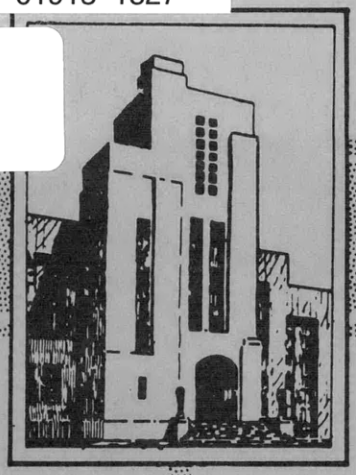
General



DEPARTMENT OF THE NAVY

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SC 4020 MICROFILM RECORDER PROGRAMMING MANUAL 1

by

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APPLIED MATHEMATICS LABORATORY

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*This was plotted with the SC 4020 on-line with the IBM 704.

ABSTRACT

The operation of the SC 4020 Microfilm Recorder on-line with the IBM 704 at the Applied Mathematics Laboratory is defined. The function and command structure of the various components of the recorder are described, and engineering features of the SC 4020 and of the CHARACTRON tube itself are included in the appendixes.

The addition of a special subroutine package to the executive routine which controls the sequential execution of programs on the IBM 704 is covered. These basic subroutines for printing, plotting, and service functions are described, including the necessary calling sequences with samples.

The necessary modifications to the command structure for off-line use of the SC 4020, including those required for use with the IBM 7090, are indicated.

I. INTRODUCTION

One of the principal functions of the Applied Mathematics Laboratory (AML) is the application of digital computer systems to the solution of a wide variety of naval engineering problems. These problems range from the solution of the neutron diffusion equations, the fundamental analysis of structures, the solution of the basic equations of hydrodynamics to the analysis of data obtained during model tests, and the processing of data collected during sea trials. With the wide variety of scientific problems being handled on the IBM 704 system and the rapid growth in the volume of work, the need for a very fast, flexible output printing device with curve plotting capabilities became apparent.

A Stromberg-Carlson Microfilm Recorder System (SC 4020) has been acquired for on-line* use with the IBM 704 system to meet this need. Figure 1 is a photograph of the SC 4020 system. Figure 2 shows the system on-line with the IBM 704 system. The SC 4020 Recorder is capable of printing and plotting on microfilm up to 15,000 characters per second under the direct control of a program running on the IBM 704. Examples and prints of output obtained using the SC 4020 are given in Figures 3, 6, 7, 8, 9, 10, 11, and 12.

Section II contains a brief description of the specific SC 4020 Recorder System acquired. More detailed engineering information is given in Appendixes A and B. Section III describes the method of communication between the SC 4020 and the IBM 704. Section IV describes the set of commands which can be executed by the SC 4020. Table 4 summarizes these commands and their execution times. Finally, Section V contains a description of the Bell System CHARACTRON Subroutine Package which has been prepared at AML to facilitate editing of tables and graphs for the SC 4020.

---

*As of January 1961, this has been converted to an off-line unit.

II. THE SC 4020 MICROFILM RECORDER

The Stromberg-Carlson Microfilm Recorder (SC 4020 Basic Recorder) in on-line operation with the IBM 704 is capable of recording digital information supplied by the computer at the rate of 15,000 characters per second. The Basic Recorder consists of a 7-inch CHARACTRON shaped beam tube, associated electronic controls and logical circuitry, and an automatic electrically operated 35 mm (Richardson) camera for high quality permanent photographic recordings.

The Microfilm Recorder is operated by commands received from the computer, the computer supplying all of the necessary data for the selection of characters and their positioning on the CHARACTRON tube screen. For normal printing, up to 64 lines with up to 128 characters per line may be recorded on a frame of film yielding a page of output. For plotting, the position of the character to be plotted is specified by selecting any one of 1024 horizontal positions together with any one of 1024 vertical positions. The character matrix consists of 64 characters; see Figure 4. Table 5 contains each character and its octal code. One of two recording densities on film may be specified. More detailed information concerning engineering features of the SC 4020 and the CHARACTRON tube itself can be found in Appendixes A and B.

In addition to the Basic Recorder, the recorder system delivered to the Applied Mathematics Laboratory includes the following equipment:

A. F-10 TYPEWRITER SIMULATOR

A typewriter simulator eliminates the necessity of supplying positioning data with each character to be printed. Instead, characters are positioned automatically along a printing line, returning to a margin upon completion of a line or upon receipt of a carriage return signal.

B. F-20 AXIS GENERATOR

An axis generator enables the recording of a coordinate grid line extending the full length or width of the plotting area by command of a single computer word. Either a horizontal or a vertical axis may be programmed, starting at any plotting position.

C. F-30 VECTOR GENERATOR

The vector generator is used to record a segment of a straight line extending to a maximum length of 1/16 of the plotting area diagonal. A vector is specified by one computer word in terms of starting X- and Y-coordinates and X- and Y-component lengths.

D. F-40 AUTOMATIC PROCESSING CAMERA*

A high-speed automatic processing camera (Kelvin-Hughes) permits visual observation of a selected frame of film 8 seconds after exposure. The processed film is projected on a 3- by 2 1/4-foot viewing screen. The frame to be viewed is selected by a programmed instruction.

An F-20 Tape Adapter** is also available for use with the SC 4020. This adapter enables off-line use of the basic unit by accepting input directly from a tape unit and processing it into a form acceptable to the recorder. The David Taylor Model Basin system may eventually include this additional piece of equipment for use with either an IBM 727 tape unit or an Ampex 407 tape unit. Figure 5 is a diagram of the complete CHARACTRON system on-line with the IBM 704.

III. USE WITH THE IBM 704

In order to select the SC 4020 Recorder as a piece of output equipment to be used on-line with the IBM 704, a "WRS 24" instruction must be given to the computer. This instruction selects the recorder in whatever state it was last used. Then commands are given to the CHARACTRON by means of the "CPY m" instruction. This causes the CHARACTRON command or data to be transferred from memory location "m" to the MQ where the SC 4020 has access to it.

Upon selection of the recorder, the computer is connected to it until another piece of input-output equipment is selected. Each command from the IBM 704 to the CHARACTRON ties up the computer for the duration of the "CPY m" instruction (24 μsec). The time for which the SC 4020 is unavailable after each command is the execution time of the command. These execution times are given in Table 4.

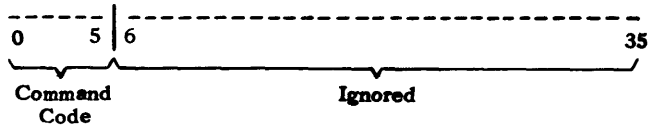
IV. SC 4020 COMMAND CODE

A. INTRODUCTION

The SC 4020 command codes are given below. Each command is followed by its mnemonic designation and its operation code. With the exception of the vector generator command, all command codes use bit positions 0 through 5.

B. CAMERA OPERATION COMMANDS

For the following set of instructions, bit positions 6 to 35 are ignored; e.g.,



*As of January 1961, this camera is no longer available with our unit.

**As of January 1961, this unit has been ordered.

1. **Select Camera 1***
   SC1 41

This command will open the shutter of the Richardson camera (off-line developing) and close the shutter of the Kelvin-Hughes camera. Subsequent SC 4020 commands will refer to the Richardson camera until another "Select Camera" instruction is received.

2. **Select Camera 2***
   SC2 42

This command will open the shutter of the Kelvin-Hughes camera (on-line developing) and close the shutter of the Richardson camera. Subsequent SC 4020 commands will refer to the Kelvin-Hughes camera until another "Select Camera" instruction is received.

3. **Select Both Cameras***
   SBC 43

This command opens the shutters on both cameras. Subsequent SC 4020 commands will refer to both cameras until another "Select Camera" instruction is received.

4. **Advance Film****
   ADF 46

This command will cause the film in the selected camera(s) to be advanced one frame and the CHARACTRON beam to be positioned at coordinate X = Y = 0.

5. **Reset****
   RES 56

This command will cause the "Advance Film" and "Stop Print" commands to be performed simultaneously. In addition, the exposure will be set to normal—"heavy." Other commands which can reset the exposure can be found among the plotting commands; i.e., EPL (Expose Light) and EPH (Expose Heavy).

C. PLOTTING COMMANDS

The output of the CHARACTRON is recorded on microfilm. The frame size is 24 by 36 mm, whereas the length and width of the image of a full page are 15 ($\pm$ 0.4) mm and 20 ($\pm$ 0.5) mm.†

The page is oriented with the origin of the coordinate system in the upper left-hand corner. The positive X-direction is to the right; the positive Y-direction is downward. Any of the 64 characters may be plotted in any of 1024 by 1024 plotting positions. Figure 4 shows the character matrix. The ratio of length to width of a page is 3 to 4;† see Figure 6. Approximately 350 dots can be resolved per row or column. Figure 7 shows different point densities in both the light and heavy modes of exposure.

---

* With the off-line unit these commands are no longer necessary.

** With the off-line unit these commands must be followed by an end-of-record gap on tape.

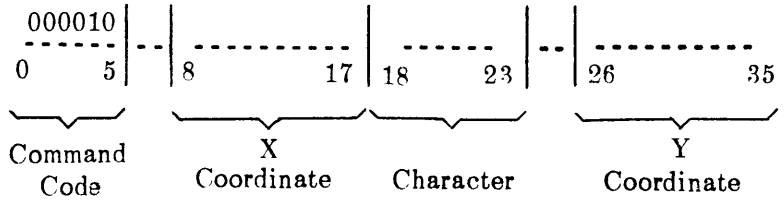
†In the off-line unit a 17 mm by 17 mm square on each frame is used, and the image has a 1 to 1 height to width ratio.

Vectors may be drawn by specifying the location of the vector origin and the signed horizontal and vertical components of the vector. For example, if (X, Y) designates the starting point of the vector and ΔX and ΔY the signed horizontal and vertical components, respectively, then $(X + \Delta X, Y + \Delta Y)$ will designate the end point; see Figure 6. Notice that a vector with a positive Y-component is drawn upward.

1. Expose Heavy and Plot Character
EPH 02

On receiving this command, the recorder sets the exposure to normal—"heavy"—and causes a specified character to be plotted in a specified location. The recorder will remain in the heavy mode of exposure during subsequent commands until a command which sets the exposure to the "light" mode is received.

The character to be plotted is given in 6-bit positions beginning at the middle of the word. The X- and Y-coordinates are assigned the last 10-bit positions of the decrement and address fields, respectively; e.g.,



2. Expose Light and Plot Character
EPL 04

On receiving this command, the recorder sets the exposure to "light" and causes a specified character to be plotted in a specified location. The recorder will remain in the light mode of exposure until a command which sets the exposure to "heavy" is received. The format of this instruction is identical to that of the "Expose Heavy" command (02).

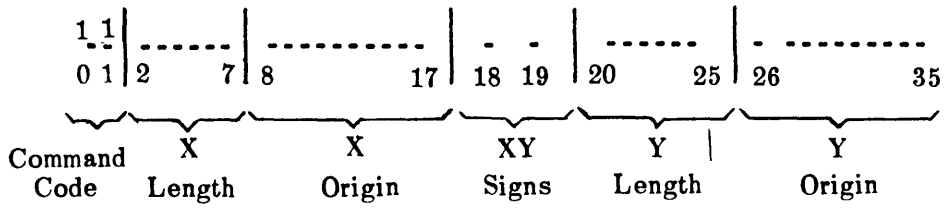
3. Plot Point
PLT 00

This command causes the recorder to plot a specified character in a specified position, using the exposure previously selected. The format of the command is identical to that of the "Expose Heavy" (02) and "Expose Light" (04) commands.

4. Draw Vector
DWR 6

This command includes the specification of the origin of the vector (X- and Y-coordinates) as well as of its signed X- and Y-component lengths. There are 6 bits to specify the

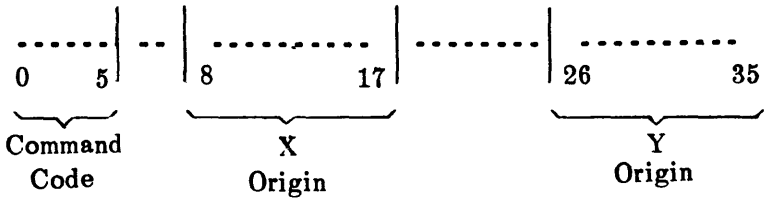
length of each component. Therefore, the maximum vector length is 2^{-4} or 1/16 of the maximum plotting area diagonal. The structure of the draw vector command follows:



Commands to set the exposure do not affect the exposure with which vectors are drawn; vectors are always drawn with "light" exposure. See Figure 12 for a comparison of vector and point plotting.

5. **Generate Horizontal Axis***
   GHA 30
   Generate Vertical Axis*
   GVA 32

These commands cause the recorder to draw a horizontal or vertical line, respectively, starting at the point given by a specified set of X- and Y-coordinates and extending to the right-hand edge or the top of the frame. The command structure is:



Commands resetting exposure do not affect the exposure with which axes are drawn; axes are always drawn with "light" exposure. Figure 8 shows some grids of different sizes which have been drawn with the axis generator.

