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A CONTRIBUTION TO COMPUTER TYPESETTING TECHNIQUES:

Tables of Coordinates for
Hershey's Repertory of Occidental
Type Fonts and Graphic Symbols

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Tables of Coordinates for Hershey's Repertory of Occidental Type Fonts and Graphic Symbols

Special publications 100-92-1

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Tables of Coordinates for Hershey's Repertory

of

Occidental Type Fonts and Graphic Symbols

by

Norman M. Wolcott

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and

Joseph Hilsenrath

Office of Standard Reference Data

These tables present coordinates from which it is possible to generate 1377 different alphabetic and graphic characters on either COM devices or on digital plotters. The tables, originally developed by Dr. A. V. Hershey of the Naval Weapons Laboratory, are augmented here by corresponding figures which show for each character the location of the tabulated points and the manner in which they are connected. The tables can be used with existing typographic systems to compose pages for scientific and mathematical publications of graphic arts quality either on COM devices or flat-bed plotters. Numerous applications are discussed and illustrated. The tables are also available on a magnetic tape in either BCD or ASCII format from the National Technical Information Service.

Keywords: alphabets, COM, computerized typesetting, digital plotting, graphics, Hershey character set, plotting, type fonts, typesetting, vectorized characters

1. Introduction

So seldom does one find, outside of the mathematical literature, a man's name in the title of a publication that a few words of explanation are in order. The tables and illustrations show how to draw, either on cathode ray tubes (CRT) or on x-y plotters, 1377 characters and symbols in such detail as to provide esthetically pleasing, and economically viable alternatives to classical and even more modern methods of "setting type" for technical publications. The wide variety of alphabets and symbols illustrated in this publication can be generated on vector plotters by connecting the points given in these tables. This method of digitizing graphic-arts characters allows them to be generated on any device which can plot vectors of arbitrary length and direction. The tables are used in conjunction with typographic computer programs to drive plotters and COM (Computer Output on Microfilm) devices.

The determination of the location and number of points to use in approximating a particular character requires a rare combination of interests and talents. For one

man to achieve the digitizing of literally thousands of characters requires a large measure of motivation, industry and fortitude – the last in nearly all of its dictionary connotations.

Dr. Allen V. Hershey, a mathematical physicist at the U.S. Naval Weapons Laboratory in Dahlgren, Virginia, carried out the digitization (by hand and eye) of the characters illustrated in this publication. The successful completion of such an ambitious undertaking as this, required a happy mixture of art and science – of alphabets and algorithms, of calligraphy and computing, and of psychology and printing. The reader would be quite correct to assume that the presence of the word *occidental* in the title of this report implies that *oriental* alphabets have also been digitized by Dr. Hershey. *

In an NWL report dated 1 August 1967 [1]. Dr. Hershey discusses the motivation for and the various considerations involved to achieve adequate digitization of both the occidental and oriental alphabets. In the latter category that report contains an engaging introduction to the origin and characteristics of the modern Japanese characters and contains illustrations of the 600 or so Kanji, the Hiragana, and the Katakana characters which he has digitized. The report concludes with a 30 page lexicon of over 1100 important Japanese words of technical interest. Today there are more automatic techniques for digitizing oriental or even occidental alphabets but these systems normally involve storing much more information per character than is needed in Hershey's method.

In subsequent NWL reports dated September 1969 [2], and September 1972 [3], Hershey describes his FORTRAN typographic and cartographic systems which utilize the library of digitized characters to compose finished pages of text, maps and drawings, and mathematical equations. More recently, the FORTRAN typographic system was described in the periodical literature [4] as a "do-it-yourself capability [for] programmers and scientists who would like to do some printing of their own". The extent to which this do-it-yourself system is able to produce high quality graphic-arts mathematical tracts is best exemplified by Dr. Hershey's publications [5, 6, 7, 8] on mathematical subjects which are, actually, his major line of interest and employment.

The above cited NWL reports have received limited distribution – too limited, we believe, in view of the present and potential utility of his system. Our contact with numerous groups interested in digitized characters for various purposes has led us to conclude that the publication of the tables of Dr. Hershey's coordinates in this publication would be a public service.

2. Computer Output on Microfilm

The proliferation of computers and their burgeoning applications produce literally mountains of paper most of which ends up, after a relatively short space of time, in the wastebasket or in the recycling box. Where programs produce large volumes of output required for archival purposes, such as parts lists, inventory records, or accounting records, etc., microform versions represent more economic, more ecologically desirable, and more physically manageable output media. The drive towards microform output of computer results has stimulated the development of a large variety of devices (now referred to as COM) for computer output on microfilm. The output of a COM device is usually on roll film (16mm and/or 35mm) or more recently on 105mm film in the form of microfiche. In any

* Numbers in brackets refer to references listed in section 7.

case, auxiliary devices are available to make film copies, and to make enlargements on paper or on short-run printing plates.

These devices are related in design to a whole series of optical phototypesetters and electronic typesetters developed for graphic arts computerized typesetting. A state-of-the-art review, of computer-assisted phototypesetting, circa 1967, (NBS Monograph 99) by M. E. Stevens and J. H. Little [9] already contains a description of the General Dynamics S-C 4020 - a precursor to all the modern COM devices.

At the time the National Bureau of Standards acquired an S-C 4020 it had already made extensive use of the Linofilm phototypesetter and the Linotron electronic typesetter at the Government Printing Office. Certain obvious advantages of an in-house machine led us to examine the output from this COM device to determine its utility in preparing computer program listings for publications. We found the results from that machine inferior to results achieved on the linofilm phototypesetter using the monowidth typewriter font (Clarinda) as shown in figure 1. Manufacturers of state-of-the-art COM devices can now supply monowidth type fonts capable of producing graphic-arts quality output for program listings and similar material from computer print tapes.

While the monowidth characters normally supplied with most of the COM devices are suitable for program listings, they are not adequate for scientific text as shown in figure 2 or mathematical text as shown in figure 3. Such texts can, however, be generated on many of the current COM devices via programs which utilize Hershey's digitized characters discussed and illustrated in this publication.

The remarkable versatility of Hershey's system is best exemplified by figures 4 et. seq. The first of these (figure 4) is a page taken from one of Hershey's mathematical works (reference 7). The others represent a miscellany of applications taken either from cited references or produced especially for this report.

It should be recognized that the character generation which this publication addresses is only half of what is required to produce the finished pages illustrated. The placement of the characters in their precise location on the page must be handled via suitable typographic programs. Such a suit of programs has indeed been developed by Dr. Hershey and are reported in references 2, 3, and 4. They were indispensable in the preparation of some of the illustrations in this publication.

Unless otherwise noted the figures and appendices were produced via the following process:

- a) Input was supplied via card deck and magnetic tape to the Hershey typographic system resident on the NBS-UNIVAC 1108 computer to produce a driver tape for the FR-80 COM device.
- b) The 35mm film produced by the COM device was run through a microfilm reader-printer to produce full size pages.
- c) Page numbers were applied by hand and the resulting camera-ready pages were submitted for offset-printing in the usual manner.

