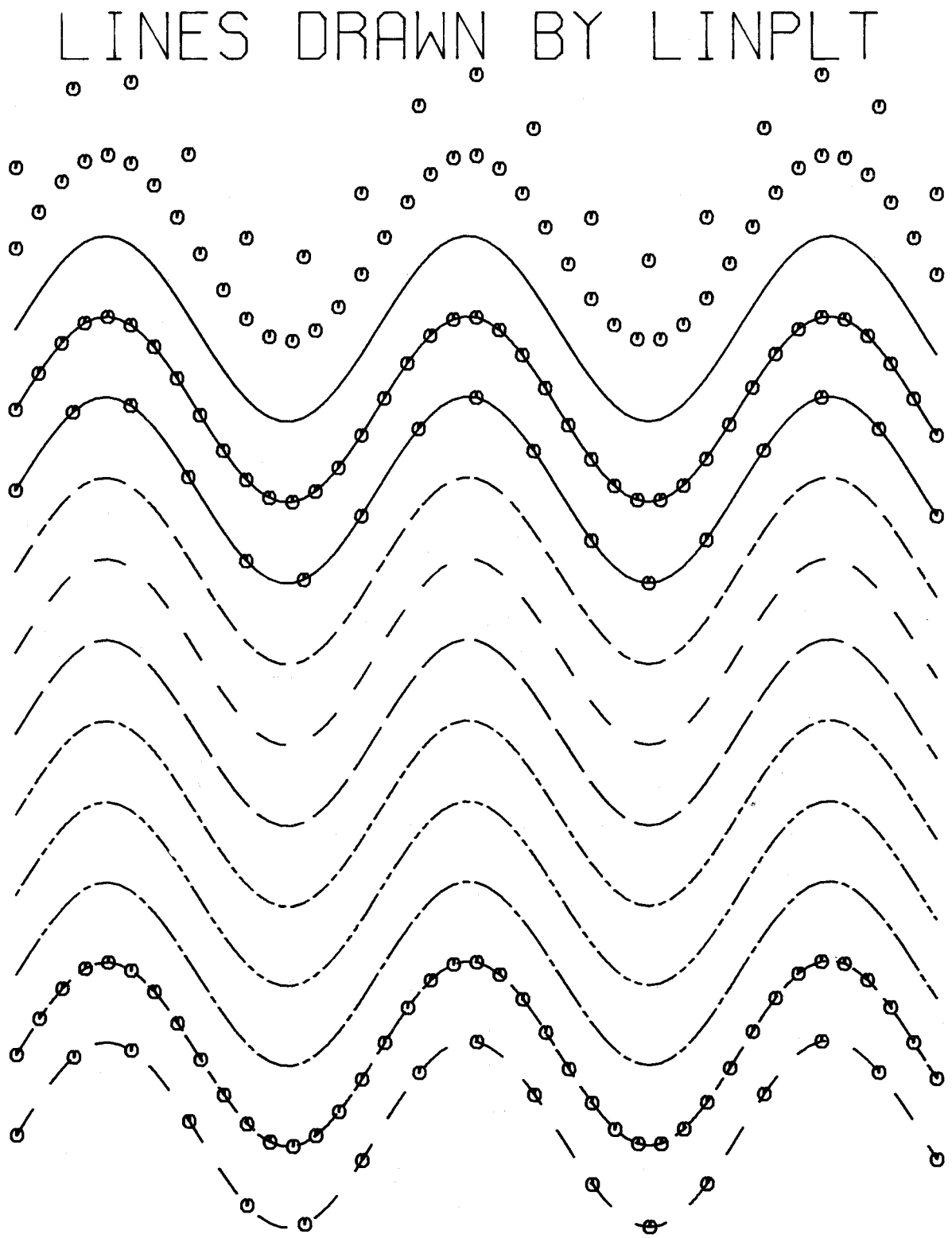


Fig. 2.5.3b Examples of Data Plotted with LINPLT

2.5.4 PNTPLT, Plot a Data Point

PNTPLT plots one data point with each call. A line from the previous pen or beam position can be drawn if desired. Repeated use of PNTPLT is less efficient than one use of RAYPLT or LINPLT. However, with PNTPLT it is possible to change symbols or dash pattern at each point.

The calling sequence is:

```
CALL PNTPLT (X, Y, ISYM, IDASH)
```

X,Y	Coordinates of point to be plotted, in user's units.
ISYM	An integer, 0 to 14 indicating the type of symbol to be used. The symbol types are shown in Figure 4.1.b. No symbol is drawn if ISYM < 0.

Caution: PNTPLT does <u>not</u> check for data points outside the scale limits of the current graph.

2.5.5 ERBRPL, Plot Data with Error Bars

ERBRPL is identical to LINPLT (Section 2.5.3) except that error bars can be included.

The calling sequence is:

```
CALL ERBRPL (XARRAY,YARRAY,N,IS,
IDASH,INDEX,ERRHI,ERRLO,ERRHI2,ERRLO2)
```

XARRAY,YARRAY,N,IS,IDASH are defined as in LINPLT.

INDEX Use one of the following:

0	no error bars
1	x error bars with hats
-1	x error bars without hats
2	y error bars with hats
-2	y error bars without hats
3	x and y error bars, with hats
-3	x and y error bars, without hats

ERRHI and ERRLO	first set of arrays of error values
ERRHI2 and ERRLO2	second set of arrays of error values (used only when |INDEX| = 3 and may be omitted otherwise).

The error arrays should always contain positive numbers (or zeros) to be added to or subtracted from XARRAY or YARRAY. If |INDEX| = 1, ERRHI and ERRLO are the arrays of values to be added to and subtracted from XARRAY. If |INDEX| = 2, ERRHI and ERRLO are used with YARRAY. In either case, ERRHI2 and ERRLO2 may be omitted. If |INDEX| = 3, ERRHI and ERRLO apply to XARRAY while ERRHI2 and ERRLO2 apply to YARRAY. Care must be taken so that no negative or zero values appear when using logarithmic scales.

2.5.6 FENCE, Plot Data with Vertical Lines

For each point FENCE draws a line from the x-axis to the point. The lines can be dashed or solid and the data points can be further identified by symbols.

The calling sequence is:

```
CALL FENCE(XARRAY,YARRAY,N,IS,IDASH)
```

XARRAY, YARRAY, N, IS, and IDASH are defined as for LINPLT, Section 2.5.3.

2.5.7 PLTFNC, Plot a Function

This subroutine is used to plot a function, y = F(x). The calling sequence is:

```
CALL PLTFNC(DIV,XMIN,XMAX,IDASH)
```

DIV	Maximum distance in inches that may be skipped while scanning F(x). For a very wiggly function, DIV should be small. If DIV = 0, the program uses .1 inch.
XMIN,XMAX	Plotting limits in user's coordinates. F(x) will be plotted from x = XMIN to x = XMAX.
IDASH	0 for a solid line; 1, 2, 3, 4, 5, or 6 for a dashed line. The dash patterns are illustrated in Figure 2.5.3a.

The function to be plotted must be called FUNCTION F(x) and must be supplied by the user. Other parameters may be passed via COMMON statements. A computed GO TO may be used if it is needed to make F(x) the name of several different functions, including library functions such as SIN(x). An example is shown in the discussion of SETFNC.

Functions with exponent underflow or overflow can be handled by PLTFNC and, in most cases, the user will see all of his function that lies within the ordinate limits previously chosen for the graph, perhaps by a call to SETFNC (Section 2.3.5).

2.5.8 PLTPAR, Plot a Parametric Function

This subroutine is used to plot a function described parametrically as

$$x = F1(T)$$

$$y = F2(T)$$

The calling sequence is:

```
CALL PLTPAR (DIV,TMIN,TMAX,IDASH)
```

DIV	Maximum distance (in T) that may be skipped while scanning F1(T) and F2(T). If DIV = 0., the program will choose (TMAX-TMIN)/50.
TMIN,TMAX	Minimum and maximum value of T, respectively.
IDASH	0 for a solid line; 1, 2, 3, 4, 5, or 6 for a dashed line. The dash patterns are illustrated in Figure 2.5.3a.

PLTPAR will plot F2 versus F1. T-values will be chosen at most DIV apart but significant changes in the direction of the curve will cause T-values to be chosen closer together, so that the curve will be fairly smooth.

FUNCTION F1(T) and FUNCTION F2(T) must be supplied by the user.

Functions with exponent overflow or underflow within the given limits for the parameter T can be handled by PLTPAR. In most cases, the user will see all of his function that lies within the scale limits previously chosen

for the current graph, perhaps by a call to SETPAR (Section 2.3.6).

2.6 ADVANS, Advance Film or Paper

The calling sequence is:

```
CALL ADVANS
```

ADVANS has no parameters. It will advance the film or paper to a new plotting area.

ORGRAPH uses a buffering system. Plot commands are stored in the computer until the buffer area is full or until a command is given to empty the buffer. The command to empty the buffer closes the picture. On magnetic tape a picture is taken to be a block, which is a set of records. Each block is numbered sequentially starting with 1.

A call to ADVANS will empty the buffer and close the picture.

Warning: At the first call to a setup subroutine (such as SETPLT) ORGRAPH is initialized and a picture is started. Subsequent calls to a setup routine will close the previous picture and start a new one. Therefore, the following sequence

```
CALL SETPLT (...)
CALL TITLE (...)
```

```
      CALL LINPLT (...)
    1 CALL ADVANS
    2 CALL SETPLT (...)
      CALL TITLE (...)
      CALL LINPLT (...)
    3 CALL ADVANS
```

will produce <u>three</u> blocks on magnetic tape; one for each labeled statement. The "picture" (or, more precisely, block) closed by statement 2 is empty. As a consequence a request to plot 2 graphs may result in the plotting of only one graph. This happens because the operator will set the plotter for 2 <u>blocks</u>. He may remove the tape as soon as the second block is finished.