D. TYPEWRITER SIMULATOR COMMANDS

The typewriter simulator mode of operation permits the automatic positioning of successive characters on a line and successive lines on a page, expediting the performance of normal printing. In order that successive characters will be properly positioned with respect to each other, each character is assigned 8 horizontal and 16 vertical plotting positions. Thus each line has 128 character positions, and each page has 64 line positions.

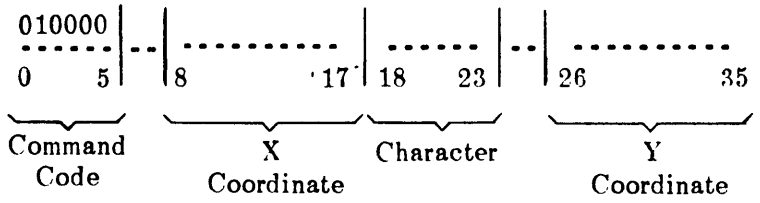
---

* These commands must be followed by an end-of-record gap on the tape for use with the off-line unit.

The two commands which initiate the typewriter simulator mode of operation are given as follows:

1. **Print Specified Point**
   PSP 20

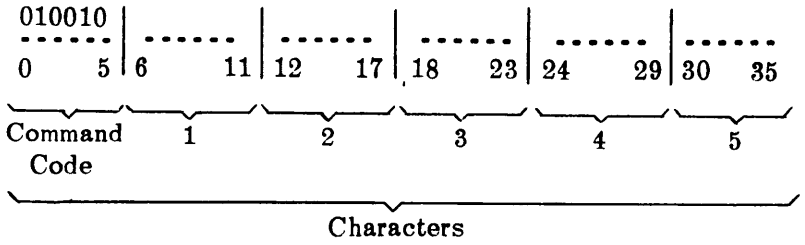
The format for this command is:



The specified character is plotted centered at the specified position. Subsequent characters printed in the typewriter simulator mode will appear in successive character positions.

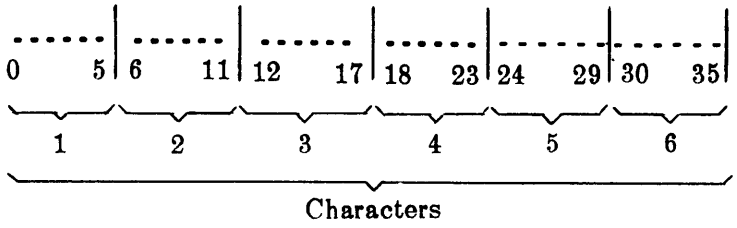
2. **Print Current Point**
   PCP 22

This command causes the character specified in bit positions 6 to 11 to be printed, leaving the CHARACTRON beam as previously positioned. Characters specified in bit positions 12 through 35 are printed in successive character positions. Subsequent characters printed in the typewriter simulation mode will also appear in successive character positions.



3. **Typewriter Simulator Mode of Operation**

Once this mode has been initiated by either a Print Specified Point or a Print Current Point command, each successive command to the CHARACTRON will be interpreted as a set of six characters as follows:



The successive characters will be printed, with the three exceptions noted, in successive positions across a page (128 positions per line). When the last position of a line has been reached, an automatic carriage return to the beginning of the next line will occur. When the film is advanced, a repositioning of the CHARACTRON beam will occurr,** so that printing will begin at the first character position of the new frame. The first character position of a page is centered at the plotting position with coordinate X = 0, Y = 0.

Three special control characters are recognized in the typewriter simulator mode as follows:

a. Carriage Return* (CRN 52), which causes subsequent characters to be printed beginning in the first character position of the next printing line; that is, sets coordinate X = 0 and advances coordinate Y by 16 plotting positions.

b. Stop Print (SOP 12), which causes the recorder to leave the typewriter simulator mode of operation.

c. Reset (RES 56), which causes the "Advance Film," "Stop Print," and "Expose Heavy" commands to be performed simultaneously.

Thus the characters corresponding to the codes of these control characters cannot be printed while in the typewriter simulation mode.

V. STANDARD SUBROUTINE PACKAGE

A. INTRODUCTION

An executive routine, the Bell System, created at the Bell Telephone Laboratory is used to expedite the sequential operation of problems on the Applied Mathematics Laboratory IBM 704.†

The Bell System contains some of the subroutines which are most widely used (input-output routines and conversion routines, for example), and it allows great flexibility in these areas. Thus, to provide complete freedom in the use of any output media at any particular time for the great majority of problems, the basic subroutines for the SC 4020 Microfilm Recorder are being made available through the Bell System.

Two print routines, CPRINT and OUTCRT, compatible with the XPRINT** and OUTPUT routines already in the system, have been added. A generalized plot routine, CXPLOT, which will generate a grid based on the range of values specified, label it, and plot the given values is also provided.

Two service routines are to be included in the subroutine package also. One, the TCEDIT routine, will accept a tape which has been edited for the IBM 717 printer (off-line printer) and will provide input for the SC 4020. Another, the TCCOPY routine,†† will transcribe recorder instructions from a tape to the microfilm recorder.

---

*This command is not recognized in the normal (plotting) mode of operation.

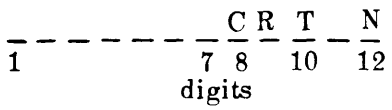
**XPRINT is similar to HPRINT in the Bell System for the IBM 7090.

†A version of the Bell System is also used on the IBM 7090.

††Not available with the off-line unit.

B. THE BELL SYSTEM CONTROL CARD CRT

The Bell System has been modified to accept a new control card with CRT in the operation field (columns 8 through 10) and N in the address field (columns 12 and 13 in this case); e.g.,



The appearance of this control card before the system control card, LOD, will cause the Bell System to load the subroutine package from the system tape into memory.

The programmer's initial code, problem number, and category, as obtained from the control card JOB, will be printed on a frame on both cameras. Subsequently, the film on both cameras will be advanced one frame.

A sample 704 sequence is:

```
JOB
CRT  N
LOD
        binary deck
TRA
```

where if N = 0 or space, the output generated by the routines of the package will be written on the recorder,* and if N $\neq$ 0, the output will be written on tape N. Output written on tape N can be transcribed to the CHARACTRON by using the TCCOPY routine.

C. PAGE PRINTING SUBROUTINES

1. CPRINT

This subroutine is the counterpart of the subroutine XPRINT. It records the Hollerith characters specified in a set of consecutive memory locations. A sample code using the CPRINT routine is given in Table 1; the output generated by it is shown in Figure 10.

A maximum of 128 characters may be printed per line, and an automatic carriage return will be effected upon printing in the last position of a line. Any of the characters in the matrix, except the three control characters recognized in the typewriter simulator mode, may be printed. A carriage-return character will position the beam to continue printing on the next line.

---

*With the off-line unit, in this case, the output will be written on tape A8.

The normal calling sequence is as follows:

```
TSX  CPRINT,4
     A,,B
     C,,D
     X,,Y
XIT  XXXRET
```

where A designates the storage location of the first BCD word to be printed;

B designates the storage location of the last BCD word to be printed;

C* specifies camera selection:

C = 0 designates that the previously selected camera(s) be used,

C = 1 designates the selection of the Richardson camera (Camera 1) ,

C = 2 designates the selection of the Kelvin-Hughes camera (Camera 2),

C = 3 designates that both cameras be selected;

D specifies frame selection:

D = 0 designates that printing is to continue on the same frame,

D = 1 designates that the film is to be advanced so that printing will start on the next frame;

X designates the X-coordinate for use in a Print Specified Point command; and

Y designates the corresponding Y-coordinate.

Printing will start one character position (eight plotting positions) to the right of the point (X, Y). It is possible to use one of two abbreviated calling sequences:

```
TSX  CPRINT,4
     A,,B
     C,,D
XIT  XXXRET
```

or

```
TSX  CPRINT,4
     A,,B
XIT  XXXRET
```

In both instances printing will start where the CHARACTRON beam is currently positioned. The first character of location A will be ignored and printing will commence with the second character. The second case assumes C and D to be zero; that is, printing will continue on the current frame of the camera(s) previously selected.

2. OUTCRT

This routine permits editing for the SC 4020 Recorder to be carried out in a manner similar to that of the OUTPUT routine already available in the Bell System for editing output

*C is ignored by the IBM 7090 version of the subroutine package.

for the IBM 717 line printer. A sample code using the OUTCRT routine is presented in Table 2, and the output generated by this code is shown in Figure 11.

Characters are positioned automatically at the printing line beginning five character positions to the right of the margin. A maximum of 120 characters may be printed per line.

The format statements which control the printing are written as for the OUTPUT routine. For a description of format statements, refer to the Programmer's Reference Manual, FORTRAN Automatic Coding System for the IBM 704, Form No. C28-6003, pp.25–30. The first character of the output generated for each line of printing is a control character.

The following control characters have the same function as in routine OUTPUT:

Δ – single space before printing
0 – double space before printing
1 – start a new page before printing

All other characters will cause a single space before printing.

The following five types of digital conversions are possible:

a. Floating binary to floating decimal,
b. floating binary to fixed decimal,
c. binary integer to decimal integer only (decrement of word converted),
d. binary integer to decimal integer (complete word conversion), and
e. binary to octal integer.

There are two types of calling sequences available. For example:

```
TSX  OUTCRT,4
NTR  F,,N
NTR  A
NTR  B,2
NTR  C
XIT  XXXRET
```

Here the format statement beginning at location F controls the printing of the contents of location A, the contents of location B as modified by index register 2, and the contents of C. N* designates the camera selection as follows:

N = 0 No camera is selected,
N = 1 camera 1 is selected,
N = 2 camera 2 is selected, and
N = 3 both cameras are selected.

The second type of calling sequence is:

```
TSX  OUTCRT,4
NTR  F,,N
MON  A,,B
```

*N is ignored by the 7090 version of the subroutine package.

Here F and N are interpreted as in the previous case; however, a consecutive block of core from locations A to B, inclusive, is printed under the control of the format statement. No indexing is allowed.

D. GRAPH PLOTTING SUBROUTINE

1. CXPLOT

This routine can be used to generate and label graphs such as those shown in Figures 3 and 12. It will perform the scaling required and plot sets of points whose coordinates are given in floating point form. If so specified, these points will be connected in sequence, using the vector generator. The set of grid lines to be drawn may be specified together with a format to control their labeling. The printing of specified horizontal and vertical titles is also included. The CHARACTRON commands generated can be sent directly to the CHARACTRON, be written on tape, or both.* The routine examines and interprets each set of pseudo-operations, performing them in the sequence in which they are given. Thus, sets of pseudo-operations can be used as required. A sample program using the CXPLOT routine is given in Table 3. The output generated by it is shown in Figure 12.

The entry to this routine is by means of a

TSX CXPLOT,4

instruction. The routine will examine the calling sequence to be found in the memory locations, immediately following the location of this TSX instruction. The following pseudo-operations will be recognized in the calling sequence:

Selection of equipment: FVE C,t,N

This pseudo-operation selects the output equipment to be used by the routine; normally, it must be the first pseudo-operation used by a program.

C** designated CHARACTRON and camera(s) selection as follows:

C = 0 will indicate that the CHARACTRON is not to be selected,
C = 1,2 will select the recorder and camera C,
C = 3 will select the recorder and both cameras, and
C > 3 will indicate that the proper camera(s) has been selected.

N designates tape selection:

N = 0 will indicate that the output is to be written on tape A8.
N ≠ 0 will write the instructions generated for the recorder as binary output on tape N; a select camera C command will be written on tape N; and if C = 0 a select camera 1 will be written on tape N.

---

*Commands must be written on tape with the 7090 version.

**C will be ignored by the 7090 version.

t designates film advance:

t ≠ 0 will cause the film to be advanced one frame on camera C, and

t = 0 will indicate that there is to be no film advance.

Upon the selection of the recorder by any of the means mentioned, a "Stop Print" command will be executed to assure that the CHARACTRON is in the plotting mode.

Termination of plot: MZE C,t,N

The MZE pseudo-operation gives information required to terminate either a particular plot or a set of plots.

C* designates camera selection as follows:

C = 0 will indicate that the film is *not* to be advanced on either camera,

C = 1,2 will advance the film one frame on camera C,

C = 3 will advance the film one frame on both cameras, and

C > 3 will advance the film in whatever camera(s) is currently selected.

N designates tape usage:

N = 0 will indicate tape A8 is to be used, and

N ≠ 0 will cause an advance film command to be generated and the output block still in memory to be written on tape N.

t is an end-of-file indicator if N ≠ 0:

t = 0 will indicate that no end-of-file is to be written on tape N, and

t ≠ 0 will cause an end-of-file to be written on tape N.

An MZE instruction with C = t = N = 0 will be treated as a skip instruction, and control will pass to the next pseudo-operation.

Printing of horizontal titles: SIX SX, l, SY
SIX F, SIZE,D

The SIX pseudo-operations give information required for printing titles horizontally. They will always occur in pairs and in the specified order. In the first instruction of the pair, when

l ≠ 0, SX and SY designate the X- and Y-coordinates locating the center of the title,

l = 0, SX and SY designate the X- and Y-coordinates locating the position at which the first character of the title is to be centered.

In the second instruction of the pair,

F designates the starting location of the format statement to be used for printing,

*C will be ignored by the 7090 version.