For the text we did not make use of Hershey's Typographic System. We used only his character digitization and his COM output routines. The line justification was carried out by an existing typography program, developed at NBS by Mrs. Carla Messina, simply by incorporating Hershey's character widths instead of those normally used on the Linotron 1010.

The text itself was keyboarded on-line to the Department of Commerce's text editing system via an ASCII coded terminal. The corrected text was dumped on a

9-track magnetic tape which was processed on the NBS computer via a new program to produce a tape to drive the COM device. This technique allowed us to take advantage of Hershey's character digitizations, while avoiding the use of punched cards for text and typographic instructions - the latter being quite cumbersome.

3. The Digitized Character Set

The starting point for the programmer desiring to produce graphic arts output on CRT devices and plotters is a digitized set of alphabetic and graphic characters. The digitizations should conform to several restrictions: (1) They should be adequate in detail to provide suitable representations of the desired characters; (2) They should not be overly definitive to minimize core requirements on the host computer; and (3) The organization scheme should be flexible so as to allow for modification, replacement, or extension of the character set.

It is our view that the vectored digitizations in this report (which were developed by Dr. A. V. Hershey, Naval Weapons Laboratory, Dahlgren, Va.) conform adequately to these requirements. As to whether these vectored characters are capable of graphic arts quality, it is only necessary to refer to figures 4 et. seq. and to the numerous reports (references 5-8) which have been issued using them, to confirm the capability for quality typographic and graphical composition. The core requirement is the availability of the equivalent of 25000 36-bit words which is not excessive for this data base. Characters can be easily omitted, modified, or added to the list so that the core requirement can be tailored to the problem at hand. Figure 15 gives some examples of characters which have been generated locally for use with the NBS typographic routines.

As indicated above the occidental repertory of digitized characters has been in existence since 1967. Unfortunately at the time it was first presented this prodigious effort did not receive the widespread notice it deserved, possibly because the representations of the characters were of such high quality that the casual reader did not realize that they were computer output and not graphic arts displays.

In order to make the digitizations more available and to supply more detailed information on how the characters are generated, the present publication lists the individual character digitizations of the occidental character set and indicates by graphic displays the way in which each character is composed from its digital representation. Needless to say the application of the digitizations is not limited to cathode ray printers. The tables can also be used with other computer driven devices such as digital pen plotters, electrostatic printers, or optical recorders.

4. Description of the Hershey Occidental Repertory

There are 1377 characters in the Hershey set, each of which is assigned a number between 1 and 3296. The characters are described as uniplex, duplex, or triplex according to the number of parallel strokes used in the construction of the character. The description as simplex, complex, or gothic, indicates the extent to which the characters contain tapered segments. Three sizes of characters are available: the principal or normal size (21 raster units high, em=32), the indexical size (13 raster units high, em=21), and the cartographic size (9 raster units high).

The appearance of the various alphabets when drawn at a normal typographic scale is shown in figure 6. In addition numerous special characters are available. A listing of these and the associated character numbers is found in Appendix C.

4.1 The Table of Character Digitizations. In the Hershey system, characters are drawn by connecting lines between successive (x,y) coordinate pairs. The coordinates of each character are given in 'raster coordinates', which are integers ranging from +49 to -49. The (x,y) coordinates for each character in the occidental repertory are given in Appendix A. A useful quantity is the printer's em, or the distance between the bottoms of two successive lines of close packed text. The em is 32 raster units for characters in the principal size, and 21 raster units for the indexical size.

The table in Appendix A is organized in the following way: The first column is the character number, the first pair of numbers separated by colons (:) are the left and right boundaries of the character in raster coordinates, and succeeding pairs of numbers set off by colons denote the (x,y) set for that character. An (x,y) coordinate pair of (-64,0) indicates that the pen is lifted at that point in the character; a coordinate pair of (-64,-64) indicates that the end of the character has been reached.

An ASCII tape of the table in Appendix A is available for those desiring the digitizations in machine readable format. It can be obtained from the National Technical Information Service.

4.2 The Graphic Character Representations. Large scale drawings of the characters comprising the table in Appendix A are given in Appendix B. Coordinate pairs are denoted by small circles, and the left and right boundaries of each character (the character width) are denoted by short vertical lines. The character number is located in the upper left hand corner, and the origin of coordinates for each character is located at the center of each display. It should be noted that in the displays a right handed coordinate system is used in which the +x axis is toward the right and the +y axis is toward the bottom of the page. This is in accord with the normal printing convention in which distance down the page is considered positive.

4.3 Indices to Alphabets and Special Symbols. The names of the characters and symbols that can be generated from the tables in Appendix A are listed in Appendix C together with the numbers assigned to them in the Hershey system. It should be noted where alphabets are concerned, the table lists only the number for the first letter. Numbers for the rest of the alphabet follow in succession.

4.4 Applications. The original application of the digitizations was for use with the Hershey Typographic System. Figures 4 through 10 show some samples generated using the character set in conjunction with the Typographic System. Among these are examples from Dr. Hershey's own mathematical publications (figure 4), a mathematical manuscript in German (figure 9), etc. Figure 11 shows some typical scientific text from a test run, made while interfacing the NBS typographic routines with the Hershey character set. Appendix C was also set with Hershey's System.

The applications of the Hershey system discussed thus far were to publications requiring graphic-arts quality art work which must be produced on one of the more versatile COM devices or on a large flat-bed plotter. Certain of the character sets presented in this publication can be applied with profit by installations which have only a small drum plotter. While the characters generated on these ubiquitous devices suffer some deterioration, as can be seen from figures 12 et. seq., they never-the-less are an improvement over the lettering normally found on such devices. At NBS a subset of the occidental set has been converted into a FORTRAN subroutine which is used with a digital plotter to provide graph titles of improved legibility (see figure 12). In another application, a sub-set of the occidental

repertory was used to develop a monowidth type font suitable for providing renditions of computer card listings (See figure 13). Another routine has been written to generate vue-graphs using the Hershey character set (See figure 14). The vue-graphs are prepared by first making an ink drawing of the vue-graph material with a digital plotter, then making a reduction on an office copying machine. From this the final vue-graph can be made using a thermal printer. Other applications will be limited only by the ingenuity of the user.

5. Operational Considerations

In order for a digital character set to be useful, there must be a way of transforming the digital characters to a graphic output medium, be it microfilm or hard copy. While in principle it would be possible to do this on-line with a main frame computer, in practice it is more convenient to generate an intermediate file on magnetic tape, and then to use this magnetic tape to drive the graphic output device. The computer program used to generate the intermediate tape file depends on the output characteristics desired. We have purposely used a variety of programs in order to indicate the flexibility of the digital character set. For vue-graphs (figure 14), or computer-listings (figure 1) for which no typography (justification, hyphenation, paging) is required, a simple FORTRAN program is all that is needed.