The remedy is

```
      CALL SETPLT (...)
      CALL TITLE (...)
      CALL LINPLT (...)
      CALL SETPLT (...)
      CALL TITLE (...)
      CALL LINPLT (...)
      CALL ADVANS
```

Here ADVANS is called only after <u>all</u> the plotting is done.

The END = parameter in a READ statement is useful for a program where several sets of data are to be plotted:

```
100 READ (5,1,END = 900) DATA
          .
          .
          .
     PLOTTING CALLS
          .
          .
          .
     GO TO 100
900 CALL ADVANS
     STOP
     END
```

3. COMMON PARAMETER AREA

3.1 Introduction

This chapter describes the parameters appearing in the Common Parameter Area (CPA), which is used by most ORGRAPH subroutines.

Initially the system sets each word in the CPA to some value by a DATA statement. Consequently, it is only necessary to change the values of those parameters initially set to values other than the required ones. Often the values initially assigned to the CPA need not be changed to obtain a desired graph.

A full description of the CPA is given in Section 3.2. Some notes on the CPA are found in Section 3.3. The method for changing the CPA is given in Section 3.4. Section 3.5 contains a short description in table form of the CPA.

3.2. Definition of the Common Parameter Area

The Common Parameter Area is a labeled COMMON block of 50 words. Some of the parameters are used as REAL*4; some are used as INTEGER*4. In the following list those values marked ICPA are used as INTEGER*4.

ICPA(1) Repetition factor for x-array.

See Section 1.6.2. To plot every (four-byte)

word in the x-array, ICPA(1) = 1. To plot every other word, ICPA(1) = 2. This value is used when the x-array is REAL*8. To plot every third word, ICPA(1) = 3; and so on. If the x-array is INTEGER*4, then set ICPA(1) = -1. If ICPA(1) is negative, the x-array is taken to be INTEGER*4 and the repetition factor is |ICPA(1)| .

Preset value: +1.

CPA(2) Type of scaling function for x-axis.

See Section 1.6.4.

'LINE' means linear scale.

'LOG1' means log scale.

If the number of cycles requested is smaller than the number of cycles in the range of x-values, then the number of cycles requested is used <u>starting</u> with the minimum.

'LOG2' means log scale.

If the number of cycles requested is smaller than the number of cycles in the range of x-values, then the number of cycles requested is used <u>ending</u> with the maximum.

Preset value: 'LINE'

CPA(3) Graph minimum for x-axis.

For log scale it is the log of the graph minimum.

Note: The set-up routines such as SETPLT set this word by calling subroutines RANGE (which

stores x-min in it) and SCALE (which modifies it to the graph minimum).

Preset value: 0.0.

CPA(4) Graph maximum for the x-axis.

For log scale it is the log of the graph maximum. The note on CPA(3) with the appropriate changes applies to CPA(4).

Preset value: 10.0.

CPA(5) Length of graph in inches (along the x-axis)

Preset value: 10.0.

CPA(6) Units per division or inches per cycle, x-axis.

For linear scale: units per major division along the x-axis.

For log scale: length of one cycle in inches.

Preset value: 1.0.

Note: Normally <u>not</u> directly set by user. The user should define CPA(6) only if he is not using one of the setup routines (Section 2.3) or subroutine SCALE (Section 4.5).

CPA(7) Margin available (top and bottom), for labeling the x-axis above or below the graph, in inches.

Preset value: 0.5.

CPA(8) Alignment for gridded paper, x-axis.

For blank paper, CRT, or printer, use zero.

For preprinted gridded paper that is linear along

the x-axis, use number of divisions per inch.

For preprinted gridded paper that is logarithmic along the x-axis, use the number of cycles.

Note: Intended for aligning the bold divisions of the preprinted gridded paper with the scales along the x-axis.

Preset value: 0.0.

CPA(9) Height of data symbols in inches.

Preset value: 0.1.

ICPA(10) Symbol frequency control.

This word is used to control the number of data points per symbol when symbols have been requested in a call to LINPLT or ERBRPL or when RAYPLT is used. It does not control which symbol is used.

1: symbols at every point

2: symbols at every other point, etc.

Preset value: +1

<u>Note</u>: CPA(11) through CPA(18) are the y-axis parameters corresponding to the x-axis parameters defined in CPA(1) through CPA(8).

ICPA(11) Repetition factor for y-array.

See Section 1.6.3. To plot every (four-byte) word in the y-array ICPA(11) = 1. To plot every other word, ICPA(11) = 2. This value is used when the y-array is REAL*8. To plot every third

word, ICPA(11) = 3; and so on. If the y-array is INTEGER*4, then set ICPA(11) = -1. If ICPA(11) is negative, the y-array is taken to be INTEGER*4 and the repetition factor is |ICPA(11)| .

Preset value: +1.

CPA(12) Type of scaling function for the y-axis.

See Section 1.6.4.

'LINE' means linear scale.

'LOG1' means log scale.

If the number of cycles requested is smaller than the number of cycles in the range of y-values, then the number of cycles requested is used <u>starting</u> with the minimum.

'LOG2' means log scale.

If the number of cycles requested is smaller than the number of cycles in the range of y-values, then the number of cycles requested is used <u>ending</u> with the maximum.

Preset value: 'LINE'.

CPA(13) Graph minimum for y-axis.

For log scale it is the log of the graph minimum.

Note: The setup routines such as SETPLT set this word by calling subroutines RANGE (which stores y-min in it) and SCALE (which modifies it to the graph minimum).

Preset value: 0.0.

CPA(14) Graph maximum for the y-axis.

For log scale it is the log of the graph maximum.

The note on CPA(13) with the appropriate changes applies to CPA(14).

Preset value: 10.0.

CPA(15) Height of graph in inches (along the y-axis).

Preset value: 10.0.

CPA(16) Units per division or inches per cycle, y-axis.

For linear scale: units per major division along the y-axis.

For log scale: height of one cycle in inches.

Preset value: 1.0.

Note: Normally <u>not</u> directly set by user. The user should define CPA(16) only if he is not using one of the setup routines (Section 2.3) or subroutine SCALE (Section 4.5).

CPA(17) Margin available (left and right), for labeling the y-axis on the left and right sides of the graph, in inches.

Preset value: 1.0.

CPA(18) Alignment for gridded paper, y-axis.

For blank paper, CRT, or printer, use zero.

For preprinted gridded paper that is linear along the y-axis, use number of divisions per inch.

For preprinted gridded paper that is logarithmic along the y-axis, use the number of cycles.

Note: Intended for aligning the bold divisions of preprinted gridded paper with the scales along the y-axis.

Preset value: 0.0.

ICPA(19) Out-of-bounds mode.

This is used when a point to be plotted with RAYPLT, LINPLT, ERBRPL, FENCE, PLTFNC, or PLTPAR lies outside of the graph boundaries.

0: no arrows if data goes outside boundaries.

1: arrows at point of interpolated boundary crossings.

2: arrows and printing of interpolated values.

+3: plotting will stop when an out-of-bound point is encountered. If this mode is used with ERBRPL, LINPLT, and RAYPLT, then control is returned to the user's program when an out-of-bound point is found.

-3: plotting will stop when an out-of-bound point is encountered. If X(I), Y(I) is the out-of-bound point, then ICPA(19) is set to I. Control is returned to the user's program.

Note: This mode should be used only with ERBRPL, LINPLT, and RAYPLT. Note also that in mode -3 this word must be reset each time one of the above-mentioned plotting routines is used.

6: no checking for out-of-bound points. Use with caution.

7: draw the current symbol at the interpolated boundary crossing. This mode is used only if symbols are used in plotting the data points.

Preset value: 1

CPA(20) Flag symbol used during labeling.

This flag is used as the terminating symbol for an alphanumeric string in TITLE, LABEL, ARROW, or LEGEND.

Preset value: $

CPA(21) Plotter

'MECH': mechanical plotter

'CRT': Cathode Ray Tube plotter

'PRNT': line printer

'NONE': subroutine INTL has not been called.

This word is set by subroutine INTL.

Note: The set-up routines such as SETPLT call INTL.

Preset value: 'NONE'.

ICPA(22) Light intensity for CRT labeling.

Preset value: 16

ICPA(23) Light intensity for CRT lines.

Preset value: 18

ICPA(24) Light intensity for CRT points.

Preset value: 25

CPA(25) Distance (in inches) from x-axis to labels.

This is the distance between the x-axis and the farthest side of the symbols in the label.

Preset value: .5

CPA(26) Height (in inches) of largest tick mark on x-axis.

0.0 means no tick marks.

Preset value: .15

CPA(27) Distance from x-axis to scales.

The distance in inches between the x-axis and the closest side of the numbers to be drawn.

Preset value: .05

CPA(28) Height (in inches) of numbers used in scales for the x-axis.

0.0 means no scales

Preset value: .15

ICPA(30) Scale direction control.

It is usually requested that the scales on a graph be set so that the graph minimum is at the left-hand side on the x-axis and the bottom on

the y-axis. The graph maximum is set at the right-hand side and the top, respectively. This parameter allows the scales to be set backward. The following choices are available:

0: Forward on both the x-axis and the y-axis.

1: Backward on x only.

2: Backward on y only.

3: Backward on x and on y

Preset value: 0

ICPA(31) Suppression of ends of scales.

At the corner of a graph where scaled axes meet, it may happen that the scales of the end points along the different axes fall one on top of the other. One way to avoid this is to suppress the scale at one of the end points.