SIZE designates the letter size and may have values 0, 1, 2, or 3 specifying that letters of 1, 2, 4, or 8 times normal size are to be printed.

If SIZE = 0 and D is nonzero, then characters of normal size will be printed, but using the vector generator. This will result in characters slightly larger than when printed from the matrix. If a tag is specified it will take precedence over D.

The format statement starting at location F must be of the form

(xHyz)

where x designates an integer indicating the number of Hollerith characters which follow the H;

y designates a control character:

y = 1 starts a new page, i.e., the film is to be advanced on the camera indicated by z,*

y ≠ 1 indicates that the current frame is to be used;

z designates a control character used for camera selection as follows:

z = 1 selects camera 1,

z = 2 selects camera 2,

z = 3 selects both cameras, and

z ≠ 1, 2, or 3 indicates that the proper camera has already been selected.

Printing of vertical titles: SVN SX, l, SY
SVN F, SIZE, D

The SVN pseudo-operations give information required for printing titles vertically. They are similar to the SIX pseudo-operations in format.

Generation and labeling of grid lines:

PON Rx_o,,Rx_N
PON Ry_o,,Ry_N
PON n,e,n′
PON m,e,m′
PON Fx,,Fy
- - - - - - - - - - - -
PON X_o,,X_N
PON Y_o,,Y_M

The PON pseudo-operations specify the grid lines to be drawn, the exposure to be used in drawing them, and the formats to control their labeling, as well as the scaling to be used in the plot.

*z is ignored by the 7090 version.

The first pseudo-operation

$$\text{PON } Rx_o,,Rx_N$$

contains the locations in which the range of x-values is specified. Rx_o designates the location in which the lower end of the range is to be found, and Rx_N designates the location in which the upper end of the range is to be found. The limits for the range will be assumed to be in floating point form.

The second pseudo-operation

$$\text{PON } Ry_o,,Ry_M$$

contains the locations in which the range of y-values is specified.

The third pseudo-operation

$$\text{PON n,e,n}'$$

contains an integer n, specifying the number of uniform intervals in the X-direction to be bounded by grid lines; and an integer n', specifying that the first grid line and every n'th grid line following will be labeled. If e = 1, the labeled grid lines will be drawn heavy, otherwise they will be light.

The fourth pseudo-operation

$$\text{PON m,e,m}'$$

is similar to the third but refers to the y-direction.

The fifth pseudo-operation

$$\text{PON FX,,FY}$$

contains the locations of format statements to be used in labeling the horizontal and vertical grid lines, respectively. These should be of the form,

$$\text{(F c.d)}$$

where F indicates that a conversion from a floating point number to a fixed point number should be performed, and that the fixed point number should be printed;

c designates the "column width" ($c \leqslant 9$); and

d designates the number of digits to be retained beyond the decimal point [$d < (c-1)$].

The sixth pseudo-operation

$$\text{PON } X_o,,X_N$$

contains the range of horizontal positions to be used for the graph ($0 \leqslant X_o < X_n \leqslant 1023$). If this instruction is omitted, the equivalent of a

$$\text{PON 96,,992}$$

will be executed. (See Figure 9.)

The seventh pseudo-operation

$$\text{PON } Y_o,,Y_M$$

contains the range of vertical positions to be used for the graph ($0 \leqslant Y_o < Y_N \leqslant 1023$). If this instruction is omitted (it must be omitted if the previous one is), the standard equivalent of a

$$\text{PON } 0,,896$$

will be executed. (See Figure 9.)

Generation of graph: $\underline{\text{PTW } Lx_o, \text{ EX, } Ly_o}$
$\underline{\text{PTW N,}\alpha, \text{ CHAR}}$

This pair of pseudo-operations specifies the character and the exposure to be used in plotting, the memory area containing the sets of (x, y) values to be plotted, and the scaling factors to be used.

Lx_o designates the starting memory location for the sequence of values of x to be plotted, and Ly_o designates the starting location for the corresponding values of y. N designates the number of pairs of values of x and y to be plotted. Thus locations Lx_o to $Lx_o + N - 1$ are assumed to contain the values of x corresponding to the values of y found in locations Ly_o to $Ly_o + N - 1$.

EX designates the exposure to be used in plotting. If EX = 0, the exposure will be heavy; otherwise, the light mode will be used.

For each pair of values, (x, y), a corresponding pair of coordinates (X, Y), is computed as follows:

$$X = ax + b$$
$$Y = cy + d$$

a, b, c, and d are called scaling parameters. They depend on the range of coordinates to be used when plotting the range of values specified.

If $\alpha = 0$, the scaling factors computed from the previous set of PON pseudo-operations will be used.

If $\alpha \neq 0$, the four locations following the pair of PTW instructions should contain floating point values of a, b, c, and d in this order. The Hollerith character to be used for the plot is given in the six least significant bit positions (30 to 35) of location CHAR.

If the character specified is the space, the vector generator will be used for the plot, and successive points will be connected, using straight line segments.

Generation of special grid line: PTH X, t, Y

This pseudo-operation permits the programmer to draw grid lines directly.

If t = 0, 2, or 4, a horizontal grid line will be drawn beginning at (X, Y) and extending to the right edge of the frame.

If t = 1, 3, 5, or 7, a vertical grid line will be drawn from (X, Y) to the upper edge of the frame.

End of calling sequence: XIT XXXRET

This pseudo-operation indicates the end of the calling sequence. The exit from this subroutine will be to the line following that of this pseudo-operation.

E. TAPE-TO-CHARACTRON ROUTINES

1. TCEDIT

This routine makes it possible to use the SC 4020 Recorder to print a tape which has been edited for the IBM 717 line printer.

The calling sequence for this routine follows:

```
TSX  TCEDIT,4
     C,,D
XIT  XXXRET
```

where C* designates camera selection:

C = 0 camera was previously selected,
C = 1 camera 1 is selected,
C = 2 camera 2 is selected, and
C = 3 both cameras are selected;

D designates type of printer control:

D = 0 program control,
D = 1 single space, and
D $\geq$ 2 double space.

2. TCCOPY**

The TCCOPY routine reads a tape containing commands for the SC 4020 Microfilm Recorder, selects the recorder as a piece of input-output equipment, and sends the commands to it.

Each record read must consist of 20 binary words plus a check sum. Reading will be terminated when an end-of-file is sensed on the tape.

If the output goes on the Traid camera only, the writing will be done at approximately tape speed.

The calling sequence used is:

```
TRA TCCOPY
```

The input will be on tape unit 6 if the CRT card has N = 0 or space. If N $\neq$ 0, the input will be on tape unit N. Upon reading an end-of-file on tape, a transfer to location "Return" within the Bell System will be effected.

*C will be ignored by the 7090 version.

**TCCOPY is not available in the 7090 version.

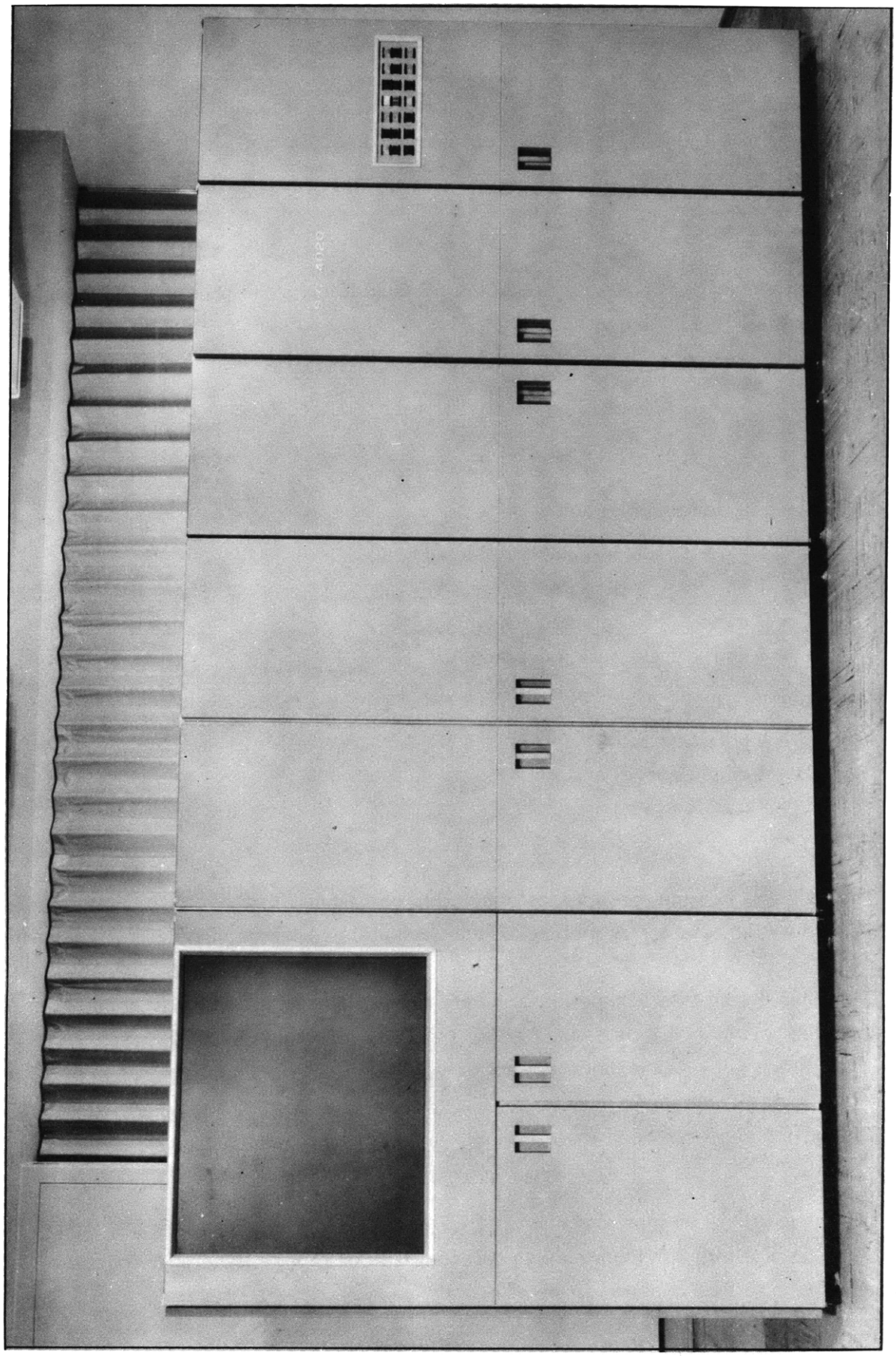


Figure 1 – SC 4020 Microfilm Recorder

Figure 2 – SC 4020 Microfilm Recorder On-Line with IBM 704

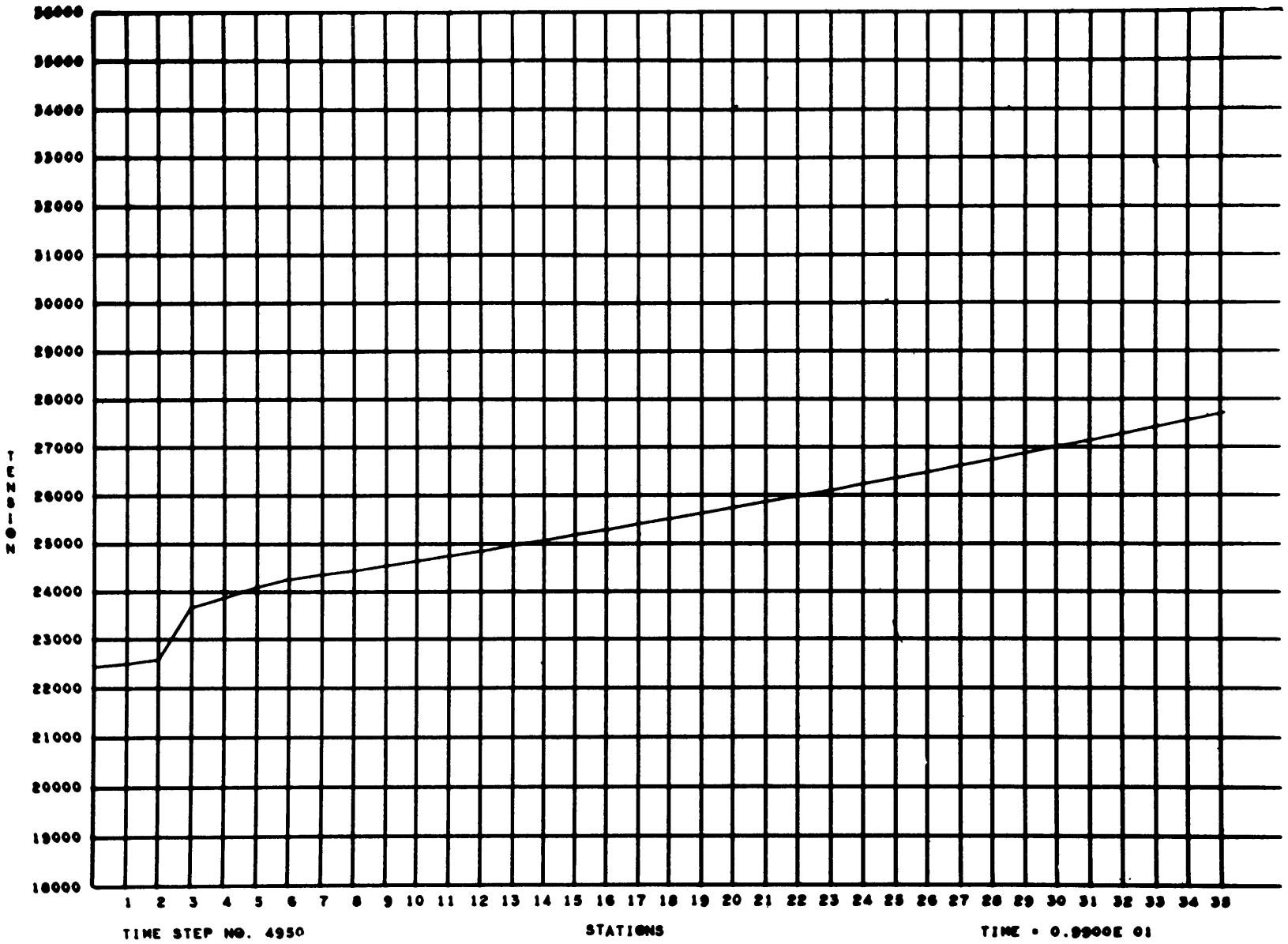


Figure 3 – Sample Output of Generalized Cable Problem Using CXPLOT Routine

This was plotted with the SC 4020 on-line with the IBM 704.