Where more typographic features are desired as in composing tables or pages of formulae or equations, a typographic program must be used. Two typographic programs were used to prepare this publication. The first is Dr. A. V. Hershey's Typographic System¹ which was used as indicated above. The second approach, by means of which the body of this report was generated, was to use an existing NBS typography program which performed the line justification and page makeup. That program was modified to use the Hershey character set and associated character widths.

For the highest quality output a large flat-bed pen plotter with multi-pen capability should be used. This is the technique used by Hershey to produce his reports (Ref. 3-10). Fairly good quality can also be obtained on a drum plotter, but variable line widths are difficult to obtain if a turret pen is not available. The speed of a pen plotter is one to two characters per second depending on the size and complexity of the character.

The next best quality is obtained with a 35mm graphics COM recorder with 16,000 addressable rasters in each of the x and y directions. This is the resolution of the COM device on which the bulk of this publication was produced.

A graphics COM recorder customarily consists of a tape drive, a programmable mini-computer, perhaps a disc drive, a cathode ray tube on which the images are drawn by the CRT electron beam, a 35mm camera which photographs the CRT tube face, and a film transport mechanism which advances the film between frames. The beam on the CRT tube face can be directed to one of approximately 12,000 x 16,000 addressable positions. The minimum separation between addressable positions is called a raster unit. The minimum spot size is larger than a raster unit - in the FR-80 it is approximately seven raster units. The 35mm film can be developed to produce either a positive or a negative image. The 35mm film is then used to produce hard copy or printing plates by photographic techniques.

To use the vector characters for different type sizes, it is essential that a method be available for varying the width of the strokes on the output device. On

digital pen plotters this is accomplished by use of a turret pen with pen widths varying from .3mm to 1.2mm. On a COM device there are usually methods for varying spot size and spot intensity under program control. For extremely large characters it is possible to replace each vector by a number of parallel vectors to increase the line width beyond that obtainable by varying pen or spot size. Ref. 3-10 contain numerous examples of these techniques as applied to actual publications.

On the device we used, the output using the Hershey characters was limited by tape speed, roughly 60 characters per second. As an example this text, which contains 24,000 characters required 400 seconds to process on the FR-80. COM devices containing internally stored fonts operate at a much higher speed - roughly 5,000 characters per second. As an example, the half million or so characters in Appendix E were produced in about 100 seconds using the internally stored characters which are supplied with the FR-80.

Higher speeds could also be obtained for the Hershey characters by writing a special program for a particular COM unit in which some of the characters resided in core in the mini-computer, or on an attached disc. Such an approach has in fact been implemented by one manufacturer.

6. Acknowledgments

The authors wish to acknowledge the assistance of Steve Soroka in preparing the program to produce the pictures in Appendix B, to Mrs. Carla Messina for the program to interface the NBS typographic system with the Hershey system, to M. Leighton Greenough for editorial advice, to Mrs. Constance Seymour for assistance in preparation of the manuscript and last, but not least, to Dr. A. V. Hershey. He deserves our thanks, and that of the readers as well, not only for having developed such a remarkably useful and important system but also for the generosity with which he has shared the fruits of his labor with others.