The integer in this word determines which scale ends, if any, are to be suppressed as follows:

0: No scale end suppressed.

1: Leftmost scale along abscissa suppressed.

2: Rightmost scale along abscissa suppressed.

4: Lowest ordinate scale suppressed.

8: Topmost ordinate scale suppressed.

The sum of two or more distinct integers above will suppress the obvious combination of scale ends. Thus ICPA(31) = 7 will suppress the leftmost and rightmost abscissa scales as well as

the lowest ordinate scales. Note that ICPA(31) = 15 will suppress all the scale ends.

Preset value: 4

<u>Note</u>: CPA(35) through CPA(38) are the y-axis parameters corresponding to the x-axis parameters defined in CPA(25) through CPA(28).

CPA(35) Distance (in inches) from y-axis to labels.

This is the distance between the y-axis and the farthest side of the symbols used in the label.

Preset value: 1.0

CPA(36) Height (in inches) of largest tick mark on y-axis.

0.0 means no tick marks.

Preset value: .15

CPA(37) Distance from y-axis to scales.

The distance in inches between the y-axis and the closest side of the numbers to be drawn.

Preset value: .05

CPA(38) Height in inches of numbers used in scales for y-axis.

0.0 means no scales.

Preset value: .15

ICPA(41) Logarithmic scale control. ICPA(41) = 0 will produce nine tick marks per decade (i.e., at one, two, ..., eight, and nine times 10) regardless of length of decade and will force scale numbers

to be written only at one times 10 for each decade.

Preset value: 1

CPA(42) Minimum length (in inches) of a logarithmic cycle. Extra cycles will be cut off according to the contents of CPA(2) for the x-axis and CPA(12) for the Y-axis.

Preset value: 1.0.

CPA(45) Distance (in inches) between graphs.

Meaningful only for the mechanical plotter.

The distance that the paper will be advanced when subroutine ADVANS is called.

Preset value: 4.0

ICPA(46) Start symbols for data points.

Used only by RAYPLT, LINPLT, and ERBRPL.

If ICPA(46) = I and symbols are used to plot the data, then the symbols will be used starting with the I'th point.

Preset value: 1

ICPA(47) Stop symbols for data points.

Used only by RAYPLT, LINPLT, and ERBRPL.

If ICPA(47) = J and symbols are used to plot the data, then the symbols will not be used past the J'th point.

0 is interpreted to mean that symbols will be used through the last point to be plotted.

Preset value: 0

CPA(48) Length of dash pattern.

This word controls the length in inches of each distinct piece of the dash pattern being currently used. With it the user can obtain distinguishable differences within the same pattern.

Preset value: 0.5

CPA(49) Angle of rotation.

The angle of rotation in degrees for the picture. An angle of 90 will allow the y-axis to run along the length of the paper.

Preset value: 0.0

3.3. Notes on the Common Parameter Area

The preset values for the margins are 0.5 inch for the top and bottom margins, CPA(7), and 1.0 inch for the left and right margins, CPA(17). The margin values are used as soon as the package is initialized. If the margins are to be changed by the user, the change should be made before the package is initialized. The package is initialized by calling INTL. Subroutine INTL is called by the setup routines such as SETPLT. Therefore, the setup routines also initialize the package.

For single-precision data stored in singly-dimensioned arrays, the repetition factors, ICPA(1) and ICPA(11), should be 1, as preset. For double-precision data stored in singly-dimensioned arrays, the repetition factor should be 2. The 32 low-order bits are not used in plotting. Doubly-dimensioned arrays are stored with the values of each column (first index) consecutively placed and the columns placed end-to-end. Thus a set of single-precision X values dimensioned as X(5,60) will appear in the machine as

X(1,1),X(2,1),X(3,1),X(4,1),X(5,1),X(1,2),...,X(5,60).

To plot X(1,K) for K = 1,60 the value in ICPA(1) should be 5. However, if X is dimensioned as X(60,5) and you wish to plot X(K,1) for K = 1,60, then ICPA(1) should be set to 1, which is the preset value of ICPA(1).

The size of the graph, CPA(5) and CPA(15), is set for a 10-inch-by-10-inch graph. In the Cathode Ray Tube plot the picture frame is 14 inches long. To fill the frame (if desired) the value of CPA(5) would be 14.0.

The height of symbols used in plotting data, CPA(9), is preset to 0.1 inch. If the graph is to be reduced photographically for publication, a larger value may be desirable. Note also that the height of the scale numbers, CPA(25), is preset at 0.15.

The out-of-bounds mode, ICPA(19), is used only when a data point falls outside the frame. Its preset value will result in arrows being drawn at the point the interpolated line (from the last point drawn in the graph to the out-of-bounds point) intersects the boundary of the graph. If ICPA(19) = -3, then the user should exercise great care in resetting ICPA(19) every time control is passed to the main program.

In alphanumeric strings used for labels and titles, the symbol which matches CPA(20) is taken to be a flag and is not plotted. The preset value is '$'. If the user wants to plot a $, then CPA(20) must be changed.

3.4. Changing the CPA

A special subroutine is available for putting values into or getting values out of the Common Parameter Area. The calling sequence is

```
CALL QQQCPA(LOC,VALUE)
```

LOC	An integer, $-50 \leq LOC \leq 50$. If LOC > 0, then VALUE will be put in CPA(LOC). If LOC < 0, then CPA(-LOC) will be put in VALUE. If LOC=0, the entire CPA (50 words) will be printed, as a debugging aid.
VALUE	The number stored in CPA if LOC is positive, or number retrieved if LOC is negative. Not used if LOC is zero. VALUE should be REAL if the corresponding value in the Common Parameter Area is REAL, or INTEGER if the corresponding CPA value is INTEGER.

Examples:

1. CALL QQQCPA (1,2) sets CPA(1) to 2
2. CALL QQQCPA (-4,XMAX) sets XMAX to CPA(4)
3. CALL QQQCPA (0) prints CPA

Two subroutines, QQMARG and QQSIZE, can be used to change the margins and the graph size, respectively. The calling sequences are

```
CALL QQMARG(XMARG,YMARG)
```

XMARG	Top and bottom margins in inches (CPA(7))
YMARG	Left and right margins in inches (CPA(17))

```
CALL CQSIZE(XLNTH,YHGT)
```

XLNTH	Length of graph (along x-axis, CPA(5))
YHGT	Height of graph (along y-axis, CPA(15))

Note that for pen - and - ink plots, YHGT + 2*XMARG must be less than or equal to the paper width (11 inches for the narrow plotter, 29.5 inches for the wide plotter). For Cathode-Ray-Tube plots, YHGT + 2*XMARG must be less than or equal to 13 inches, and XLNTH + 2*YMARG must be less than 19 inches.

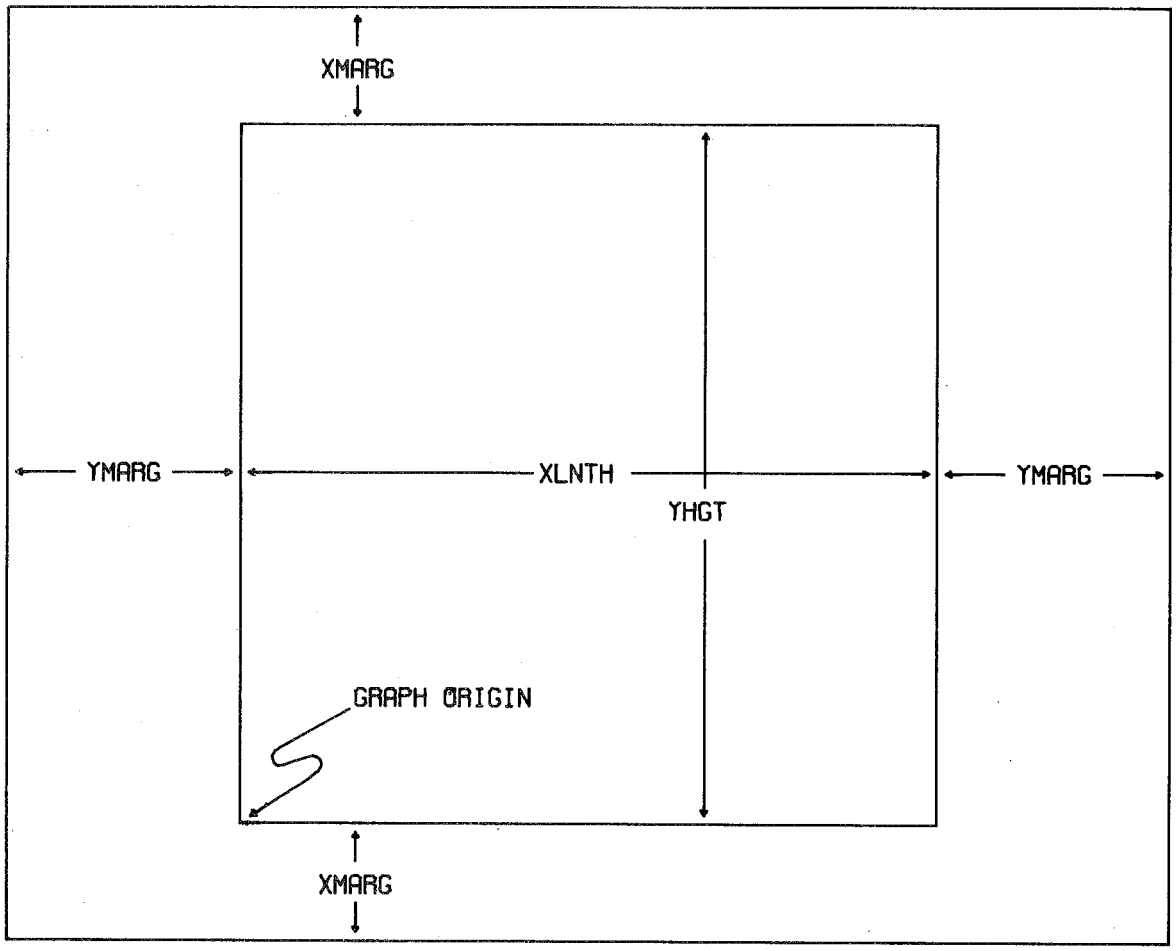


Fig. 3.4 Graph Size and Margins

3.5. Table of the CPA

Distances, heights, margins, and lengths are in inches.