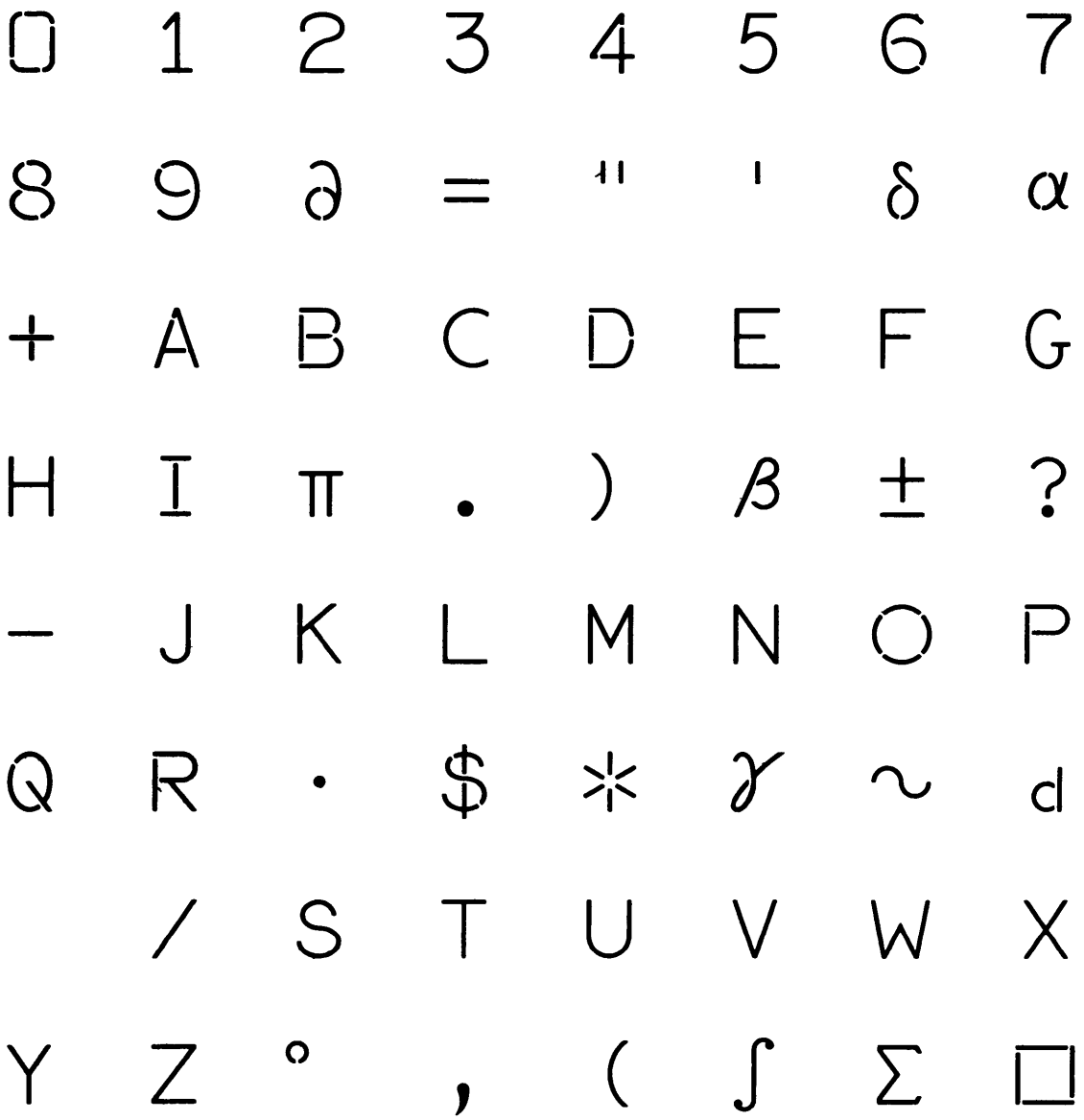
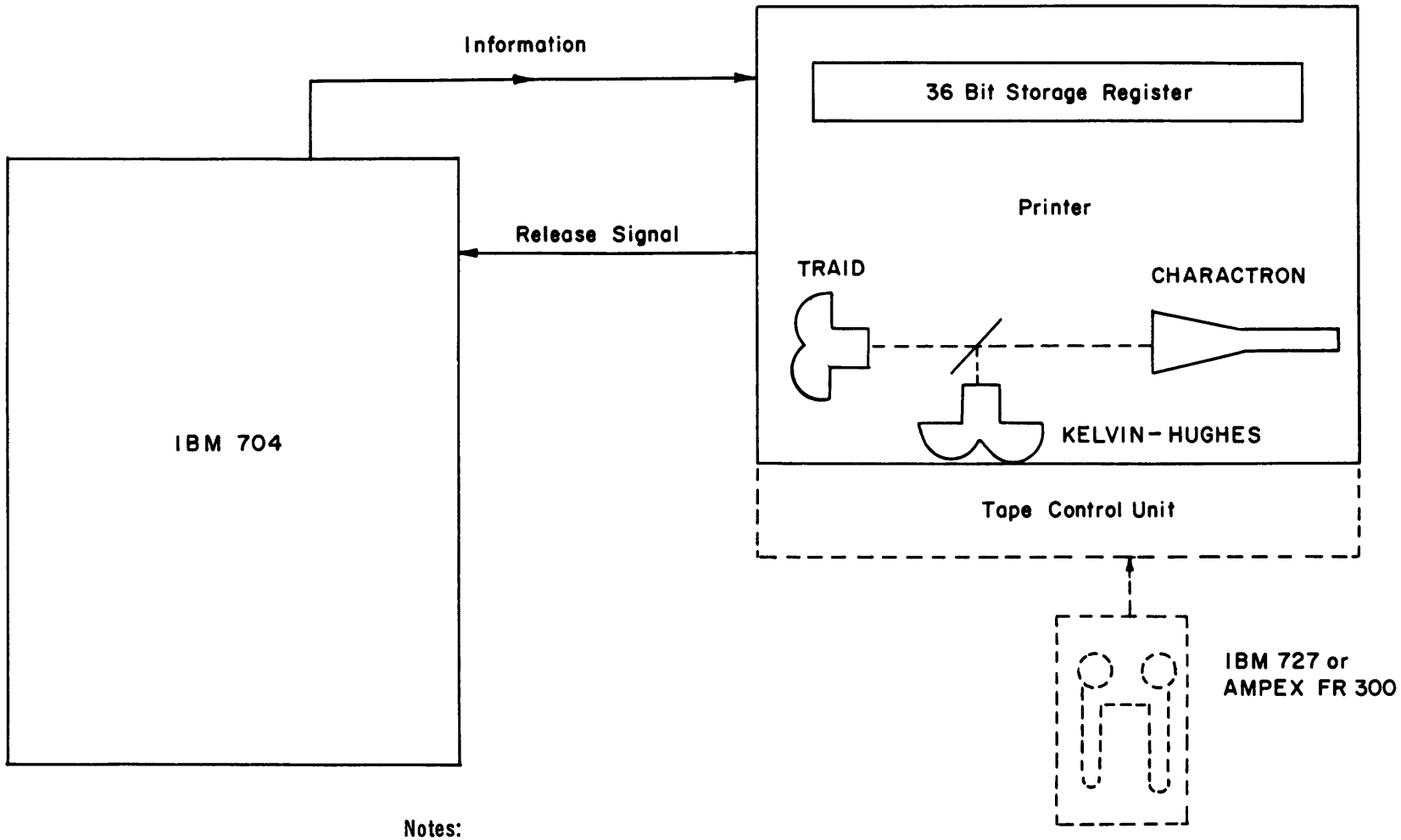


Figure 4 – SC 4020 CHARACTRON Matrix



Notes:

Print Rate: up to 15,000 characters per second.
Computer released 24 μsec after instruction is initiated.
Accuracy greater than 0.5 percent.