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SUBROUTINE NPRINT(K,ITEST,IC,IBLANK,IOTAPE,IPTAPE,IEND)          NPRI 10
C THIS VERSION OF NPRINT USES A FORTRAN WRITE STATEMENT          NPRI 20
C SUBROUTINE NPRINT -NTRAN PRINT- PRINTS OUT RECORDS OF LENGTH   NPRI 30
C NCOUT FROM THE STRING IC -1A1 FORMAT- THE CURRENT LENGTH OF   NPRI 40
C CHARACTERS IN IC IS K. IF K IS LESS THAN NCOUT NOTHING IS DONE NPRI 50
C UNLESS THE LAST RECORD IS TO BE WRITTEN INDICATED BY IEND=1    NPRI 60
C WHEN IEND=-1 THE ENTIRE CONTENTS OF IC IS WRITTEN OUT BUT THE NPRI 70
C TAPE IS NOT ENDFILED AND EACH RECORD IS NCOUT CHARACTERS LONG  NPRI 80
C WHEN IEND=1 THE LAST RECORD IS FILLED WITH IBLANKS FROM K+1 TO NPRI 90
C NCOUT AND AN END OF FILE IS PLACED ON IPTAPE. ITEST IS NEGATIVE NPRI 100
C FOR PRINTING, ZERO FOR PRINTING AND WRITING TAPE AND POSITIVE FOR NPRI 110
C WRITING TAPE. IOTAPE IS THE SYSTEM PRINTER. IPTAPE IS THE TAPE. NPRI 120
C DIMENSION IC(4100)                                              NPRI 130
NCOUT=132                                                       NPRI 140
10 IF (K) 20,20,80                                              NPRI 150
20 IF (IEND) 70,70,40                                             NPRI 160
40 IF (ITEST) 60,50,50                                             NPRI 170
50 ENDFILE IPTAPE                                              NPRI 180
60 WRITE (IOTAPE,19) (IC(I),I=1,NCOUT)                            NPRI 190
WRITE (IOTAPE,9)                                                 NPRI 200
70 RETURN                                                       NPRI 210
80 IF (IEND) 90,110,90                                             NPRI 220
90 IF (NCOUT*(K/NCOUT)-K) 100,110,100                           NPRI 230
100 K = NCOUT*((K/NCOUT) + 1)                                     NPRI 240
110 IF (K-NCOUT) 20,160,160                                         NPRI 250
160 N=N+1                                                       NPRI 260
170 IF (ITEST) 170,170,180                                         NPRI 270
170 WRITE (IOTAPE,19) (IC(I),I=1,NCOUT)                            NPRI 280
WRITE (IOTAPE,59) N,NCOUT                                         NPRI 290
180 IF (ITEST) 210,200,200                                         NPRI 300
200 WRITE (IPTAPE,39) (IC(I),I=1,NCOUT)                            NPRI 310
210 IF (K - NCOUT) 10,220,240                                       NPRI 320
220 K=0                                                       NPRI 330
DO 230 I=1,NCOUT                                              NPRI 340
230 IC(I)=IBLANK                                              NPRI 350
GO TO 10                                                       NPRI 360
240 J=K                                                       NPRI 370
K=0                                                       NPRI 380
K1=NCOUT+1                                              NPRI 390
DO 250 I=K1,J                                              NPRI 400
K=K+1                                              NPRI 410
250 IC(K)=IC(I)                                              NPRI 420
K1=K+1                                              NPRI 430
DO 260 I=K1,J                                              NPRI 440
260 IC(I)=IBLANK                                              NPRI 450
GO TO 110                                                       NPRI 460

```

Figure 1. A portion of a computer program typeset on the Mergenthaler Linofilm at the G.P.O. via the NBS program SETLST using a monowidth CLARINDA typeface.

$$\Phi(T) = \sum_{i=1}^{10} A_i \cdot x^{i-1}.$$

On the other hand, a modification of the form given in [24] diminishes specific heat rms deviations by a factor of about 1/2. Maximum deviations in C_v^0/R (given below) become 0.02 percent in our present range of interest for methane, $80 \leq T \leq 360$ K. This accuracy is at least an order of magnitude better than can be obtained from PVT data when using the thermodynamic computation,

$$C_r(\rho, T) = C_v^0(T) - T \cdot \int_0^\rho (\partial^2 P / \partial T^2) \cdot d\rho / \rho^2.$$

The modified form (8) uses an argument, $\omega \equiv \epsilon/x$. Constant ϵ is found by trial,

$$\Phi(T) = A_1 + A_2 \cdot x^{1/3} + A_3 \cdot x^{2/3} + A_4 \cdot x + A_5 \cdot \omega / (e^\omega - 1), \quad (8)$$

$$\epsilon = 5.022\ 880 \quad A_3 = -1.847\ 272$$

$$A_1 = 2.599\ 898 \quad A_4 = 0.821\ 122$$

$$A_2 = 1.444\ 942 \quad A_5 = 4.720\ 791.$$

The specific heat is obtained via $C_v^0 = dE^0/dT$,

$$C_v^0/R = A_1 + \frac{1}{3} \cdot A_2 \cdot x^{1/3} + \frac{5}{3} \cdot A_3 \cdot x^{2/3} + 2 \cdot A_4 \cdot x + A_5 \cdot [\omega / (e^\omega - 1)]^2 \cdot e^\omega. \quad (9)$$

The entropy is obtained via its definition,

$$\Delta S \equiv Q_r/T = \int_{T_1}^T [C_r \cdot dT/T + P \cdot dv/T].$$

Introducing the published value of S^0/R at $T_1 = 60$ K yields,

$$S^0/R = A_0 + \ln(T/60) + A_1 \cdot \ln(x) + 4 \cdot A_2 \cdot x^{1/3} + \frac{5}{2} \cdot A_3 \cdot x^{2/3} + 2 \cdot A_4 \cdot x + A_5 \cdot [\omega / (e^\omega - 1) - \ln(1 - e^{-\omega})] \quad (10)$$

with constant $A_0 = 18.852\ 484$.

Specific heat at constant pressure, and the enthalpy function now are simply

$$C_p^0/R = 1 + C_v^0/R, \quad (11)$$

$$(H^0 - E_0^0)/RT = 1 + \Phi(T). \quad (12)$$

Figure 2. This page from the NBS Journal of Research Section A is representative of the notational complexity of scientific text not easily handled by normal COM devices.

3. Derivation of the τ - γ Relations

We have seen that as $n \rightarrow \infty$:

$$\sum_{\nu=1}^n \frac{(\log \nu)^k}{\nu} = \frac{(\log n)^{k+1}}{k+1} + \gamma_k + o(1). \quad (3.1)$$

Hence

$$\sum_{\nu=1}^{2n} \frac{(\log \nu)^k}{\nu} = \frac{(\log 2n)^{k+1}}{k+1} + \gamma_k + o(1). \quad (3.2)$$

The binomial series for $(\log 2\nu)^k = (\log 2 + \log \nu)^k$ gives