Parameter x	Parameter y	Description	Preset Value
ICPA(1)	ICPA(11)	Repetition factor	+1
CPA(2)	CPA(12)	Type of scaling function	'LINE'
CPA(3)	CPA(13)	Graph minimum	0.0
CPA(4)	CPA(14)	Graph maximum	10.0
CPA(5)	CPA(15)	Length and width of graph	10.0
CPA(6)	CPA(16)	Units per division or inches per cycle	1.0
CPA(7)	CPA(17)	Margin available	0.5 1.0
CPA(8)	CPA(18)	Alignment for gridded paper	0.0
CPA(9)		Height for data symbols	0.1
CPA(10)		Symbol and line control	+1
ICPA(19)		Out-of-bounds mode	+1
CPA(20)		Flag symbol used in labeling	$
CPA(21)		Plotter	'NONE'
ICPA(22)		Light intensity for CRT labeling	16
ICPA(23)		Light intensity for CRT lines	18
ICPA(24)		Light intensity for CRT points	25
CPA(25)	CPA(35)	Distance from axis to label	0.5

CPA(26)	CPA(36)	Height of largest tick mark	0.15
CPA(27)	CPA(37)	Distance from axis to scales	0.05
CPA(28)	CPA(38)	Height of numbers used in scales	0.15
ICPA(30)		Forward or backward scales	0
ICPA(31)		Suppression of ends of scales	4
ICPA(41)		Logarithmic scale control	1
CPA(42)		Minimum length for a logarithmic cycle	1.0
CPA(45)		Distance between graphs	4.0
ICPA(46)		Start symbols for data points	1
ICPA(47)		Stop symbols for data points	0
CPA(48)		Length of dash pattern	0.5
CPA(49)		Angle of rotation	0.0

4. BUILDING BLOCK SUBROUTINES

4.1. Introduction

Each of the Building Block Subroutines does only a small part of making a graph. They are provided in this way so that the user can combine them as needed for a "special" problem; that is, one that cannot be solved with the Combination Subroutines described in Chapters 2 and 5.

The user's program may call both Building Block Subroutines and Combination Subroutines, as needed.

The Building Block Subroutines are

Name	Purpose	Section
INTL	Initialize ORGRAPH	4.2
RANGE	Find data limits	4.3
ORDER	Arrange data in order	4.4
SCALE	Set up scale factors	4.5
AXIS	Draw scales	4.6
BOX	Draw a box or frame	4.7
GRID	Draw grid lines	4.8
LEGEND	Draw a legend	4.9
LABEL	Plot a label	4.10
ARROW	Draw an arrow	4.11
QQINCH	User's units to inches	4.12
QQLINE	Draw a line	4.13
QQPORC	Pen or beam motion	4.14

QQQSYM	Draw symbols	4.15
QQQNUM	Draw numbers	4.16
QQWHER	Current pen position	4.17
QQQORG	Change coordinate system	4.18
QQNEWS	ORGRAPH news	4.19

4.2. INTL, Initialize ORGRAPH

INTL must be called before any plotting with ORGRAPH can be done. The setup routines (Section 2.3) begin by calling INTL. INTL sets certain internal parameters in ORGRAPH to the proper starting values.

The calling sequence is:

```
CALL INTL (MACHIN, BUFFER, LENGTH, NAME)
```

MACHIN	Use one of the following:
'MECH'	Pen-and-ink mechanical plotter
'CRT'	Cathode Ray Tube plotter
'PRNT'	Line printer
BUFFER	Name of an area set aside in the user's program for use by the plotting routines.
LENGTH	Length, in four-byte words, of BUFFER. 3000 to 8000 is recommended.
NAME	User's name, 12 characters or less, ending with a $ and enclosed in apostrophes. Example: 'SMITH$' or 'JOHN Q. DOE$'. Used to plot a special name frame.

Once INTL has been called, the type of plotter has been specified and all further plotting will be routed to that plotter (unless INTL is called again with a different MACHIN).

INTL should be called at the beginning of each new graph if the setup routines (Section 2.3) are not used.

4.3. RANGE, Find Data Limits

This subroutine will scan a set of values and find the maximum and minimum. The maximum and minimum values are placed in the CPA. RANGE is useful primarily when the graph is tc be set up according to the limits of the data.

The calling sequence is:

CALL RANGE(XARRAY,NX) for the x-axis;

CALL RANGE(YARRAY,MNY) fcr the y-axis;

XARRAY	Array of x-values
NX	Number of elements to be scanned in XARRAY
YARRAY	Array of y-values
MNY	Negative number whose absolute value is the number of elements to be scanned in YARRAY.

Range will scan the array and find the minimum and maximum. For the first call shown above (positive second parameter) the minimum is put in CPA(3) and the maximum is put in CPA(4). For the second call (negative parameter) the minimum is put in CPA(13) and the maximum in CPA(14).

RANGE uses the repetition factor, CPA(1) for x-axis, CPA(11) for the y-axis.

RANGE does not actually draw anything. It is only used to set values in the CPA.

4.4. ORDER, Arrange Data in Order

Suppose that there is a set of x_i, y_i pairs to be plotted. The $\{x_i\}$ are stored in XARRAY. The $\{y_i\}$ are stored in YARRAY. Suppose, further, that the $\{x_i\}$ are not in order, that is, for some i, $x_i > x_{i+1}$. It is usually more efficient to order the XARRAY before plotting. Also, if the unordered data points are plotted with connecting lines, the lines will zigzag.

A subroutine is provided to put the $\{x_i\}$ in nondescending order and "carry" the $\{y_i\}$ along, that is, the interchanges made in XARRAY will also be made in YARRAY. The calling sequence is

```
CALL ORDER (XARRAY, YARRAY, NX)
```

XARRAY	Array of $\{x_i\}$
YARRAY	Array of $\{y_i\}$
NX	Number of points in XARRAY

NX numbers in XARRAY will be ordered. The minimum and maximum values, X_{min} and X_{max}, will be put in CPA(3) and CPA(4) respectively, so that RANGE need not be called for the $\{x_i\}$. However, RANGE should still be called for the $\{y_i\}$.

If ICPA(1) = 1, the $\{x_i\}$ are considered to be single-precision values stored consecutively. If ICPA(1) = 2, the $\{x_i\}$ are considered to be in alternate storage locations. Thus, double-precision data may be sorted by setting CPA(1) = 2; the low-order part will be moved with the high-order part. (However, the comparison is still done in single precision;

values which do not differ in the high-order part may be sorted incorrectly.)

Option 1: Suppose that there are five arrays of y-data to be plotted versus one array of x-data. Suppose the x-values are stored in XARRAY with DIMENSION XARRAY(30) and the y-values are stored in YARRAY with DIMENSION YARRAY(5,30). Suppose that the x-data are to be ordered and all five sets of y-data are to be moved accordingly. To do this, set ICPA(11), the y-repetition factor, to 5:

```
CALL QQCCPA(11,5)
CALL ORDER (XARRAY, YARRAY, 30)
```

Every time an x is moved in the ordering process, all five y's are moved also.

Option 2: It is also possible to arrange the data in order of increasing y-values. For this, the calling sequence is:

```
CALL ORDER(YARRAY,XARRAY,MNY)
```

MNY	Negative number whose absolute value is the number of elements to be sorted in YARRAY.

This behaves very much like the case where the third parameter is positive. The difference is that the minimum and maximum values of the first-mentioned array, YARRAY in this case, are put in CPA(13) and CPA(14), respectively, instead of CPA(3) and CPA(4). The repetition factor, ICPA(11), is used for the first-mentioned array; ICPA(1) for the second array.

ORDER does no plotting. It may be used for purposes not involving plotting. It is not necessary to initialize ORGRAPH (Section 4.2, INTL) before using ORDER.

Warning: The arrays are sorted in place. Thus, the original order may be destroyed. If the original order is needed later, the arrays should be copied before ORDER is called.

Another warning: ORDER is usually called before SCALE. This is because ORDER puts values in the CPA which may later be changed by SCALE. If ORDER is used after SCALE (or after any of the set-up routines in Section 2.3) the appropriate CPA values must be saved before ORDER is called and restored afterwards, e.g.

```
CALL QQQCPA (-3,SAVE3)
CALL QQQCPA (-4,SAVE4)
CALL ORDER (XARRAY, YARRAY, NX)
CALL QQQCPA (3, SAVE3)
CALL QQQCPA (4, SAVE4)
```

4.5. SCALE, Set Up Scale Factors

SCALE sets scale factors, graph size, scale minimum and maximum. No plotting is done by SCALE.

Normally, SCALE is called twice, once for the x-axis and once for the y-axis. With these two calls, SCALE sets CPA(2), CPA(3), CPA(4), CPA(5), CPA(6), CPA(8), CPA(12), CPA(13), CPA(14), CPA(15), CPA(16), and CPA(18).