Figure 5 – AML On-line CHARACTRON System

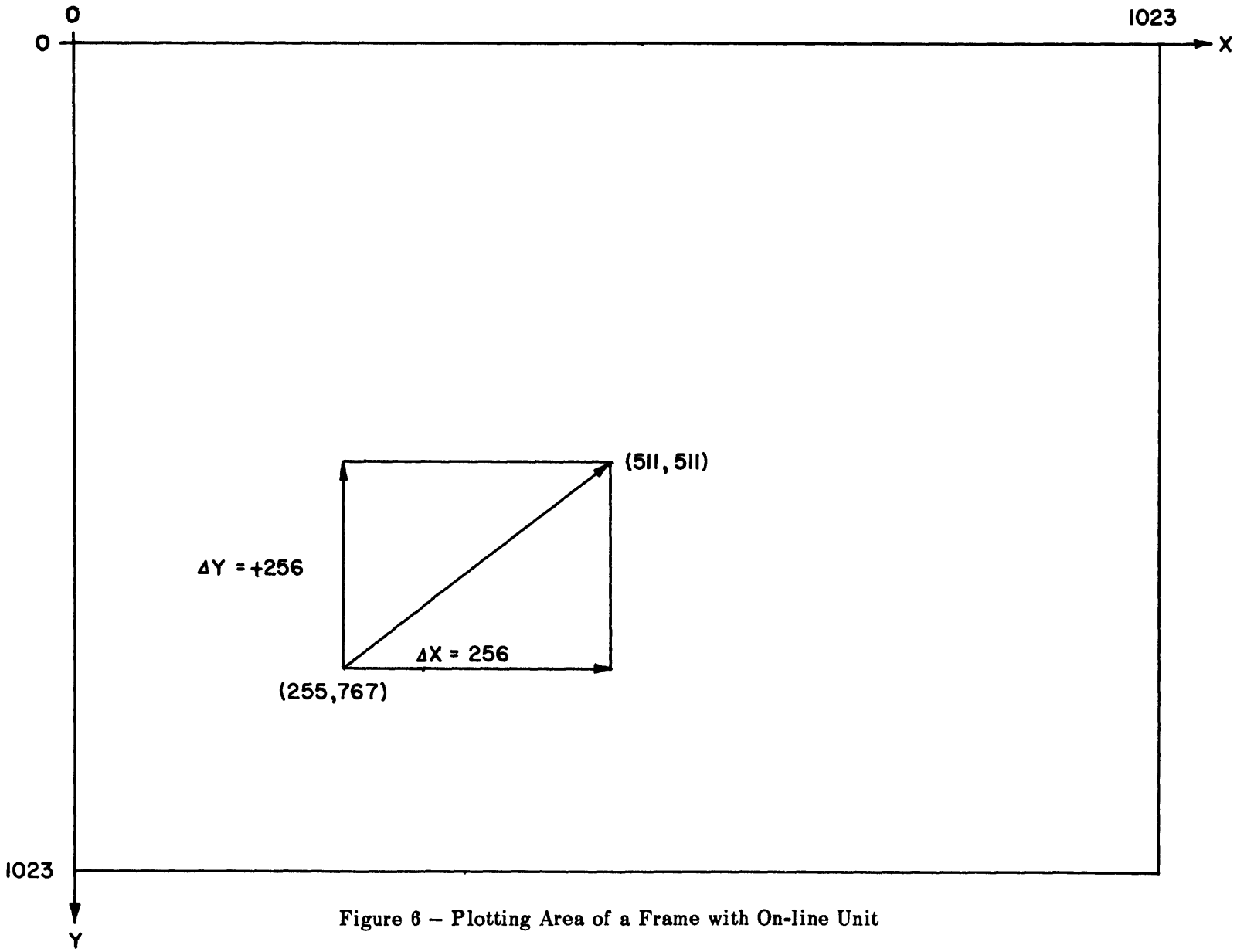


Figure 6 – Plotting Area of a Frame with On-line Unit

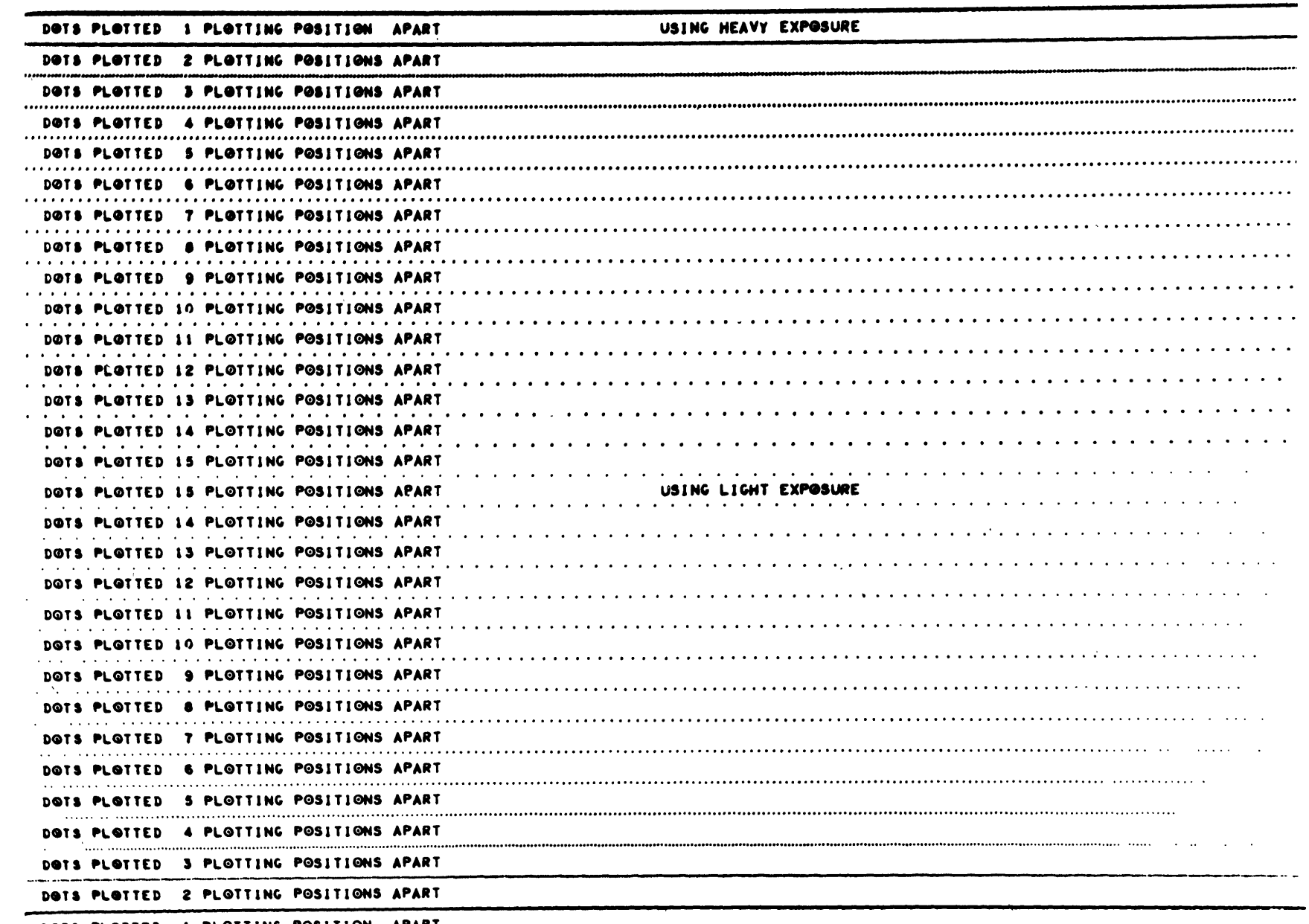


Figure 7 – Point Plotting Densities

This was plotted with the SC 4020 on-line with the IBM 704.

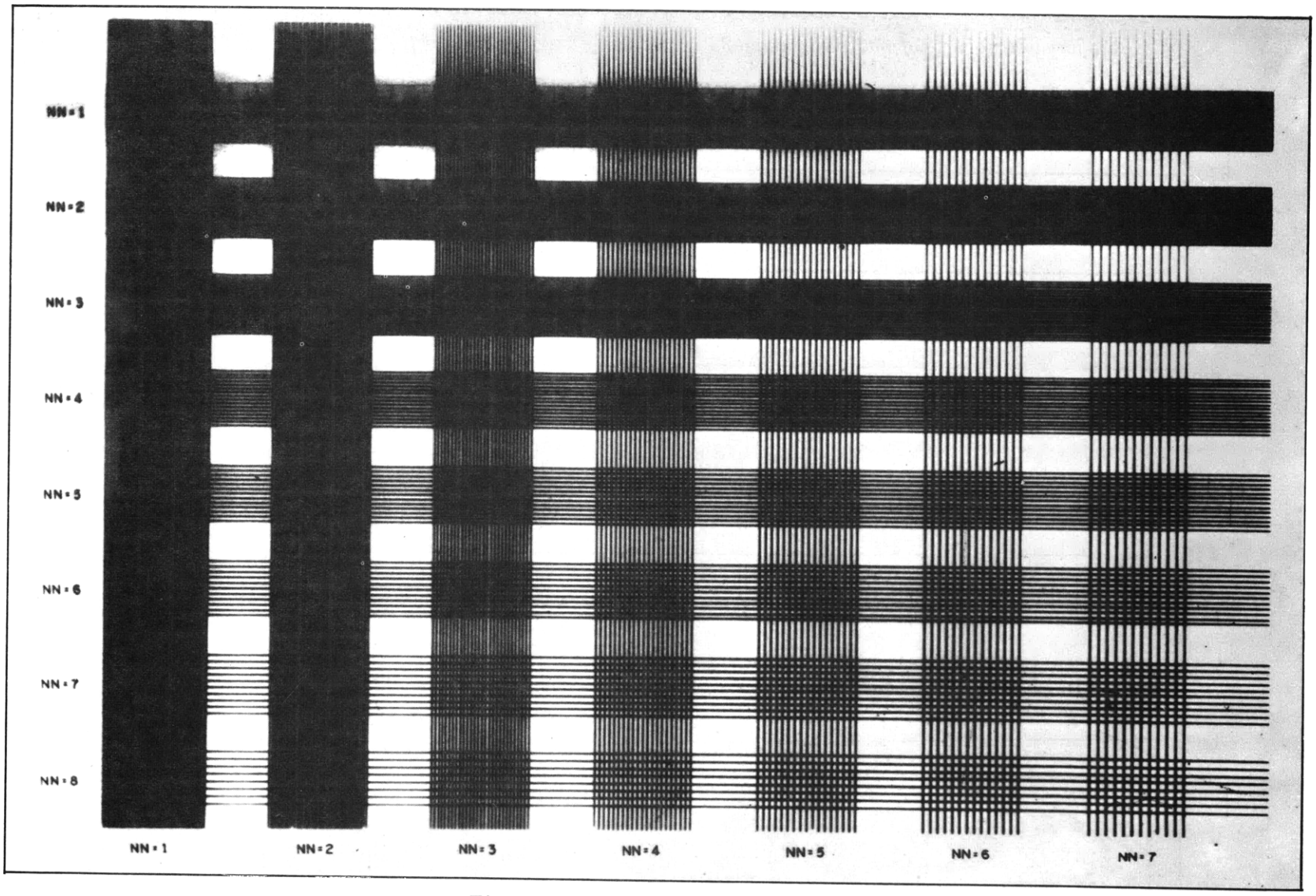


Figure 8 – Axis Generator Densities

This was plotted with the SC 4020 on-line with the IBM 704.

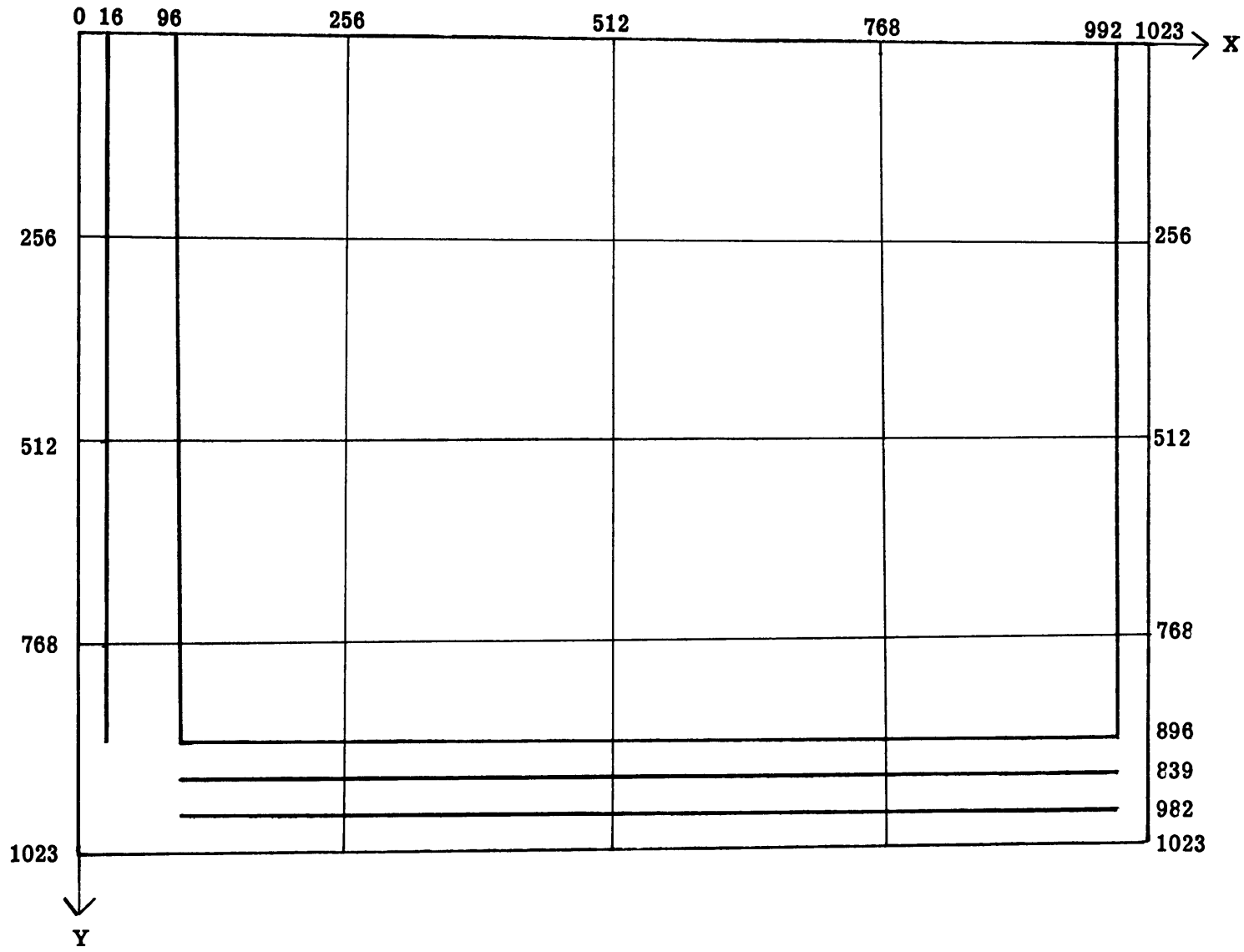


Figure 9 – Standard Plotting Area and Suggested Positions for Titles and Labels

THIS ROUTINE PRINTS HOLLERITH INFORMATION ON THE SC 4020 MICROFILM RECORDER AFTER ADVANCING THE FILM 1 FRAME IF SO SPECIFIED BY THE CALLING SEQUENCE. PRINTING WILL COMMENCE 1 PRINTING POSITION AFTER THE (X,Y) POSITION SPECIFIED.

IF EITHER OF THE ABBREVIATED CALLING SEQUENCES IS USED, PRINTING WILL COMMENCE WITH THE SECOND CHARACTER SPECIFIED BUT AT THE CURRENT POSITION OF THE BEAM.

A MAXIMUM OF 128 CHARACTERS MAY BE PRINTED PER LINE WHILE UP TO 64 ROWS MAY BE PRINTED ON A FRAME. ALL CHARACTERS WHICH MAY BE PRINTED IN THE TYPEWRITER SIMULATOR MODE ARE ACCEPTABLE TO THE CPRINT ROUTINE.

Figure 10 – Sample Output, CPRINT Routine

This was plotted with the SC 4020 on-line with the IBM 704.