$$\begin{aligned} 2 \sum_{\nu=1}^n \frac{(\log 2\nu)^k}{2\nu} &= \sum_{\nu=1}^n \frac{1}{\nu} \left\{ \sum_{t=0}^k \binom{k}{t} (\log 2)^{k-t} (\log \nu)^t \right\} \\ &= \sum_{t=0}^k \binom{k}{t} (\log 2)^{k-t} \sum_{\nu=1}^n \frac{(\log \nu)^t}{\nu} \\ &= \sum_{t=0}^k \binom{k}{t} (\log 2)^{k-t} \left[\frac{(\log n)^{t+1}}{t+1} + \gamma_t + o(1) \right] \end{aligned} \quad (3.3)$$

where we have used (3.1) in the last stage.

Integrating (with respect to β) the binomial expansion of $(a + \beta)^k$ from 0 to b , or otherwise, we find

$$\sum_{t=0}^k \binom{k}{t} a^{k-t} \frac{b^{t+1}}{t+1} = \left[\frac{(a+\beta)^{k+1}}{k+1} \right]_0^b = \frac{(a+b)^{k+1}}{k+1} - \frac{a^{k+1}}{k+1}.$$

We use this with

$$a = \log 2, \quad b = \log n$$

to get

$$\sum_{t=0}^k \binom{k}{t} (\log 2)^{k-t} \frac{(\log n)^{t+1}}{t+1} = \frac{(\log 2n)^{k+1}}{k+1} - \frac{(\log 2)^{k+1}}{k+1}. \quad (3.4)$$

Substituting from (3.4) in (3.3) we get

$$2 \sum_{\nu=1}^n \frac{(\log 2\nu)^k}{2\nu} = \frac{(\log 2n)^{k+1}}{k+1} - \frac{(\log 2)^{k+1}}{k+1} + \sum_{t=0}^k \binom{k}{t} (\log 2)^{k-t} \gamma_t + o(1) \quad (3.5)$$

Figure 3. This page from the NBS Journal of Research Section B is representative of both the notational and spacial complexity of mathematical text. See figure 4 for a comparison of the typographic quality of similar material produced via the Hershey system.

coincides with the circle of radius r . The area of a spherical cap with polar angle θ on a sphere of unit radius is given by the equation

$$\iint \sin \theta d\theta d\phi = 2\pi(1 - \cos \theta) \quad (16)$$

The equation for the streamline therefore is

$$\text{flux} = 2\pi q \left(1 - \frac{z}{\sqrt{r^2 + z^2}} \right) - \pi r^2 W = 0 \quad (17)$$

upstream of the source, and is

$$\text{flux} = -2\pi q \left(1 - \frac{|z|}{\sqrt{r^2 + z^2}} \right) - \pi r^2 W = -4\pi q \quad (18)$$

downstream of the source. The two equations are equivalent. Solution for z leads to the equation

$$\left(\frac{W}{q} \right)^{\frac{1}{2}} z = \frac{1 - \frac{W}{2q} r^2}{\sqrt{1 - \frac{W}{4q} r^2}} \quad (19)$$

along the streamline. The velocity of flow from the source is given by the equation

$$\frac{q}{r^2 + z^2} = W \left(1 - \frac{W}{4q} r^2 \right) \quad (20)$$

along the streamline. The square of the local velocity is given by the equation

$$v^2 = W^2 - \frac{2qWz}{(r^2 + z^2)^{\frac{3}{2}}} + \frac{q^2}{(r^2 + z^2)^2} = W^2 \left(\frac{W}{q} r^2 - \frac{\frac{3}{16}W^2}{q^2} r^4 \right) \quad (21)$$

When the square of the velocity is integrated over the surface of the boundary, the only surviving component of ds is $2\pi r dr$ in the z -direction by symmetry. Thus the force f on the boundary is given by the equation

$$f = \pi \rho W^2 k \int \left(1 - \frac{W}{q} r^2 + \frac{\frac{3}{16}W^2}{q^2} r^4 \right) r dr \quad (22)$$

Integration with respect to r in the range

$$0 \leq r^2 \leq \frac{4q}{W} \quad (23)$$

leads to the equation

$$f = 0 \quad (24)$$

Thus the force on the boundary is not equal to the force on the source.

That the force on the boundary can be zero may be seen by a consideration of the variation of v^2 along the boundary. At the vertex of the boundary there is a stagnation point and the Bernoulli pressure is positive. At a point opposite to the source the square of the velocity is the sum of the squares of the free-stream velocity and the radial velocity from the source. The Bernoulli pressure is negative and is applied over

Figure 4. This page taken from reference 7 shows the typographic quality of this application of the Hershey character set. The art for this page was produced by a 60% reduction from an original drawn on a flat-bed plotter.

EINSTEIN: Zur einheitlichen Feldtheorie

der Divergenzbildungen bei Tensordichten von beliebigem Range:

$$\mathfrak{U}^{ik}_{\cdot i \cdot k} - \mathfrak{U}^{ik}_{\cdot k \cdot i} \equiv - (\mathfrak{U}^{ik} \Lambda_{ik}^\sigma)_{/\sigma} \quad (5)$$

Die Punkte bei \mathfrak{U} bedeuten beliebige Indizes, die in allen drei Gliedern der Gleichung dieselben sind, nämlich diejenigen, welche bei den Divergenzbildungen nicht betroffen werden.

Der Beweis von (5) stützt sich ausser auf die Definitionsformel

$$\mathfrak{U}^{\sigma \cdot i}_{\tau \cdot \cdot i} = \mathfrak{U}^{\sigma \cdot i}_{\tau \cdot , i} + \mathfrak{U}^{\sigma \cdot i}_{\tau \cdot \Delta \sigma} \cdots - \mathfrak{U}^{\sigma \cdot i}_{\alpha \cdot \Delta \sigma} \cdots \quad (6)$$

insbesondere auf die Identität (2). Gleichung (5) hängt eng zusammen mit dem Vertauschungsgesetz der kovarianten Differentiation, das ich der Vollständigkeit halber ebenfalls angeben will. Sei T ein beliebiger Tensor, dessen Indizes ich der Bequemlichkeit halber weglassen, so gilt

$$T_{;i;k} - T_{;k;i} \equiv - T_{;\sigma} \Lambda_{ik}^\sigma \quad (7)$$

Von der Identität (5) machen wir nun Anwendung auf die Tensordichte \mathfrak{B}_{kl}^α , deren untere Indizes wir heraufgezogen denken. Wir finden so als einzige nicht triviale Identität

$$\mathfrak{B}_{kl/l/\alpha}^\alpha - \mathfrak{B}_{kl/\alpha/l}^\alpha \equiv - (\mathfrak{B}_{kl}^\alpha \Lambda_{la}^\sigma)_{/\sigma}$$

welche man mit Rücksicht auf (3b) auf die Form bringen kann

$$(\mathfrak{B}_{kl/l}^\alpha - \mathfrak{B}_{kl}^\sigma \Lambda_{\sigma l}^\alpha)_{/\alpha} \equiv 0 \quad (8)$$

3. Die Feldgleichungen.

Nachdem ich die Identität (3b) entdeckt hatte, war es mir klar, dass bei einer natürlichen einschränkenden Charakterisierung einer Mannigfaltigkeit von der ins Auge gefassten Art die Tensordichte \mathfrak{B}_{kl}^α eine wichtige Rolle spielen müsse. Da deren Divergenz $\mathfrak{B}_{kl/\alpha}^\alpha$ identisch verschwindet, war es der nächstliegende Gedanke, die Forderung aufzustellen (Feldgleichungen), dass auch die andere Divergenz $\mathfrak{B}_{kl/l}^\alpha$ verschwinden solle. So gelangt man in der Tat zu Gleichungen, die in erster Näherung das bekannte Vakuumfeldgesetz der Gravitation liefern, wie es aus der bisherigen allgemeinen Relativitätstheorie bekannt ist.