There are four ways to use SCALE, described in the following sections. Before SCALE is called, data limits should be in

CPA(3), CPA(4), CPA(13), and CPA(14). They may be entered by calling QQQCPA, Section 3.4, or RANGE, Section 4.3, or ORDER, Section 4.4.

If you wish to specify the graph size and wish the graph to cover the range given in the CPA, see Scale 1, Section 4.5.1.

If you wish to specify the graph size and also specify the amount of space between the extreme data points and the edge of the graph, see Scale 2, Section 4.5.2.

If you wish to specify the units per major division and length in inches of a major division, rather than the graph length, see Scale 3, Section 4.5.3.

If you wish to specify the units per major division and graph size <u>or</u> units per major division and grid lines per inch on gridded paper, see Scale 4, Section 4.5.4.

4.5.1 Scale 1

This is the most common scaling option and is designed so that the user can specify the graph size (such as 10 inches by 14 inches).

The calling sequence is:

```
CALL SCALE(1,GLNTH,PAPER,FUNC)
```

for the x-axis scale, or

```
CALL SCALE(-1,GLNTH,PAPER,FUNC)
```

for the y-axis scale.

GLNTH	Length (or height) of graph in inches
PAPER	For blank paper, Cathode Ray Tube plotter or printer: 0. For linear-scale gridded paper: the number of grid lines per inch, usually 20. or 25. For log-scale gridded paper: the number of cycles, usually 3. or 4.
FUNC	For a linear scale: 'LINE' For a log scale: 'LOG1' or 'LOG2'

'LOG1' and 'LOG2' are equivalent if PAPER cycles are enough to accommodate the range requested. If this condition is not satisfied, the top part of the range will be cut off for 'LOG1'; the bottom part will be cut off for 'LOG2'. Thus, for 'LOG1' the bottom of the scale is determined from CPA(3), x-axis, or CPA(13), y-axis. For 'LOG2' the top of the scale is determined from CPA(4), x-axis, or CPA(14), y-axis. If 'LOG' is specified, 'LOG1' is assumed.

GLNTH is divided into major scale divisions. For linear graphs, each major division will correspond to one, two, or five times some power of ten. If blank paper is specified, the divisions will be from .5 to 1 inch in length where possible. If a grid is specified, 10 grid lines will be considered one major division and a scale will be chosen to make the grid equal to GLNTH.

Usually, the graph limits are made a little larger than just enough to include the range requested. The graph then begins and ends on a major division mark. However, if the user wishes to have the extreme data points lie precisely on the edge of the graph, he may indicate this wish by making GLNTH negative. The graph length (or height) will be GLNTH for blank paper and may be slightly less than GLNTH for gridded paper (so that the scale can match the grid).

4.5.2 Scale 2

Scale 2 is very much like Scale 1, except that Scale 2 allows the user to insure that there will be a specific SPACE between the extreme data points and the edge of the graph.

The calling sequence is:

```
CALL SCALE (2,GLNTH,PAPER,FUNC,SPACE)
```

for the x-axis scale, or

```
CALL SCALE (-2,GLNTH,PAPER, FUNC,SPACE)
```

for the y-axis scale

GLNTH	Length (or height) of graph in inches
PAPER	For blank paper, CRT plotter or printer: 0. For linear-scale gridded paper: the number of grid lines per inch. For log-scale gridded paper: the number of cycles.
FUNC	For a linear scale: 'LINE' For a log scale with excess, if any, cut off at top: 'LOG1' For a log scale with excess, if any, cut off at bottom: 'LOG1' (see Scale 1 for a longer description).
SPACE	Minimum distance in inches between the data and the edges of the graph.

GLNTH must be positive in Scale 2. In Scale 1 there is a chance that a data point will fall on the edge of the graph. With Scale 2 this can be avoided. Also, with Scale 2, some SPACE can be provided on the graph for making later extrapolations. The scale will begin and end on major divisions so the space left may be slightly more than SPACE.

4.5.3 Scale 3

This is for those who know how many units they want per inch but do not know what total graph length this will lead to. Scale 3 works best on blank paper.

The calling sequence is:

```
CALL SCALE (3,UPD,DLNTH,FUNC)
```

for the x-axis or

CALL SCALE (-3,UPD,DLNTH,FUNC)

for the y-axis.

UPD	For linear scale: the units per major division For log scale: 1.0
DLNTH	Length of each division or cycle, in inches
FUNC	For a linear scale: 'LINE' For a log scale with excess, if any, cut off at top: 'LOG1' For a log scale with excess, if any, cut off at bottom: 'LOG2' (See Scale 1 for a longer description)

Scale 3 will determine the length or height of graph necessary so that the length of each division is DLNTH.

Option: If UPD is positive, the minimum and maximum may be rounded. If UPD is negative, they will not be changed.

Caution: There is no check to see if the calculated graph length or height will fit on the paper or film.

4.5.4 Scale 4

The use of Scale 4 allows the user to specify the units per major division and either the graph length or the number of grid lines per inch. If the user specifies gridded paper, the system will select a length of major division to match the grid on the paper. The graph length is then

calculated. If the user specifies blank paper, he must also specify the graph length (or height) which is then divided evenly into the number of major divisions required.

Scale 4 is used only for linear scales.

```
CALL SCALE (4,GLNTH,PAPER,'LINE',UPD)
```

for the x-axis, or

```
CALL SCALE (-4,GLNTH,PAPER,'LINE',UPD)
```

for the y-axis.

GLNTH	Graph length (or height) in inches. This is used only if PAPER is 0.
PAPER	Number of lines per inch on gridded paper.
UPD	Units per major division . 0. for blank paper or CRT.

Option: As in Scale 1, if GINTH is positive, the range is rounded to major divisions. If GLNTH is negative, the graph length (or height) is GLNTH and the range is not rounded.

4.6. AXIS, Draw Scales

Subroutine AXIS may be called as often as desired; each call will draw a scale somewhere, with tick marks and numbers if desired.

The calling sequence is:

```
CALL AXIS(LOCATE,TICKSP,HGT)
```

LOCATE	Use one of the following:
1:	x-axis, bottom of graph
2:	x-axis, top of graph
3:	x-axis, at Y = 0.
-1:	y-axis, left side of graph
-2:	y-axis, right side of graph
-3:	y-axis, at X = 0.
TICKSP	Approximate distance apart, in inches, of the closest tick marks. A typical value is 0.2.
HGT	Height of numbers in inches.

AXIS will draw an axis with tick marks at appropriate intervals (.1, .2, or .5) between each major division such that they are either slightly closer or slightly further apart than the suggested spacing. For log scales, TICKSP is the distance between the closest ticks and many different ticking patterns are possible. The length of the largest ticks will be equal in inches to CPA(26) or CPA(36) depending on whether it is the x- or the y-axis.

HGT suggests a height for the numbers. However, if there is not enough space for numbers at each division, the actual height will be less than HGT. If HGT is 0., no numbers will be generated.

If TICKSP is 0., no ticks will be drawn.

If TICKSP is positive, the ticks will be inside the graph; if negative, they will be outside, and spacing = TICKSP .

If HGT is positive, the numbering is parallel to the axis; if negative, the numbering is perpendicular, and height = |HGT|.

LOCATE = 3 applies to the case where the range goes through 0., so that the origin is not at a corner of the graph. It is probably better not to draw a grid in this case; the lines may pass through the numbers.

4.7. BOX, Draw a Box

BOX is used to draw a frame around the graph, to draw a box around the legend, or to draw a box in some other specified place.

There are three cases:

Case 1: Draw a frame or part of a frame around the graph.

The calling sequence is:

```
CALL BOX (N)
```

N is a <u>positive</u> integer 1 to 15 indicating sides to be drawn.

1	top
2	right
4	bottom
8	left

To have more than one side drawn, add the values for the sides needed. For the top and right sides, CALL BOX(3). For all four sides, CALL BOX(15).

Since the AXIS routine draws a line along the axis, it is usually not necessary to draw all four sides with BOX. A typical call is CALL BOX(3) to complete the frame after the bottom and left side have been done by AXIS.

The CPA is used to decide where the edges of the graph are so BOX should not be called before the graph dimensions are set in the CPA.

Case 2: Complete a box in one corner of the graph.

The calling sequence is:

CALL BOX (0, XBOX, YBOX)

|XBOX|	length of box
|YBOX|	height of box
XBOX positive	left side
XBOX negative	right side
YBOX positive	bottom
YBOX negative	top

This will finish a box, |XBCX| by |YBOX| inches, in one of the four corners, as determined from the signs of XBCX and YBOX. Typically, this is used to put a frame around a legend drawn with subroutine LEGEND. Subroutine GRID can be called with the same values for XBOX and YBCX so that grid lines will not be drawn inside the box.

Case 3: Draw a box or part of a box in a specified place.

The calling sequence is:

```
CALL BOX (NN, XBOX, YBOX, XCORN, YCORN)
```

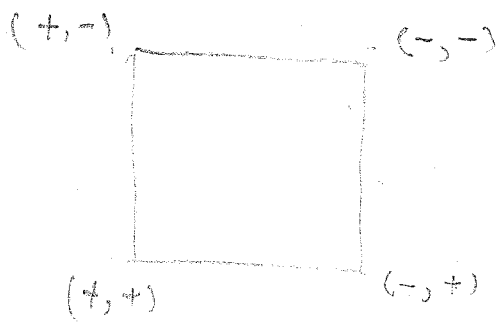
NN	is a <u>negative</u> integer -1 to -15 indicating which sides are to be drawn.
-1	top
-2	right
-4	bottom
-8	left

If more than one side is to be drawn, add the values of NN for the sides needed. CALL BOX (-15, XBOX, YBOX, XCORN, YCORN) will draw a complete box.

|XBOX|	length of box, in inches
|YBOX|	height of box, in inches
XCORN,YCORN	coordinates, in inches, of the lower left corner of the box, if XBOX and YBOX are positive.