AML PROBLEM 1-840-959-01

TABLE OF NUMBERS USING OUTCRT PRINT ROUTINE

VALUE	X	Y	Z	X1	Y1	Z1
1	2.5000E 01	2.4500E 02	1.5312E 00	3.8281E 01	2.5828E 02	6.3279E 04
2	3.0000E 01	2.5500E 02	1.5455E 00	4.6364E 01	2.7136E 02	6.9198E 04
3	3.5000E 01	2.6500E 02	1.5588E 00	5.4559E 01	2.8456E 02	7.5408E 04
4	4.0000E 01	2.7500E 02	1.5714E 00	6.2857E 01	2.9786E 02	8.1911E 04
5	4.5000E 01	2.8500E 02	1.5833E 00	7.1250E 01	3.1125E 02	8.8706E 04
6	5.0000E 01	2.9500E 02	1.5946E 00	7.9730E 01	3.2473E 02	9.5795E 04
7	5.5000E 01	3.0500E 02	1.6053E 00	8.8289E 01	3.3829E 02	1.0318E 05
8	6.0000E 01	3.1000E 02	1.5897E 00	9.5385E 01	3.4538E 02	1.0707E 05
9	6.5000E 01	3.2000E 02	1.6000E 00	1.0400E 02	3.5900E 02	1.1488E 05
10	7.0000E 01	3.3000E 02	1.6098E 00	1.1268E 02	3.7268E 02	1.2299E 05
11	7.5000E 01	3.4000E 02	1.6190E 00	1.2143E 02	3.8643E 02	1.3139E 05
12	8.0000E 01	3.5000E 02	1.6279E 00	1.3023E 02	4.0023E 02	1.4008E 05
13	8.5000E 01	2.4500E 02	1.1136E 00	9.4659E 01	2.5466E 02	6.2391E 04
14	9.0000E 01	2.5500E 02	1.1333E 00	1.0200E 02	2.6700E 02	6.8085E 04
15	9.5000E 01	2.6500E 02	1.1522E 00	1.0946E 02	2.7946E 02	7.4056E 04
16	1.0000E 02	2.7500E 02	1.1702E 00	1.1702E 02	2.9202E 02	8.0306E 04
17	1.0500E 02	2.8500E 02	1.1875E 00	1.2469E 02	3.0469E 02	8.6836E 04
18	1.1000E 02	2.9500E 02	1.2041E 00	1.3245E 02	3.1745E 02	9.3647E 04
19	1.1500E 02	3.0500E 02	1.2200E 00	1.4030E 02	3.3030E 02	1.0074E 05
20	1.2000E 02	3.1500E 02	1.2600E 00	1.5120E 02	3.4620E 02	1.0905E 05
21	1.2500E 02	3.2500E 02	1.2745E 00	1.5931E 02	3.5931E 02	1.1678E 05
22	1.3000E 02	3.3500E 02	1.2885E 00	1.6750E 02	3.7250E 02	1.2479E 05
23	1.3500E 02	3.4500E 02	1.3019E 00	1.7575E 02	3.8575E 02	1.3309E 05
24	1.4000E 02	3.5500E 02	1.3148E 00	1.8407E 02	3.9907E 02	1.4167E 05
25	1.4500E 02	1.7000E 02	0.	0.	2.5000E 01	4.2500E 03
26	1.5000E 02	1.8000E 02	1.8000E 00	2.7000E 02	3.0000E 02	5.4000E 04
27	1.5500E 02	1.9000E 02	1.8095E 00	2.8048E 02	3.1548E 02	5.9940E 04
28	1.6000E 02	2.0000E 02	1.8182E 00	2.9091E 02	3.3091E 02	6.6182E 04
29	1.6500E 02	2.1000E 02	1.8261E 00	3.0130E 02	3.4630E 02	7.2724E 04
30	1.7000E 02	2.2000E 02	1.8333E 00	3.1167E 02	3.6167E 02	7.9567E 04
31	1.7500E 02	2.3000E 02	1.8400E 00	3.2200E 02	3.7700E 02	8.6710E 04
32	1.8000E 02	2.4000E 02	1.8462E 00	3.3231E 02	3.9231E 02	9.4154E 04
33	1.8500E 02	2.5000E 02	1.8519E 00	3.4259E 02	4.0759E 02	1.0190E 05
34	1.9000E 02	2.6000E 02	1.8571E 00	3.5286E 02	4.2286E 02	1.0994E 05
35	1.9500E 02	2.7000E 02	1.8621E 00	3.6310E 02	4.3810E 02	1.1829E 05
36	2.0000E 02	2.8000E 02	1.8667E 00	3.7333E 02	4.5333E 02	1.2693E 05
37	2.0500E 02	2.9000E 02	1.8710E 00	3.8355E 02	4.6855E 02	1.3588E 05
38	2.1000E 02	3.0000E 02	0.	0.	9.0000E 01	2.7000E 04
39	2.1500E 02	3.1000E 02	0.	0.	9.5000E 01	2.9450E 04
40	2.2000E 02	3.2000E 02	0.	0.	1.0000E 02	3.2000E 04
41	2.2500E 02	3.3000E 02	1.3200E 01	2.9700E 03	3.0750E 03	1.0147E 06
42	2.3000E 02	3.4000E 02	1.1333E 01	2.6067E 03	2.7167E 03	9.2367E 05
43	2.3500E 02	3.5000E 02	1.0000E 01	2.3500E 03	2.4650E 03	8.6275E 05
44	2.4000E 02	3.6000E 02	9.0000E 00	2.1600E 03	2.2800E 03	8.2080E 05
45	2.4500E 02	3.7000E 02	8.2222E 00	2.0144E 03	2.1394E 03	7.9159E 05
46	2.5000E 02	3.8000E 02	7.6000E 00	1.9000E 03	2.0300E 03	7.7140E 05
47	2.5000E 02	3.8500E 02	7.0000E 00	1.7500E 03	1.8850E 03	7.2572E 05
48	2.5500E 02	3.9500E 02	6.5833E 00	1.6787E 03	1.8187E 03	7.1841E 05
49	2.6000E 02	4.0500E 02	6.2308E 00	1.6200E 03	1.7650E 03	7.1482E 05

Figure 11 – Sample Output, OUTCRT Routine

This was plotted with the SC 4020 on-line with the IBM 704.

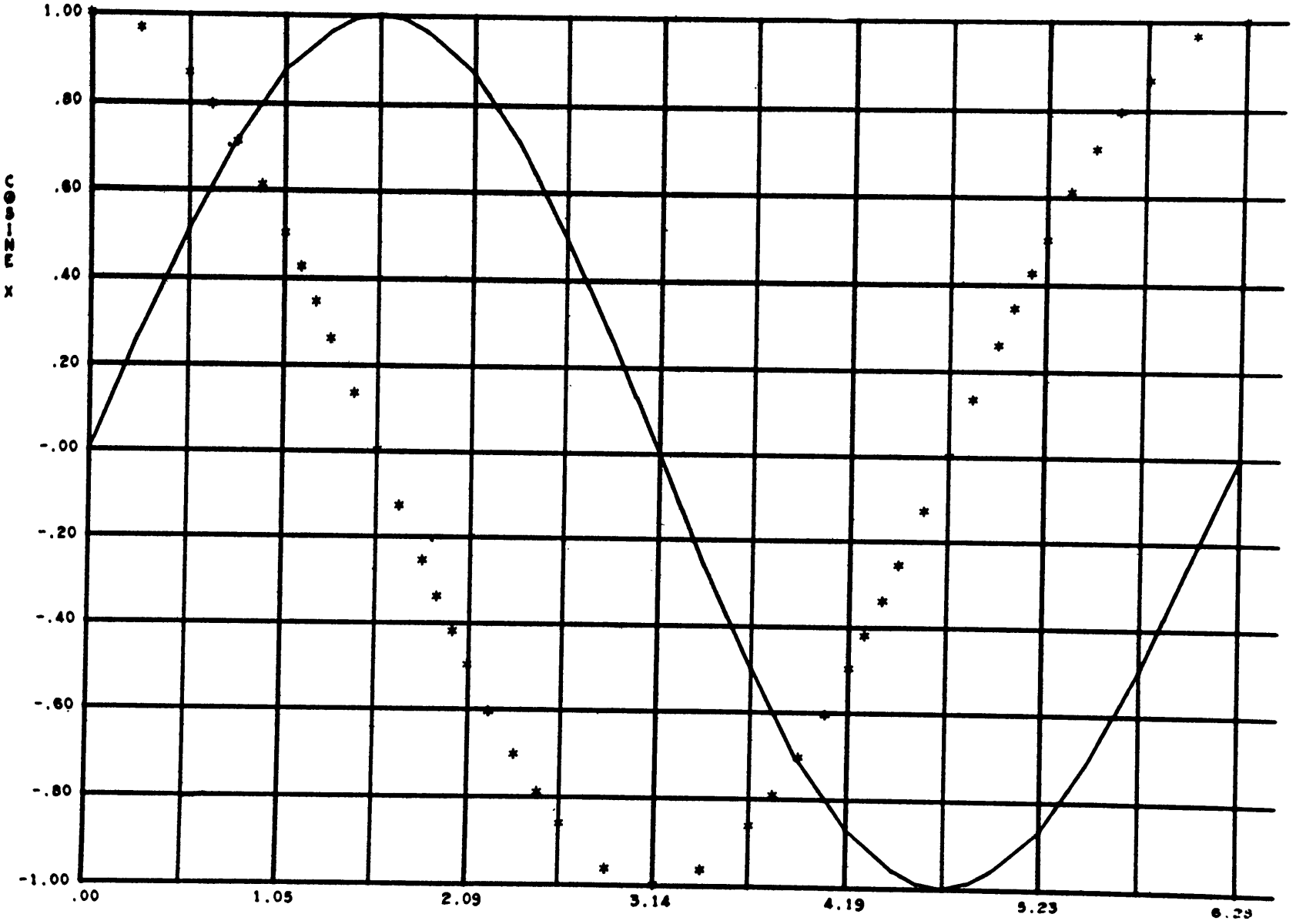


Figure 12 – Sample Output, CXPLOT Routine, Point Plotting, and Vector Plotting

This was plotted with the SC 4020 on-line with the IBM 704.

TABLE 1

Sample Code Using CPRINT Routine to Generate Figure 10

```
        TSX CPRINT,4
            A,,B-1
            3,,1
            0,,336
        XIT XXXRET
        TSX CPRINT,4
            B,,C-1
            0,,0
            0,,400
        XIT XXXRET
        TSX CPRINT,4
            C,,D-1
            0,,0
            0,,464
        XIT XXXRET
        TSX CPRINT,4
            D,,D+6
            0,,0
            544,,344
        XIT XXXRET
A       BCD       THIS ROUTINE PRINTS HOLLERITH INFORMATION ON THE SC 402
        BCD  0 MICROFILM RECORDER AFTER ADVANCING THE FILM 1 FRAME IF SO
        BCD  SPECI- FIED BY THE CALLING SEQUENCE.  PRINTING WILL COMMENCE
        BCD   1 PRINTING POSITION AFTER THE (X,Y) POSITION SPECIFIED.
B       BCD       IF EITHER OF THE ABBREVIATED CALLING SEQUENCES IS USED,
        BCD   PRINTING WILL COMMENCE WITH THE SECOND CHARACTER SPECIFIED
        BCD 7BUT AT THE CURRENT POSITION OF THE BEAM.
C       BCD       A MAXIMUM OF 128 CHARACTERS MAY BE PRINTED PER LINE WHI
        BCD  LE UP TO 64 ROWS MAY BE PRINTED ON A FRAME.  ALL CHARACTERS
        BCD  WHICH  MAY BE PRINTED IN THE TYPEWRITER SIMULATOR MODE ARE A
        BCD 6CCEPTABLE TO THE CPRINT ROUTINE.
D       BCD 7FIGURE 10 - SAMPLE OUTPUT, CPRINT ROUTINE
```

TABLE 2

Sample Code Using OUTCRT Routine to Generate Figure 11

```
     LXA T1,1
     TSX OUTCRT,4
     NTR FU,,3
     XIT XXXRET
     TSX OUTCRT,4
     NTR FF0,,3
     XIT XXXRET
     TSX OUTCRT,4
     NTR FF1,,3
     XIT XXXRET
     TSX OUTCRT,4
     NTR F1,,3
     NTR V,1
     NTR X,1
     NTR Y,1
     NTR Z,1
     NTR X1,1
     NTR Y1,1
     NTR Z1,1
     XIT XXXRET
     TIX*-10,1,1
     TSX OUTCRT,4
     NTR F2
     XIT XXXRET
     TSX RETURN,4
 F0  BCD 7(H147(1H )25HAML PROBLEM  1-840-959-01 )
     OCT 777777777777
 F1  BCD 3(N16,1P6E15.4)
     OCT 777777777777
FF1  BCD  (1H016(1H )75H VALUE          X          Y          Z
     BCD 9  X1          Y1          Z1               )
     OCT 777777777777
F2   BCD 5(1H047(1H )10H FIGURE 11 )
     OCT 777777777777
FF0  BCD  (1H030(1H )43HTABLE OF NUMBERS USING OUTCRT PRINT ROUTINE  )
     OCT 777777777777
 T1  DEC 50
```