Dagegen ergab sich so keine Vektorbedingung für die ϕ_α , derart, dass alle ϕ_α mit verschwindender Divergenz mit jenen Feldgleichungen vereinbar waren. Dies beruht darauf, dass in erster Näherung (wegen Vertauschbarkeit des gewöhnlichen Differenzierens) die Identität

$$\mathfrak{B}_{kl/l/\alpha}^\alpha \equiv \mathfrak{B}_{kl/\alpha/l}^\alpha$$

Figure 5. A further example of a well set page employing the German-Gothic characters digitized by Dr. A. V. Hershey. The art for this page was produced by a 60% reduction from an original drawn on a flat-bed plotter.

SR

SIMPLEX ROMAN

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

DR

DUPLEX ROMAN

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

CR

COMPLEX ROMAN

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ @

TR

TRIPLEX ROMAN

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

CI

COMPLEX ITALIC

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ @

TI

TRIPLEX ITALIC

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

SS

SIMPLEX SCRIPT

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

Figure 6. Here we see the appearance of various alphabets when drawn via the Hershey system at normal typographic scale (21 raster units). The same set can also be produced in indexical size (13 raster units). Capitals can also be produced in cartographic size (9 raster units).

CS

COMPLEX SCRIPT

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

SG VT SIMPLEX GREEK

A	B	Γ	Δ	Ε	Ζ	Η	Θ	Ι	Κ	Λ	Μ	Ν	Ξ	Ο	Π	Ρ	Σ	Τ	Υ	Φ	Χ	Ψ	Ω
α	β	γ	δ	ε	ξ	η	ϑ	ι	κ	λ	μ	ν	ξ	ο	π	ρ	σ	τ	υ	φ	χ	ψ	ω
1	2	3	4	5	6	7	8	9	0	:	!	()	-	+	×	/	=		"			

CG VT COMPLEX GREEK

A	B	Γ	Δ	Ε	Ζ	Η	Θ	Ι	Κ	Λ	Μ	Ν	Ξ	Ο	Π	Ρ	Σ	Τ	Υ	Φ	Χ	Ψ	Ω
α	β	γ	δ	ε	ζ	η	ϑ	ι	κ	λ	μ	ν	ξ	ο	π	ρ	σ	τ	υ	φ	χ	ψ	ω
1	2	3	4	5	6	7	8	9	0	:	!	()	-	+	.		=	√	"			

GF GOTHIC ENGLISH

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

GG GOTHIC GERMAN

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 a b c d e f g h i j k l m n o p q r s t u v w x y z
 1 2 3 4 5 6 7 8 9 0 , . () - + * / = \$ &

GI GOTHIC ITALIAN

A B C D E F G H I J K L M N O P Q R S T U V W X Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0 . () - + * / = &

CC COMPLEX CYRILLIC

Figure 6. (concluded).

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

Θε υιχκ βρον οξ υμψ οερ θε λαξν δογ.

Τηε ϑυιχκ βροων φοξ ζυμπσ οζερ τηε λαξψ δογ!

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

The quick brown fox jumps over the lazy dog.

Те уичк брон фоъ умпс овер те лазы дог.

Figure 7. The above variations of a line of text illustrate the typographic variety to be found in the Hershey character set discussed in this handbook.

The Rose Revived

worth in 1793, and later gave us the China Monthly roses. A handful of these may be found in modern catalogues, but they are a little thin in texture and uncertain in design, and nearly all of them are scentless, so that I feel that they have been retained chiefly for their willingness to flower from May till December, a merit for which at least 'Cramoisie Superieure' (Coquereau, 1832) deserves a place in the garden (especially in its floriferous climbing form), though it may not possess all the character that we look for in an antique rose.

The China Monthly roses, under the name 'Bengales', seem to have been more popular on the continent than in this country, on the other hand, the contemporary Scotch Briars, which occupy a similar niche in modern catalogues, enjoyed a much greater popularity in these islands than elsewhere. They were raised from our native Burnet Rose, originally, it is said (Miss Wilmot, *The Genus Rosa*), by Robert Brown of Perth in 1793, and very rapidly several hundred varieties were produced, many of which must have been scarcely distinguishable. Half a dozen or so are, fortunately, still easy to obtain.

MATHEMATICS

FRACTIONS

$$\frac{1}{2} \qquad \frac{1}{2} \qquad \frac{7}{15} \qquad \frac{1}{2} \qquad \frac{1}{2}$$

RADICALS

$$\sqrt{2} \qquad \sqrt{2} \qquad \frac{1}{\sqrt{\pi}} \qquad \sqrt{\frac{1}{2}} \qquad \sqrt{\frac{1}{2}}$$

ABBREVIATIONS

$$(\text{cm})/(\text{sec}) \qquad 2 \sin \theta \cos \theta \qquad \tan^{-1} \frac{y}{x} \qquad \cos^2 \theta - \sin^2 \theta \qquad (\text{erg})/(\text{°})$$

EXPONENTS

$$x^{2n+1} \qquad e^{i\omega t} \qquad e^{-\frac{r^2}{4\hbar t}} \qquad e^{-x^2} \qquad x^{\frac{1}{2}}$$

SUMS

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} \qquad p(z) = \sum_{n=0}^N c_n z^n \qquad p(z) = \prod_{n=1}^N (z - a_n) \qquad \frac{\sin \theta}{\theta} = \prod_{n=1}^{\infty} \left(1 - \frac{\theta^2}{n^2 \pi^2} \right)$$

FUNCTIONS

$$\Gamma(z) \qquad J_n(z) \qquad w(z) \qquad P_n^m(z) \qquad F(\phi, k)$$

DERIVATIVES

$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} = 0 \qquad \frac{dw}{dz} = \frac{\partial u}{\partial x} - i \frac{\partial u}{\partial y} = \frac{\partial v}{\partial y} + i \frac{\partial v}{\partial x} \qquad \left(\frac{\partial \varphi}{\partial x} \right)^2 + \left(\frac{\partial \varphi}{\partial y} \right)^2 = 1$$

INTEGRALS

$$\int_a^b f(x) dx \qquad f(a) = \frac{1}{2\pi i} \oint \frac{f(z)}{z-a} dz \qquad \int_a^b \frac{p(x)}{q(x)} dx \qquad \int_a^b \frac{p(x)}{q(x)} dx$$

VECTORS

$$\mathbf{a} \cdot \mathbf{b} \times \mathbf{c} = \mathbf{a} \times \mathbf{b} \cdot \mathbf{c} \qquad \int \mathbf{a} \cdot d\mathbf{s} = \int \nabla \cdot \mathbf{a} d\tau \qquad \oint \mathbf{a} \cdot d\mathbf{r} = \int \nabla \times \mathbf{a} \cdot d\mathbf{s} \qquad \mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = \mathbf{b} \mathbf{a} \cdot \mathbf{c} - \mathbf{c} \mathbf{a} \cdot \mathbf{b}$$

MATRICES

$$\begin{aligned} y_1 &= a_{11}x_1 + a_{12}x_2 + a_{13}x_3 \\ y_2 &= a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \\ y_3 &= a_{31}x_1 + a_{32}x_2 + a_{33}x_3 \end{aligned} \qquad \begin{aligned} y &= A \mathbf{x} \\ x &= A^{-1} y \end{aligned} \qquad A = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix} = \|A_{ij}\|$$