The user can specify the position of any corner of the box with XCORN, YCORN.

XBOX	YBOX	XCCRN, YCORN is the location of the
positive	positive	lower left corner
positive	negative	upper left corner
negative	positive	lower right ccrner
negative	negative	upper right ccrner,
		relative to the origin.



4.8. GRID, Draw Grid Lines

Subroutine GRID will draw grid lines. The spacing of the grid lines will be arranged so as to match the major divisions. The user can request either a dense or a sparse grid. For both horizontal and vertical lines, GRID must be called twice.

The calling sequence is:

```
CALL GRID(+DIST,0.,0.)
        for vertical lines,
```

or

```
CALL GRID(-DIST,0.,0.)
        for horizontal lines
```

DIST	Approximate distance between grid lines. The actual value will be chosen to fit the scale. Use a small DIST for a dense grid, large DIST for a sparse grid.

Option: A blank area may be left in one of the corners for a legend.

The calling sequence is:

```
CALL GRID(+DIST,XBOX,YBOX)

CALL GRID(-DIST,XBOX,YBOX)
```

|XBOX|	|XBOX| is length of blank area. Positive XBOX means left side; negative XBOX means right side.
|YBOX|	|YBOX| is height of blank area. Positive YBOX means bottom; negative YBOX means top.

On the Cathode Ray Tube Plotter, the grid lines are drawn with intensity of [ICPA(23) - 2] at major intervals.

Grids take considerable plotting time.

4.9. LEGEND, Plot a Legend for the Graph

Subroutine LEGEND is used to plot short descriptions of the different data sets appearing on the graph. (If more elaborate descriptions are required, the user can build his own legend using LABEL, Section 4.10.)

The legend normally goes in one of the four corners of the graph and this is the way LEGEND works if the first calling sequence below is used. However, an option is available to allow the legend to go anywhere, even outside the graph.

The calling sequence is:

```
CALL LEGEND(TITLE,ISYMB,NS,DESCR,NFORM,XBOX,YBOX)
```

TITLE	A character string to be used as the title of the legend. It must end with the flag character in CPA(20), normally $.
ISYMB	An array of integers referring to the centered symbols used in the graph. (Symbols 0 through 14 in Figure 4.1b are centered symbols.)
NS	The length of the ISYMB array. This is normally equal to the number of sets of data that have been plotted.
DESCR	An array containing the descriptions for the NS symbols. The format of DESCR is related to the value of NFORM.

NFORM=1	means that DESCR is an array of REAL*4 numbers of DIMENSION(NS).
NFORM=2	means that DESCR is a string of characters consisting of NS substrings, each terminated by a $ (or whatever is in CPA(20)).
NFORM>2	means that DESCR is a string of characters, NFORM characters for each symbol to be described.
XBOX	|XBOX| is length of area reserved for the legend. Positive XBOX means left side; negative XBOX means right side.
YBOX	|YBOX| is height of area reserved for the legend. Positive YBOX means bottom; negative YBOX means top.

LEGEND will fit the TITLE into the space indicated by XBOX, YBOX and then list the symbols (ISYMB) and descriptions (DESCR) using two-thirds or less of the height of the TITLE.

Options:

a. Consecutive Symbols

If the symbols to be plotted are consecutive in Figure 4.10b, then only the integer corresponding to the first symbol need be given in ISYMB. ISYMB is then a single value, not an array. To alert the system that Option a. is desired, make NS a <u>negative</u> integer. The system will then generate and plot an array of |NS| consecutive symbols, beginning with ISYMB.

b. Dash Patterns

For values of ISYMB from 128 to 134, samples of dash

patterns 0 through 6, (see LINPLT for description of dash patterns) respectively, will be drawn instead of symbols.

c. Legend not in Corner

To put the legend in a position other than one of the four corners the calling sequence is:

```
CALL LEGEND(TITLE,ISYMB,NS,DESCR,-NFORM,XBOX,YBOX,XCORN,YCORN)
```

XCORN,YCORN Coordinates in inches of the upper left corner of the legend.

The system is alerted that Option c. is wanted by the appearance of a <u>negative</u> number, NFORM, in the fifth position. The user should take care that the location requested is inside the graph + margin area. For legends outside the graph, it is usually necessary to increase the margin size CPA(17), before the initialization call to INTL.

4.10. LABEL, Plot Labels and Titles

This is a multipurpose label and title subroutine. It will plot a centered or right- or left- adjusted title for the graph and centered or right- or left- adjusted labels for the axes. With LABEL the user can put letters of numbers or symbols anywhere on the graph. Superscripts and subscripts are also possible.

There are several varieties of calling sequences:

Calling sequence 1, for a centered or right- or left-adjusted BCD title or label:

```
CALL IABEL(IND,HGT,BCD,-1)
```

IND	Indicator for title or label locations, -6 to -1, 1 to 6; see Figure 4.10a.
HGT	Height (in inches) of the characters
BCD	A string of characters ending in a $, such as 'IABEL$'. BCD can also be the name of an array of BCD characters, in which a $ must appear after the last character in BCD to be drawn.

This will put the string BCD (except for the $) in the indicated place. If the string is too long for the graph, a height less than HGT will be used.

Calling sequence 2, titles and labels including special characters (a special character is any character in Figure 4.10b which cannot be keypunched with a single key stroke):

```
CALL IABEL(IND,HGT,BCD,ISYM)
```

IND,HGT	Defined as above
BCD	A string of characters (or the name of an array of characters) ending in a $ and including at least one other $ elsewhere in the string.
ISYM	An array of integers which will be used by LABEL to interpret the $'s in BCD. There must be as many integers in ISYM as there are $'s in BCD, including the terminal $. The last integer in ISYM must be a -1.

This sequence may be used to produce any character on the list of characters available as shcwn in Fig. 4.10b.

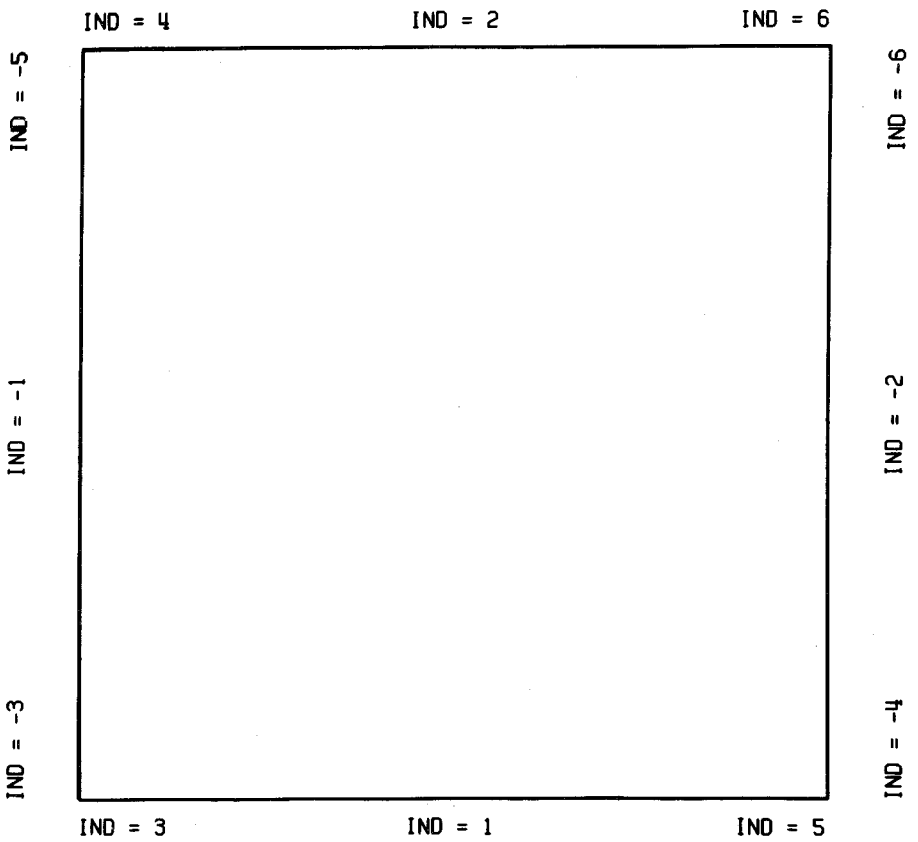


Fig. 4.10a Positions of Labels for Various Values of IND

CHARACTERS AVAILABLE IN SYMBOL ROUTINE (IBM 360/75)