TABLE 3

Sample Code Using CXPLOT Routine to Generate Figure 12

```
      TSX CXPLOT,4
      FVE 3,0,0
      SIX 576,1,948
      SIX F1
      SIX 576,1,1002
      SIX F2
      SVN 16,1,250
      SVN F3
      SVN 32,1,240
      SVN F4
      PON RX0,,RXN
      PON RY0,,RYN
      PON 12,1,2
      PON 10,1,1
      PON FX,,FY
      PTW LX0,0,LY0
      PTW 29,0,CHAR
      PTW LX1,0,LY1
      PTW 45,0,CHAR1
      MZE 3,0,0
      XIT XXXRET
   F1 BCD 2(3H   X)
   F2 BCD 9(45H  FIGURE 12.    SINE --- AND COSINE *** CURVES)
   F3 BCD 2(8H   SINE X)
   F4 BCD 3(10H  COSINE X)
  RX0 DEC 0
  RXN DEC 6.28
  RY0 DEC -1.0
  RYN DEC 1.0
   FX BCD 1(F5.2)
   FY SYN FX
 CHAR OCT 60
CHAR1 OCT 54
  LX0 DEC 0,.26,.52,.79,1.05,1.31,1.44,1.57,1.70,1.83,2.09,2.35,2.61
      DEC 2.88,3.14,3.40,3.66,3.92,4.18,4.44,4.57,4.71,4.84,4.97,5.23
      DEC 5.49,5.75,6.01,6.28
  LY0 DEC 0,.26,.50,.71,.87,.96,.99,1.0,.99,.96,.87,.71,.50,.26,0,-.26
      DEC -.50,-.71,-.87,-.96,-.99,-1.0,-.99,-.96,-.87,-.71,-.50,-.26,0
  LX1 DEC 0,.26,.52,.65,.79,.92,1.05,1.14,1.22,1.31,1.44,1.57,1.70
      DEC 1.83,1.92,2.01,2.09,2.22,2.36,2.49,2.62,2.88,3.14,3.40
      DEC 3.66,3.79,3.92,4.06,4.19,4.27,4.36,4.45,4.58,4.71,4.84,4.97
      DEC 5.06,5.15,5.23,5.36,5.49,5.62,5.77,6.02,6.28
  LY1 DEC 1.0,.965,.866,.793,.707,.609,.5,.423,.342,.258,.130,0,-.130
      DEC -.258,-.342,-.423,-.5,-.609,-.707,-.793,-.866,-.965,-1.0
      DEC -.965,-.866,-.793,-.707,-.609,-.5,-.423,-.342,-.258,-.130
      DEC 0,.130,.258,.342,.423,.5,.609,.707,.793,.866,.965,1.0
```

TABLE 4

SC 4020 Commands

Command		Octal Representation	Approximate Recorder Execution
ADF (1)†	Advance film	46	80 μ sec
*ADF (2)	Advance film	46	500 μ sec
**CRN	Carriage return	52	
DWR	Draw vector	60 to 77	288 μ sec
EPH	Expose heavy	02	72 μ sec
EPL	Expose light	04	72 μ sec
GHA	Generate horizontal axis	30	1 μ sec
GVA	Generate vertical axis	32	1 μ sec
***PCP	Print current point	22	348 μ sec
***PSP	Print specified point	20	72 μ sec
PLT	Plot	00	72 μ sec
RES (1)	Reset	56	80 μ sec
*RES (2)	Reset	56	500 μ sec
*SBC	Select both cameras	43	50 μ sec
*SC1	Select camera 1	41	50 μ sec
*SC2	Select camera 2	42	50 μ sec
SOP	Stop print	12	72 μ sec

*In the AML off-line unit only camera 1 is available and need not be selected.

**This command is only recognized in the typewriter simulator mode of operation; the time required for its execution is equal to the time required to print a character in the mode.

***In the typewriter simulator mode of operation, the execution time per word transmitted is 348 μ sec, unless the word includes a reset command.

†The number in parenthesis indicates which camera, camera 1 or camera 2, is selected.

TABLE 5

Octal Representation of Characters

Character	Octal Representation	Character	Octal Representation
0	00	–	40
1	01	J	41
2	02	K	42
3	03	L	43
4	04	M	44
5	05	N	45
6	06	O	46
7	07	P	47
8	10	Q	50
9	11	R	51
Stop Print (∂)	12	Carriage Return (·)	52
=	13	$	53
($''$)	14	*	54
($'$)	15	(γ)	55
Reset (δ)	16	Reset ($\sim$)	56
(α)	17	(d)	57
+	20	Blank	60
A	21	/	61
B	22	S	62
C	23	T	63
D	24	U	64
E	25	V	65
F	26	W	66
G	27	X	67
H	30	Y	70
I	31	Z	71
(π)	32	(°)	72
.	33	,	73
)	34	(	74
(β)	35	($\int$)	75
($\pm$)	36	(Σ)	76
(?)	37	($\square$)	77

*Parentheses signify that the octal code of the character is not recognized by the 704 peripheral equipment.

APPENDIX A*

ENGINEERING FEATURES OF THE SC 4020

CONSTRUCTION

With the exception of power supplies, all electronic circuits are fabricated as removable circuit boards. Functionally related boards are grouped in "bins," permitting modular construction, simplifying maintenance, assisting the rapid localization of faults, keeping the unit size small enough for circuit substitution, and permitting ready access to electronic terminals.

ALIGNMENT CIRCUITS

The SC 4020 contains an internal test programmer and tube alignment circuits. The internal test programmer supplies inputs to the decoder circuits for character selection and deflection. These inputs occur at a repetition rate sufficient to allow a nonflickering display. Provision is made for visually observing the screen of the CHARACTRON shaped beam tube while making adjustments.

DIMENSIONS

The Applied Mathematics Laboratory unit, including the automatic processing camera and viewing screen, is 156 inches wide by 72 inches high by 34 inches deep.

POWER REQUIRED

Basic Unit with all options except Automatic Processing Camera: 208/120V, 3Ø, 4 wire at 3200 watts. Automatic Processing Camera: 208/120V, 3Ø, at 6600 watts.

INPUT AND OUTPUT SIGNALS

Inputs:	Levels: "1" or "Up" + 5 to + 50 volts
	"0" or "Down" to – 50 volts
	"Write" Line Rise Time: less than 1 μ sec
	Input Impedances: 10,000 ohms 500 $\mu\mu$ f
Outputs:	Ready Line: "Up" + 5 to + 15 volts
	"Down" 0 to – 10 volts
Resume Pulse:	Amplitude: 10 to 15 volts, negative going;
	Rise and Fall Times (10K ohms, 500 $\mu\mu$ f load): less than 1 μ sec

*Reprint of Pages 2–8 and 2–9 of SC 4020 High-Speed Microfilm Printer Utilizing the CHARACTRON Shaped Beam Tube–Technical Description–Stromberg-Carlson, San Diego.

INDICATORS

Indicator lamps on an auxiliary control panel display the content of the printer input register. Status of both computer and printer are indicated on the operator control panel. All error and interlock conditions are indicated on the auxiliary control panel. The fact that there is an error or interlock condition is indicated on the operator control panel.

See Figure 13 for a schematic drawing of the operator's panel. The conditions indicated by the lettered neons are as follows:

Inoperative

A – Internal Programmer On

B – Light Seal

C – Power Sensor

D – Spare

E – Traid Film Exhausted

F – K – H Film Gate

H – K – H Compressed Air

J – K – H Film Exhausted

Alarm

N – Traid Shutter Failure

P – Traid Power Off

R – K – H Power Off

V – No Camera Select

The remaining lettered neons are spares.

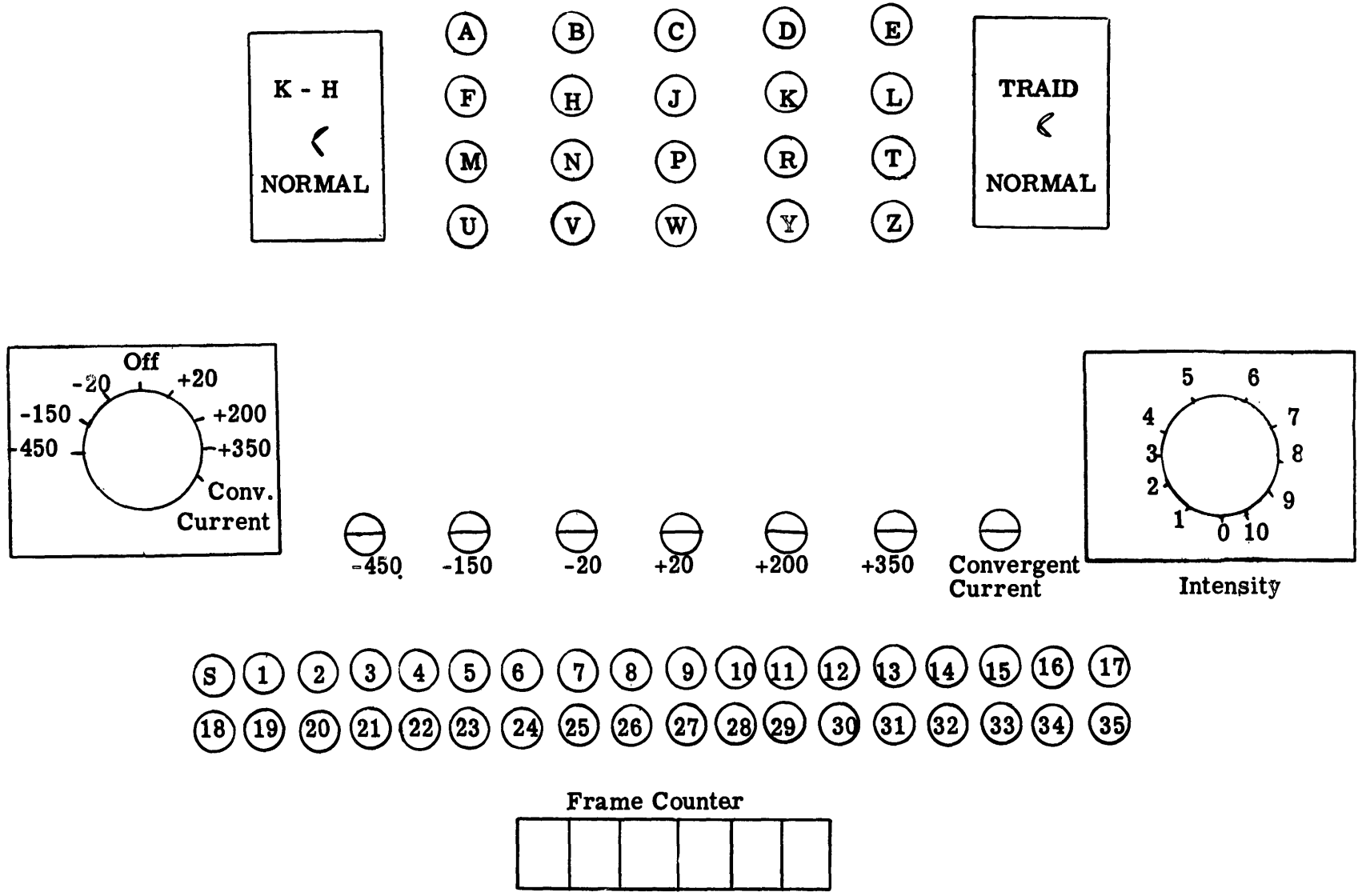


Figure 13 – SC 4020 Operator Panel

APPENDIX B*

THE CHARACTRON SHAPED BEAM TUBE, TYPE C7C, AND ASSOCIATED CIRCUITRY

The CHARACTRON Shaped Beam Tube, Type C7C, and associated driving circuitry converts rapidly changing digital electrical signals, representing a sequence of alphanumeric symbols, into a visual display of the corresponding sequence of symbols. The equipment necessary to accomplish this conversion consists of the CHARACTRON shaped beam tube with its necessary electromagnetic coils and Mu-Metal shield, the driving circuitry, and the high-voltage power supply. Figure 14 shows this in block diagram form.

Figure 15 is a view of the CHARACTRON shaped beam tube with its electromagnetic coils and Mu-Metal shield. Mechanical mounting details are not shown. The tube contains the following within its envelope:

Cathode
Control Grid
Accelerating Anode (A_2)
Focus Anode (A_1)
Horizontal and Vertical Selection Plates
Character Matrix and Matrix Shield
Horizontal and Vertical Reference Plates
Helical Accelerator (A_3)
Phosphor Viewing Screen

External to the envelope, but surrounding it, are the following:

Convergence Coil Assembly consisting of the main winding selection and reference trim windings, and horizontal and vertical centering windings.
Deflection Yoke
Mu-Metal Shield

The electron beam originates at the cathode and is controlled in intensity by the control grid. Both of these elements operate at about −3.3 kv. The accelerating anode (A_2), which operates at ground potential, imparts the initial velocity to the electron beam. As can be seen in Figure 14, this anode is in two sections. After emerging from the first section of the accelerating anode, the beam passes through the focus anode (A_1) aperture and the second section of the accelerating anode. The focus anode operates at about −2.5 kv. The electrostatic lens produced by the accelerating and focus anodes acts to focus the beam to a point in a plane parallel to but beyond the matrix.

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*Reprint of Pages A-1 to A-7 of SC 4020 High-Speed Microfilm Printer Utilizing the CHARACTRON Shaped Beam Tube—Technical Description—Stromberg-Carlson, San Diego.

The beam then passes between the vertical selection plates and the horizontal selection plates in that order. The selection voltages on these plates deflect the beam both vertically and horizontally (with respect to the matrix) by an amount proportional to the matrix coordinates of the selected character. The center or static voltage of these elements is approximately ground potential. The beam then emerges with its major component of velocity along the longitudinal axis Z of the tube but with small velocity components which are perpendicular to the tube axis and proportional to the selection voltages.