Figure 9. This replica of a page taken from reference 2 shows how effectively mathematical expressions can be handled via the Hershey character set and typographic system.

LUNAR MOTION

Rev. N. M. Wolcott

Whereas the sun in its motion through the sky and seasons appears regular, the motion of the moon is more complex. At first thought it might be supposed that the moon would follow the sun being high in the sky in summer and low in winter. A little reflection however shows that this is not the case, for whereas the sun is at its *highest* in the sky at the summer solstice, so the full moon at this time being opposite to the sun must necessarily attain its *lowest* position. Conversely the full moon at the winter solstice must then reach its highest position at that time when the sun is lowest. This then accounts for the long bright moonlit nights in winter and the minimal appearance the moon makes in summer. With regard to the moon at the periods of the first and last quarter, a little more thought is required. Since the moon moves counterclockwise about the earth and the earth counterclockwise about the sun, the first quarter moon being behind the earth in its orbit will lie at its lowest point at the time of the autumnal equinox, whilst the third quarter moon being ahead of the earth will be at its highest as the earth proceeds from summer to winter. At the vernal equinox however the roles are reversed and the first quarter moon is at its highest and the third quarter at its lowest. In the fall the moon is often seen high in the sky in the morning at nine or ten o'clock between the third quarter and the new moon. We thus see that the moon traverses a complete path through the sky along the ecliptic every 28 days, and occupies at some period during each lunar month either its highest or lowest position.

We are now in a position to understand the phenomenon of the *harvest moon*. For at the time of the autumnal equinox the full moon will be neither at its highest nor lowest point, but rather in between, and will be moving higher in the sky as the month progresses. (Remember the third quarter moon is at its highest in September.) The moon thus will be tending to rise earlier each night as it moves to the north along the ecliptic, thus partially counteracting the normal retardation in moonrise due to lunar revolution about the earth. The result is a series of nearly full moons which continue to rise day after day at about the same time of evening. Thus to the observer who glances at the sky shortly after sunset a moon will appear every evening. At the time of the vernal equinox however the moon is moving daily toward its lowest position, and hence the time of moonrise will be retarded beyond its normal hourly advance, to a period of almost two hours. The full moon is then only visible for a day or two, and we have no springtime counterpart of the harvest moon. Actually the full moon will rarely occur just at the autumnal equinox, and there will be two full moons which will share the harvest moon effect. the first of these which may occur in late August is the *harvest moon* whilst the later one which may be in October is called the *hunter's moon*.

Thus we see that a little reflection will explain the different locations in which the moon appears at various seasons of the year. It is curious that with so much interest in the exploration of the moon, these simple facts of lunar motion are not generally understood.

Figure 10. Another example of the use of the Hershey system for the preparation of scientific text.

4. Isotropic Tensors of Ranks 2, 3, 4, 5, and 6

For completeness, we list here distinct isotropic tensors of ranks 2, 3, 4, and 6, for which no reduction is needed.

TABLE 2.

Rank	Distinct and linearly independent fundamental isotropic tensors
2	δ_{ij} .
3	ϵ_{ijk} .
4	$\delta_{ij} \delta_{km}, \delta_{ik} \delta_{jm}, \delta_{im} \delta_{jk}$.
6	$\delta_{ij} \delta_{km} \delta_{pq}, \delta_{ij} \delta_{kp} \delta_{mq}, \delta_{ij} \delta_{kq} \delta_{mp}, \delta_{ik} \delta_{jm} \delta_{pq}, \delta_{ik} \delta_{jp} \delta_{mq},$ $\delta_{ik} \delta_{jq} \delta_{mp}, \delta_{im} \delta_{jk} \delta_{pq}, \delta_{im} \delta_{jp} \delta_{kq}, \delta_{im} \delta_{jq} \delta_{kp}, \delta_{ip} \delta_{jk} \delta_{mq},$ $\delta_{ip} \delta_{jm} \delta_{kq}, \delta_{ip} \delta_{jq} \delta_{km}, \delta_{iq} \delta_{jk} \delta_{mp}, \delta_{iq} \delta_{jm} \delta_{kp}, \delta_{iq} \delta_{jp} \delta_{km}$.

Independent sets of isotropic tensors of rank five have been studied by Cisotti [8] and Caldonazzo [9]. A particularly simple way of generating such a set is to write eq (3.4) in the following way:

$$\epsilon_{jkm} \delta_{ip} = \epsilon_{ijk} \delta_{mp} + \epsilon_{ikm} \delta_{jp} - \epsilon_{ijm} \delta_{kp}. \quad (4.1)$$

It is immediately clear from this equation, that any fundamental isotropic tensor of rank five in which the index i appears in the Kronecker delta can be expressed as a linear combination of fundamental tensors in which the index i appears in the alternator. A count of the number of the latter fundamental rank-five isotropic tensors reveals that there are six of them, viz:

$$\epsilon_{ijk} \delta_{mp}, \epsilon_{ijm} \delta_{kp}, \epsilon_{ijp} \delta_{km}, \epsilon_{ikm} \delta_{jp}, \epsilon_{ikp} \delta_{mj}, \epsilon_{imp} \delta_{jk}. \quad (4.2)$$

Since Weyl's result [1] implies that (3.4) or (4.1) exhaust all possible reduction equations for rank-five isotropic tensors, and since none of the six in (4.2) can be so reduced, we conclude that (4.2) is a linearly independent set.

Figure 11. A portion of a test run to check out programs to interface the Hershey character set with the NBS typographic system.

1.0M NaNO₃, pH 10, O₂ FREE

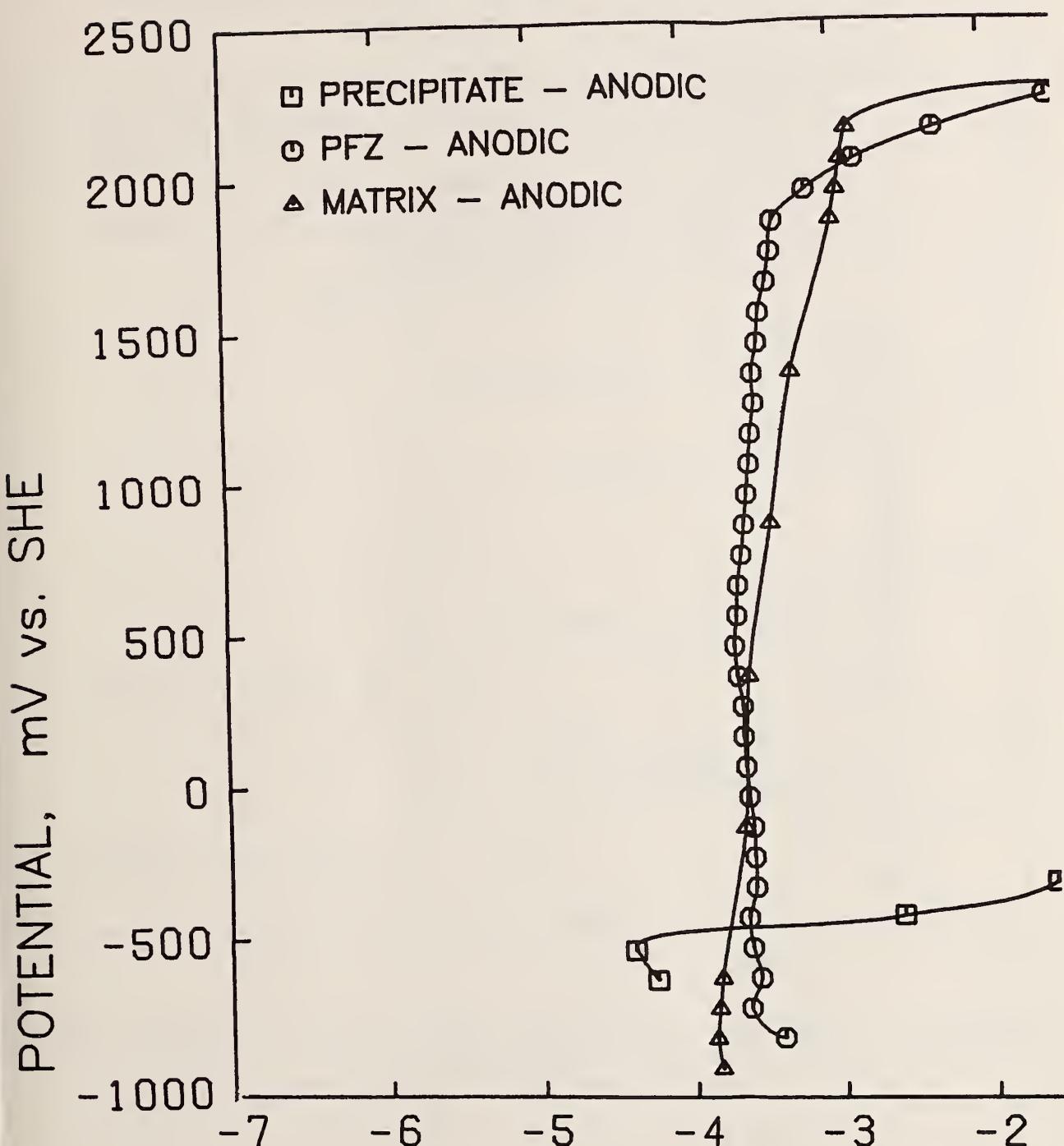


Figure 12. An example of plot produced on a drum-plotter utilizing the Hershey alphabet patterned after the LEROY® character set.