INTEGER EQUIVALENT — UPPER NUMBER
INTERNAL EQUIVALENT — LOWER NUMBER
KEY PUNCH — RIGHT OF SYMBOL

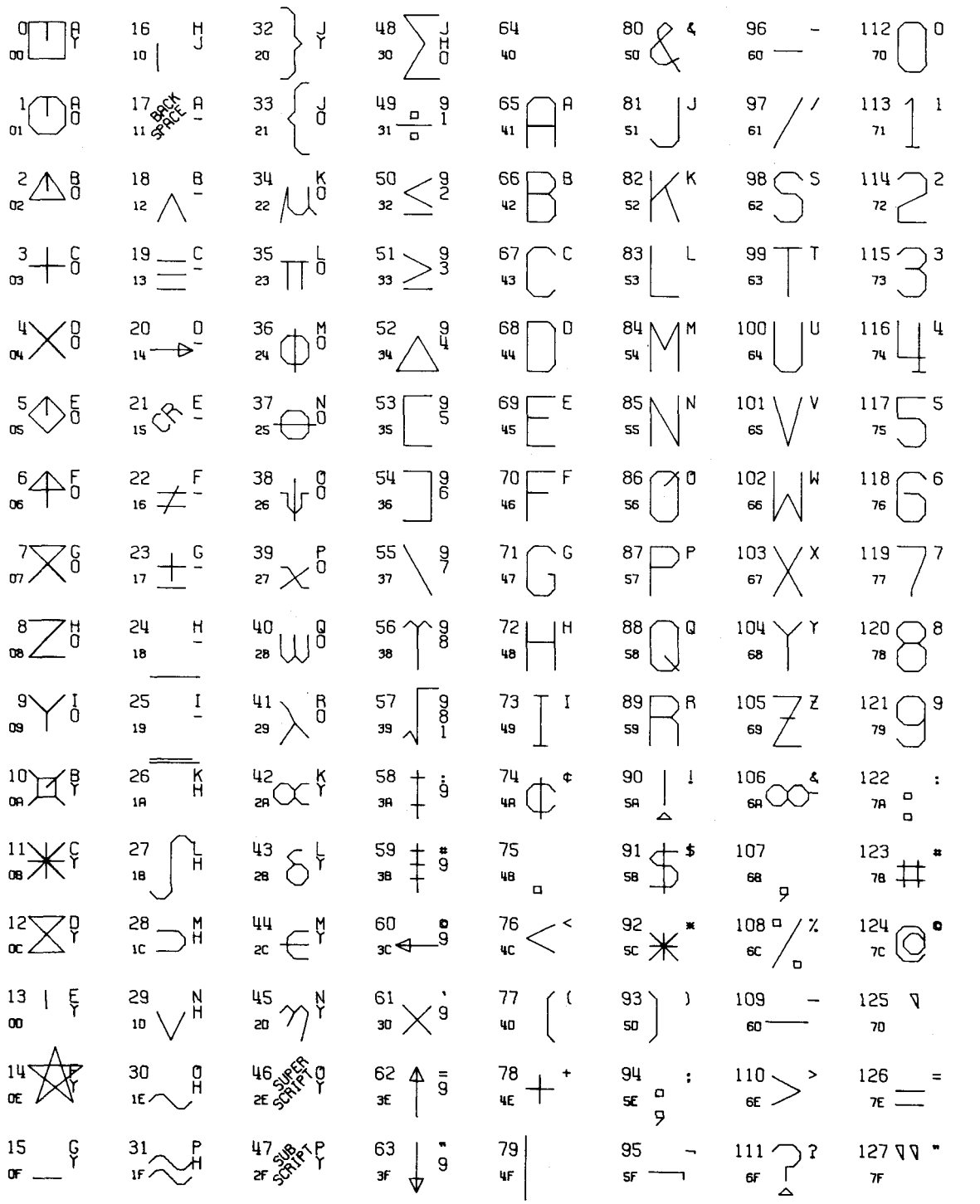


Fig. 4.10b List of Characters Available

At the position in BCD where a special character is desired, a $ should be placed. The integer equivalent (0-127; see Figure 4.10b) for the desired symbol must be placed in the ISYM array. There is no restriction on the number of $'s that may appear in BCD as long as the ISYM array contains an integer for each one. The last integer in the ISYM array must be -1, corresponding to the terminal $ in BCD.

Superscript, subscript, and second line (or carriage return) requests are also indicated via a $ in BCD and the appropriate integer in ISYM. From Figure 4.10b, the superscript code is 46, the subscript code is 47, and the second line code is 21. Characters written while in superscript or subscript mode have height 2/3 of HGT and are raised or lowered 1/2 of HGT. After a superscript request, a subscript request is used to return to normal and vice versa. For example, if a $ is encountered in BCD and the corresponding ISYM value is 46, all characters following that $ (including special characters represented by other $'s) will be written in superscript mode until a $ appears whose ISYM value is 47.

Calling Sequence 3, titles and labels including machine format numbers:

```
CALL LABEL (IND,HGT,BCD,ISYM,XNUM,LNTHS)
```

IND,HGT	Defined as above for Calling Sequence 1
BCD	Defined as in Calling Sequence 2, with the additional feature that a $ can be included in the string BCD wherever a number is wanted.
ISYM	Defined as in Calling Sequence 2, with the additional feature that a -2 indicates that a number from XNUM is to be used.
XNUM	The number or name of the number or name of the array of numbers to be used. May be real or integer. There should be as many numbers in XNUM as there are -2's in ISYM.
LNTHS	A number or name of a number or name of an array of numbers. There should be as many numbers in LNTHS as there are -2's in ISYM. These numbers indicate the number of decimal places to be given for each value in XNUM. A zero in LNTHS indicates that the corresponding value in XNUM is an integer. Other numbers will appear in F or E format.

Calling Sequence 4, titles and labels including numbers with formats.

CALL LABEL (IND,HGT,BCD,ISYM,XNUM,FMTS)

IND,HGT	Defined as in Calling Sequence 1
BCD	Defined as in Calling Sequence 2, with the feature that a $ can be included in the string BCD wherever a number is to be.
ISYM	Defined as in Calling Sequence 2, with the additional feature that a -3 indicates that a number from XNUM is to be used.
XNUM	Defined as in Calling Sequence 3.

FMTS — Formats to be used for values in XNUM. Each format should be enclosed in parentheses, e.g., '(I10)(F7.2)'. Formats must conform to requirements for QQQNUM, Section 4.16.

Calling Sequence 5, for labels anywhere on the graph:

$$\text{CALL LABEL (O,HGT,BCD,ISYM,XNUM,} \left\{ \frac{\text{LNTHS}}{\text{FMTS}} \right\} \text{,XINCH,YINCH)}$$

HGT,BCD,ISYM,XNUM,LNTHS — Defined as above

XINCH, YINCH — Location in inches of the place where the label starts (the lower left hand corner of the first symbol relative to the origin)

XNUM and LNTHS (or FMTS) are ignored if there are no -2's (or -3's) in ISYM. The label written may fall anywhere within the graph plus the margin. If it does not, the height of the characters is decreased (from HGT) until it does.

Option: The $ is used as a flag character. However, any character may be used as a flag character by putting that character in CPA(20). This method should be used if it is desired to have $ appear as a symbol.

4.11. ARROW, Label a Data Point

Subroutine ARROW is designed to permit the user to label a data point which has been previously plotted. The coordinates X, Y of the point to be labeled are assumed to be known in user's units, that is, in the coordinate system currently set up in the

CPA. (It is not required that anything was actually plotted at point X, Y).

The calling sequence is:

CALL ARROW(X,Y,IARROW,XINCH,YINCH,HGT,BCD,ISYM,XNUM,LNTHS)

X,Y	Coordinates, in user's units, of the point to be labeled.
IARROW	A flag which indicates what kind of arrow is wanted. The sign of IARROW affects the interpretation of XINCH, YINCH.
± 1	No arrow will be drawn, but BCD will be written
± 2	Straight line, no arrow head
± 3	Straight line with arrow head
± 4	Arched arrow concave down
± 5	Arched arrow concave up:
± 6	Wavy arrow:
XINCH, YINCH	Two meanings: Meaning 1 (when IARROW is positive): Coordinates in inches relative to the origin, where the label BCD is to begin. Meaning 2 (when IARROW is negative): Coordinates in inches relative to the Point X, Y, where the label BCD is to begin.

HGT, BCD, ISYM, XNUM, LNTHS are defined as in LABEL, sec. 4.10. X and Y are always scaled as data points while XINCH and YINCH are distances in inches. When IARROW is positive, the label and the end of the arrow will be placed at (XINCH, YINCH) so that labels may be placed in any blank area on the graph and connected to the data point or line with an arrow. When IARROW is negative, XINCH and YINCH are

horizontal and vertical distances away from a data point at (X, Y). For example, a monotonically decreasing data set could be labeled with XINCH and YINCH set at .05, -.05 respectively, and each label would appear to be centered (for HGT = .1) beside the data point.

If arrows or lines are called for, that is, if IARROW >1, these will begin a distance equal to CPA(9) from the data point. This allows symbols of height CPA(9) to be centered over the data point and the line or arrow to begin slightly beyond the edge of the symbol. The line will be drawn to 0.5*CPA(9) away from (XINCH, YINCH). The head of the arrow head will be .05 inches in length or 0.5*CPA(9), whichever is larger. It is possible that no arrow will appear, even though requested, when the distance between (XINCH, YINCH) and (X, Y) is not greater than 1.5*CPA(9).

Options:

a. If HGT is zero, the arrow will be drawn without a label and all parameters following HGT may be dropped.

b. If CPA(9) is set to zero, the arrow will touch the exact point and the label.

4.12. QQINCH, Convert to Inches

To convert a position in user's coordinates to inches:

CALL QQINCH (X, Y, XINCH, YINCH)

X, Y	Values in user's coordinates
XINCH, YINCH	Corresponding values in inches

$$XINCH = CPA(5) \frac{X - CPA(3)}{CPA(4) - CPA(3)} \quad \text{for linear scale}$$

$$XINCH = CPA(5) \frac{\log X - CPA(3)}{CPA(4) - CPA(3)} \quad \text{for log scale}$$

$$YINCH = CPA(15) \frac{Y - CPA(13)}{CPA(14) - CPA(13)} \quad \text{for linear scale}$$

$$YINCH = CPA(15) \frac{\log Y - CPA(13)}{CPA(14) - CPA(13)} \quad \text{for log scale}$$

4.13. QQLINE, Draw a Line

QQLINE is used to draw a solid or dashed line between two points.