After leaving the selection plates, the beam enters the field of the convergence coil. This coil, with its selection and reference trim windings, produces a magnetic field parallel with the tube axis. The beam velocity components perpendicular to tube centerline interact with the field such as to cause the beam to travel in a helical path away from the tube axis, through the matrix, and back to the tube axis. The combined effect of the selection voltage and the convergence lens causes these three effects on the electron beam in sequence:

1. Departure from tube Z-axis and gradual outward spiral to the matrix,
2. Striking of the matrix so that the beam illuminates the selected character, and
3. Gradual spiral back toward tube Z-axis.

During its travel through the convergence coil, the beam is rotated 90 degrees, with 45-degree rotation occurring ahead of the matrix and 45-degree rotation occurring after the beam has passed through the matrix. For this reason the axes of the horizontal selection plates are at 90 degrees with the axes of the horizontal reference plates. The same quadrature relationship exists between vertical selection plates and vertical reference plates.

Horizontal and vertical centering is achieved by quadrature magnetic fields produced by the horizontal and vertical centering coils in the convergence coil assembly.

When the beam strikes the stencil-like matrix, a portion of the impinging beam passes through the character-shaped aperture, and the emerging "extruded" electron beam has a cross section matching the character etched in the matrix. Figure 4 shows a typical array of symbols for a 64-character matrix.

Upon reaching the tube axis as it leaves the influence of the convergence coil, the shaped beam is redirected along the axis by the reference plates. These plates, like the selection plates, operate about a center voltage of approximately ground potential. The dynamic voltages are applied to these plates simultaneously with and proportional to the corresponding selection voltages. Thus, emerging from the reference plates is a shaped beam, traveling along the tube axis, with the shaped cross section determined by the selected matrix character or symbol. The "Astigmatism" control permits varying the A_2 voltage (and the matrix and matrix shield since they are internally connected together) with respect to the average potential on the selection and referencing plates, and thereby effects an overall control of the cross-sectional shape of the beam before and after passing through the matrix openings.

After emerging from the reference plates, the character-shaped beam then passes through the field of the focus coil, which is an electron lens with a strength depending on focus coil current and beam velocity. This electromagnetic lens determines the size of the character displayed on the phosphor screen. The coil design is such that it imparts no net rotation to the electron beam.

As the beam emerges from the influence of the focus coil, it passes through the electromagnetic field produced by the deflection yoke. The deflection yoke produces both horizontal and vertical deflection of the beam proportional to currents passing through the windings of the yoke. The resultant strength and direction of the two deflection yoke fields determine the point at which the electron beam strikes the viewing screen.

After leaving the deflection yoke, the beam enters the field of the helical accelerator (A_3) in the bell-shaped portion of the tube. The helical accelerator is a continuous spiral of high resistivity material across which the post-accelerating potential is applied. This post-accelerating potential is normally about +10 kv with respect to ground. The resulting accelerating increases beam energy to provide the required character brightness on the tube face.

The viewing screen is normally coated with P-11 phosphor, a short persistence phosphor which emits light in the blue and ultraviolet region of the spectrum, and is ideal for photographing.

The Mu-Metal shield around the tube provides electromagnetic shielding. It shields the electron beam from the detrimental effects of any external fields which may exist near the tube. The tube-driving circuitry consists of the deflection conversion circuitry, the selection conversion circuitry, and the constant current coil supplies. These are shown in Figure 14.

The selection conversion consists of digital-to-analog converters and d-c amplifiers. These convert the digital selection information (3 bits each for horizontal and vertical) into appropriate d-c voltages for application to the selection and reference plates. As explained previously, the selection plates deflect the beam to the desired character of the matrix. With a 64-character (8 x 8) matrix, a 6-bit (3 x 3) digital selection input provides for selection of any character. Signals proportional to the selection voltages are applied simultaneously to the reference plates to redirect the electron beam along the tube axis after the beam has emerged from the matrix.

The deflection conversion circuitry consists of digital-to-analog converters, d-c amplifiers, and current drivers. These convert the digital deflection information (10 binary bits each for horizontal and vertical deflection) into appropriate deflection currents. These currents, passing through the deflection yoke, deflect the electron beam so that the selected character or symbol appears on the tube face at a point whose X- and Y-coordinates correspond to the digital deflection inputs.

The constant-current coil supplies furnish the stabilized current necessary for the convergence and focus coils. Once the circuitry has been properly adjusted these currents

remain constant. These supplies furnish current for the following coils:

1. Focus coil,
2. Convergence coil—main winding and selection and reference trim windings,
3. Horizontal and vertical centering coils (located in the convergence coil assembly).

The high-voltage power supplies provide the necessary voltage levels for the proper tube operation. In addition, the focus and unblank pulses are processed through this supply since they are applied to the focus anode and control grid, respectively, which are at large negative potentials with respect to ground.

The +15-kv supply provides the voltage for helical accelerator (A_3). It is adjustable over the range of 5 kv to 15 kv with respect to ground to provide a display brightness adequate for the film used for recording the data.

The −3.3-kv supply applies a voltage between the accelerating anode (A_2), which is at ground potential, and the cathode to impart initial velocity to the electron beam. Voltages derived from this supply also provide control grid bias and focus anode (A_1) voltage for proper operation of the CHARACTRON electron gun.

A dynamic unblank pulse is mixed with the control grid bias voltage in the d-c restorer to intensify the electron beam at the correct time in each character print cycle.

Likewise, a dynamic focus pulse may be mixed with the static focus voltage to provide a sharply focused spot for vector writing or drawing of grid lines on the tube surface.

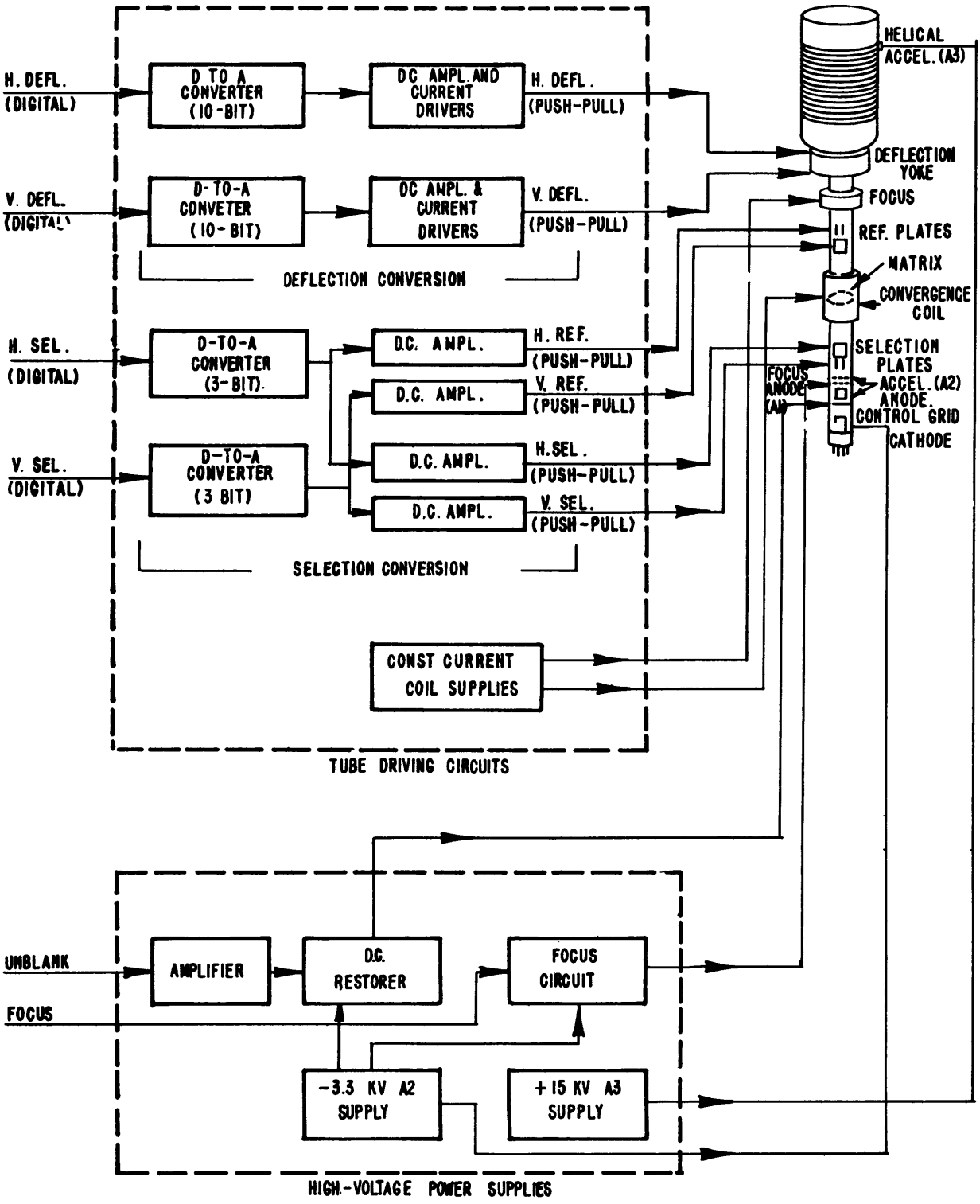

Figure 14 – CHARACTRON Shaped Beam Tube and Associated Circuitry

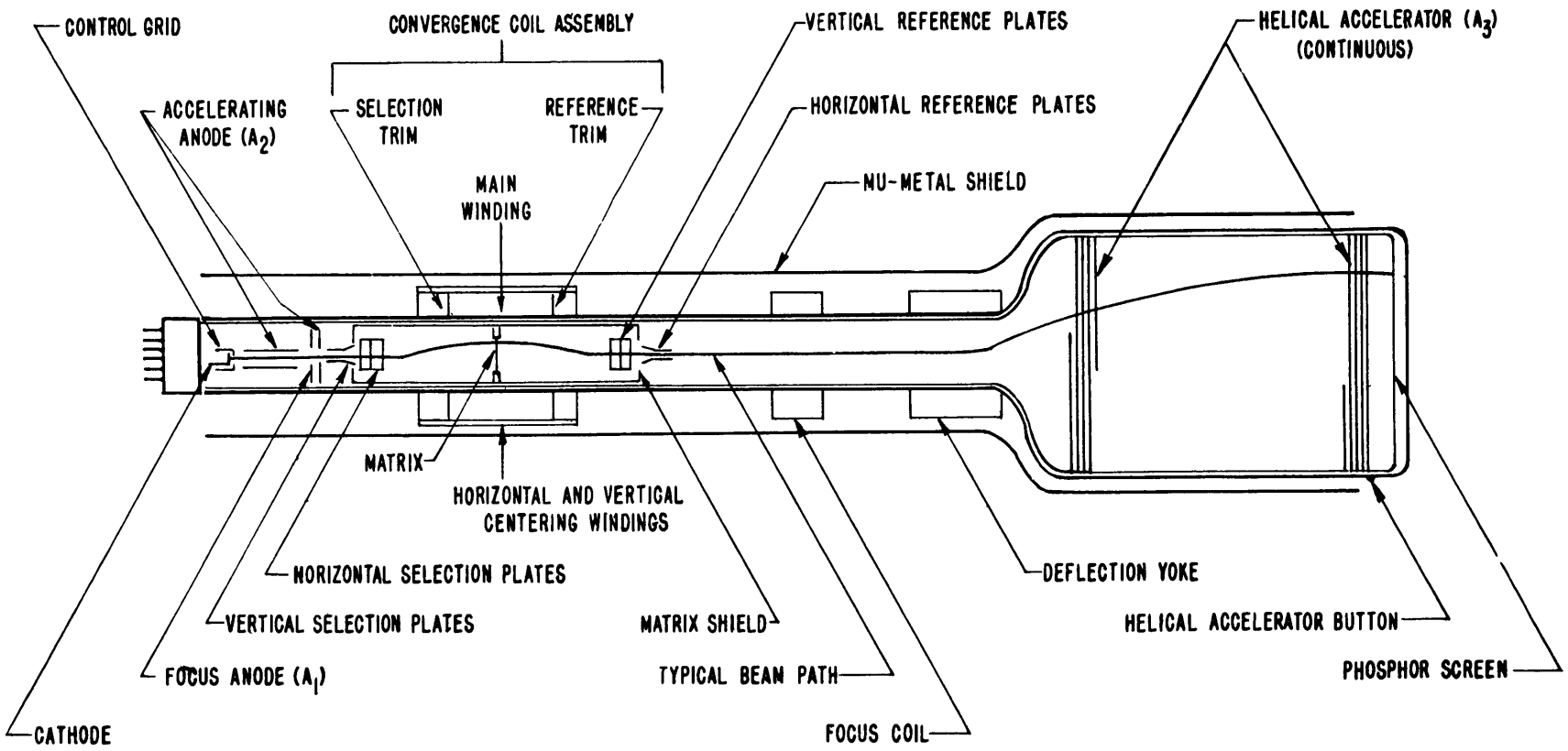

Figure 15 – CHARACTRON Shaped Beam Tube and Its Components

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