There are two cases:

Case 1: Draw a solid line between two points

The calling sequence is:

CALL QQLINE (X1, Y1, X2, Y2, 0)

X1,Y1	X and Y coordinates in <u>inches</u> for the first point.
X2,Y2	X and Y coordinates in <u>inches</u> for the second point.

Case 2: Draw a dashed line between two points

The calling sequence is:

CALL QQLINE (X1, Y1, X2, Y2, IDASH, START)

X1,Y1	Defined as for Case 1
X2,Y2	Defined as for Case 1
IDASH	An integer (1-6) representing a distinct dashed line pattern
START	A number which indicates where to start within the pattern.
0	Start at the beginning of the pattern.
positive	0. to 1. Start at this fractional part of the pattern. START = .25: Start 1/4 of the way into the pattern. START = .5: Start midway intc the pattern, etc.
negative	Start at that position in the pattern where the last call to QQLINE stopped. This allows a dashed line to be drawn though a number of points without any "breaks" in the pattern.

See Section 3.2, CPA(48), fcr control over the length of one distinct piece of the dashed pattern.

To convert user's coordinates to inches, see Section 4.13, QQINCH.

In many cases subroutine LINPLT, Section 2.5.3, may be more efficient for drawing either solid or dashed lines.

4.14. QQPORC, Pen-and-Ink or Cathode Ray Tube or Printer

QQPORC moves the pen or beam. If 'CRT' was specified in the user's CALL INTL statement, QQPORC moves the Cathode Ray Tube beam. If 'MECH' was specified, QQPORC moves the pen. If 'PRNT' was specified, a pointer indicating the current position is moved.

The calling sequence is:

CALL QQPORC (X, Y, IPEN, IZ)

X,Y	Coordinates, in inches, where beam or pen or pointer will be moved from its present position
IPEN	Use one of the following:
2	Draw a line
3	Do not draw a line
IZ	Intensity of line (used only for CRT plots). IZ ≈ 16 is typical. IZ < 10 will be scarcely visible. The largest value is 30. IZ = 20 is about twice as dark as IZ = 16.

QQPORC was written as an internal subroutine for ORGRAPH. In most cases, other subroutines, such as QQLINE, Section 4.12, or LINPLT, Section 2.5.3, are more convenient.

4.15. QQQSYM, Draw Symbols

Usually, labeling of graphs is done with LABEL, Section 4.10, or TITLE, Section 2.4. QQQSYM was written as an

internal subroutine in ORGRAPH. The two forms of the calling sequence are:

```
CALL QQQSYM (X, Y, H, BCD, THETA, N)
                                  with N > 0

CALL QQQSYM (X, Y, H, ISYM, THETA, N)
                                  with N < 0
```

X,Y — Coordinates, in inches, where the symbol is to be drawn. For the first 15 symbols shown in Figure 4.10b, the center of the symbol will be at (X,Y): for the others the lower left corner of the first symbol drawn will be at X,Y.

H — Height of the characters in inches. The width is 4/7 of the height and the spacing between the characters is 2/7 of the height.

BCD — Specifies the characters to be drawn. It may be

1) A string in apostrophes, e.g.
```
'ALPHANUMERIC DATA'
```

2) the name of an array containing character data, e.g.
```
      DIMENSION BCD(6)
      DATA BCD/'ALPHANUMERIC DATA 0123'/
                  or
      READ 1, BCD
    1 FORMAT (6A4)
```

3) the name of an array containing hexadecimal data, such as
```
      DATA BCD/ZC8C5D3D3D65A/
```

ISYM — An integer referring to one of the 128 symbols

THETA — The angle, in degrees, at which the characters are written. If a string of characters is to be drawn, the string will be rotated counterclockwise about (X,Y) to the angle THETA.

N	If N > C, N symbols will be drawn, starting with the first symbol in BCD. If N < 0, only one symbol will be drawn. ISYM determines which symbol. If N = -2, a line will also be drawn from the present position to (X,Y) If N = -1, no line will be drawn.

Options:

1. If either X or Y is 999., QQQSYM will continue writing where it left off after the previous call to QQQSYM.
2. If H = 0., the previous H and THETA will be used.
3. There are four characters which do not produce symbols but which affect the positioning of the pen. These are:
   a. Back space, 17, which may be used to position the pen to write over a previous character.
   b. Carriage Return, 21, which will position the following characters H*12/7 below the first character drawn in the string.
   c. Superscript, 46, will draw the following characters with height = 0.7 * H and raised 0.5 * H. To return to normal, call for a Subscript, 47.
   d. Subscript, 47, will draw the following characters with height = 0.7 * H and lowered 0.5 * H. To return to normal, call for a Superscript, 46.

4.16. QQQNUM, Draw Number

Subroutine QQQNUM converts machine format numbers into character strings and then calls QQQSYM.

The calling sequence is:

CALL QQQNUM (X, Y, H, A, THETA, FORMAT)

X, Y, H, THETA are defined as in QQQSYM, Section 4.15.

A — Should be replaced by the FORTRAN name of the number to be plotted. The type (REAL or INTEGER) must agree with FORMAT.

FORMAT — Specifies the manner in which the number is to be converted and plotted. Examples are '(E12.5)', '(F8.3)', '(I4)'. The portion inside the parentheses should be six characters or less. Only I, F, E, and D formats may be used. A decimal point must be used in F, E, and D formats and a number (even if 0) must appear to the right of the decimal point, e.g., '(F11.0)'. Numbers plotted with E or D format will be scaled so that the first significant figure is to the left of the decimal point, e.g.
-1.9201E-11 from FORMAT = '(E11.4)'
Explicit scaling factors, such as '(1PE9.1)' are not allowed. Numbers will be right-adjusted in the field specified by FORMAT.

Options 1 and 2 of QQQSYM also apply to QQQNUM.

4.17. QQWHER, Find Position

If you need to know the present pen or beam position:

CALL QQWHER (X, Y)

X,Y — Present position in inches

4.18. QQQORG, Move Origin

To move the origin from its present position.

CALL QCQORG (X, Y)

X,Y	Position of new origin, in inches, relative to present origin. Use only after INTL has been called.

4.19. QQNEWS, Print ORGRAPH Newsletter

QQNEWS will print out the current ORGRAPH news.

The calling sequence is:

CALL QCNEWS (N)

N	An integer which indicates whether cr not to print the news.
N = 1	News printed
N = 0	News not printed

All calls to QQNEWS, after the first, will be ignored. Execution of the first call to INTL will produce a call to QQNEWS with N = 1.

5. CONTROL STATEMENTS

The subroutines in the ORGRAPH package are kept on a disk pack and are accessible from either of the IBM 360 computers. To obtain the subroutines the following cards must appear as the first cards in the link-edit step[1]:

```
//LKED.SYSLIB ① DD
// ① DD
// ① DD
// ① DD ① DSN=A8.G1.P31394.C10207.CHANDLER.GRAPHICS,
// ① VOL=REF=ZZZZZZ,DISP=SHR
```

A set of these cards can be obtained from the ORNL-site Computer Librarian, Room A228, Building 4500N, Ext. 3-1703.

To use ORGRAPH in conjunction with other load modules, for example, the subroutines in the CTC Numerical Analysis Library,[2] the additional data definition (DD) cards should be inserted after the card containing "VOL=REF=ZZZZZZ,..." above.

No special control statements are required to use ORGRAPH with disk plotting (see ORNL Programmer's Manual, Sec. 13.3) other than those above and those usually required for the use of the disk plotting routines. For long plotting jobs on the

[1]The symbol ① stands for one blank space.

[2]G. W. Westley and J. A. Watts, Editors, "The Computing Technology Center Numerical Analysis Library", UCC-ND Report CTC-39, Oct. 5, 1970.

mechanical plotter and for any plotting job on the CRT plotter, the user must include the necessary control statements for a plot tape as described in Sections 9.1 and 13.2 of the ORNL Programmer's Manual.

ACKNOWLEDGEMENTS

The ORGRAPH package has been a continuing, long-term project and as such is the work of many people. The authors wish to express their thanks to all those who participated, by writing subroutines, reading many versions of the report, and offering helpful comments and constructive criticism. In particular, we would like to thank Janice Varner and Karen Barry for their expert assistance in the preparation of this user's manual.

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Addendum

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COMPUTER SCIENCES DIVISION

USER'S MANUAL FOR THE GRAPHICS PACKAGE ORGRAPH

ADDENDUM

C. W. Nestor, Jr.

JANUARY, 1975

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

USER'S MANUAL FOR THE GRAPHICS PACKAGE ORGRAPH

ADDENDUM

C. W. Nestor, Jr.

NEW TYPE OPTIONS FOR SETUP SUBROUTINES IN ORGRAPH

We have extended the list of TYPE options in the setup subroutines (Sec. 2.3, pp. 24-36, ORNL-4596) to include the following:

XLG1 - equivalent to XLØG (p. 26),

XLG2 - use LØG2 option for x-axis scaling [CPA(2), p. 53],

YLG1 - equivalent to YLØG (p. 26),

YLG2 - use LØG2 option for y-axis scaling [CPA(12), p. 56],

LG11 - equivalent to LØG (p. 26),

LG12 - LØG1 for x-axis, LØG2 for y-axis,

LG21 - LØG2 for x-axis, LØG1 for y-axis,

LG22 - LØG2 for x and y axes.

CORRECTION TO TABLE OF THE CPA (p. 69)

The entry for CPA(25) and CPA(35), distance from axis to label, is incomplete. The values should read

0.5 1.0

indicating a space of one-half inch from the x-axis to the bottom of the x-axis label, and a space of one inch from the y-axis to the left of the y-axis label.

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