```

@ELT,SI WOLCOT*TPF$.XTCHDT,,,164756060312
      SUBROUTINE XTCHDT (NC, AI, AD, LC)
C ****
C UNIVAC 1108 SUBROUTINE TO EXTRACT CHARACTER DIGITIZATION
C ****
C NC = CHARACTER NUMBER (FORTRAN INTEGER)
C AI = INDEX ARRAY (SYMBOLIC ADDRESS)
C AD = DATUM ARRAY (SYMBOLIC ADDRESS)
C LC = CHARACTER ARRAY (SYMBOLIC ADDRESS)
C
C
      INTEGER AI, AD
      DIMENSION AI(1),AD(80),LC(320)
001 J=NC/2
      K=ABS(NC-2*j)
      LD=FLD(18*K,18,AI(J+1))
      I=0
      NE=0
002 M=LD/4
      N=ABS(LD-4*M)
      LC(I+1)=FLD(9*N,9,AD(M+1))
      LC(I+1)=LC(I+1)-64
      LD=LD+1
      I=I+1
      IF(LC(I).NE.-64)GO TO 003
      IF(NE.EQ.-64)RETURN
003 NE=LC(I)
      GO TO 002
      END

```

Figure 13. A portion of a program listing produced on a drum-plotter using a monowidth subset of the Hershey character repertory.

TAPE UNIT TESTS 25 APR 84 TO 07 MAY 84

SUB/UNIT	ERRORS	METERS ¹	ERRORS/KM
SATURN 7 TRACK 800 CPI			
8/0	2	28811	.069
8/1	0	23438	.000
8/2	0	22002	.000
8/3	0	20017	.000
8/4	0	21019	.000
8/5	1	22203	.045
8/6	21	18097	1.160
SATURN 9 TRACK 800 CPI			
8/8	823	24376	33.763
8/9	9	23246	.387
JUPITER NRZI 800 CPI			
5/0	463	33437	13.847
5/1	19	35269	.539
5/2	44	27066	1.626
JUPITER PHASE ENCODED 1600 CPI			
5/3	168	24830	6.766
5/4	37	35294	1.048

Figure 14. A vue-graph prepared from a page produced on a drum-plotter using a subset of the Hershey character repertory.

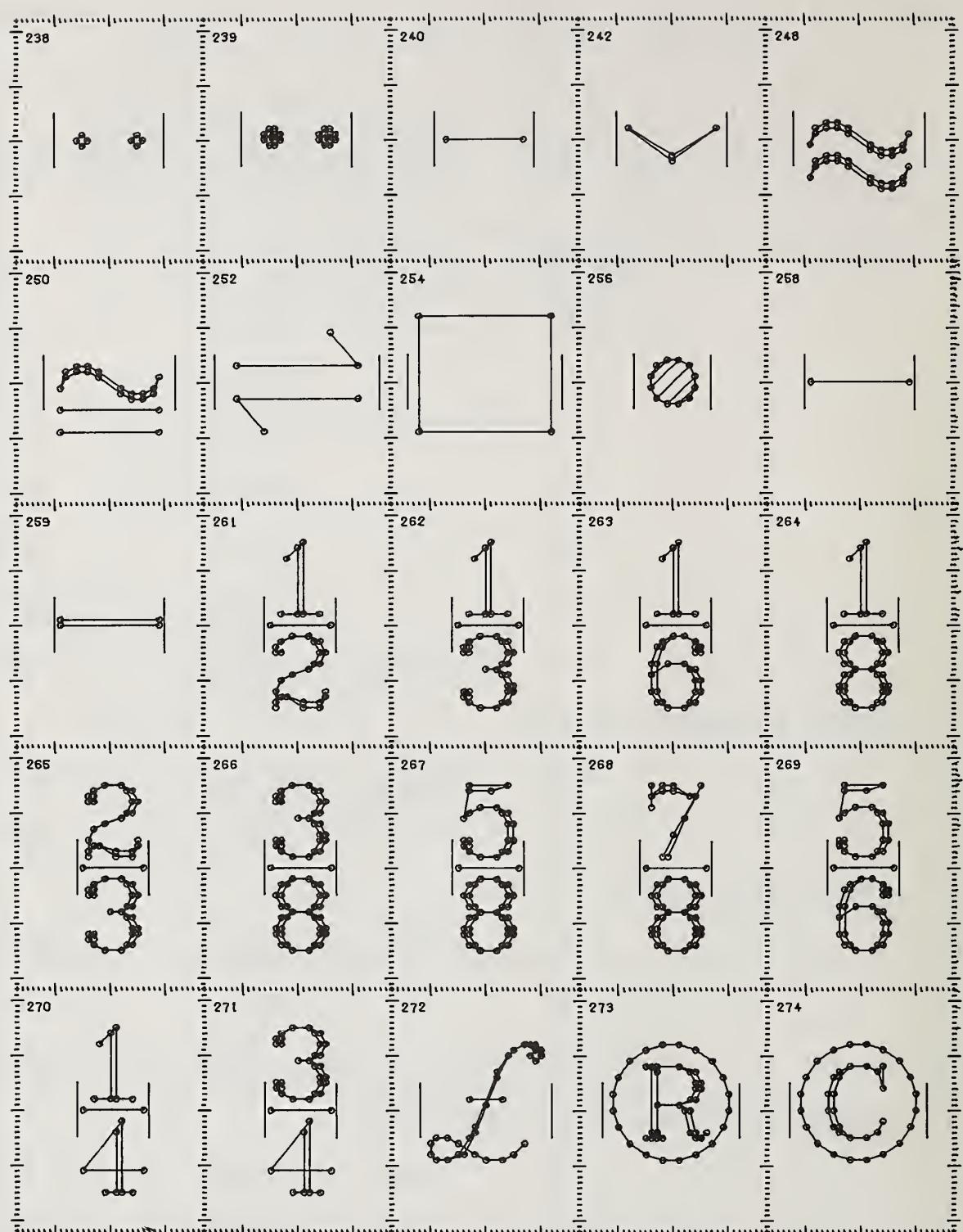


Figure 15. These special characters were digitized at NBS to meet the publication requirements of the Office of Standard Reference Data. The illustration was produced on a standard drum plotter.

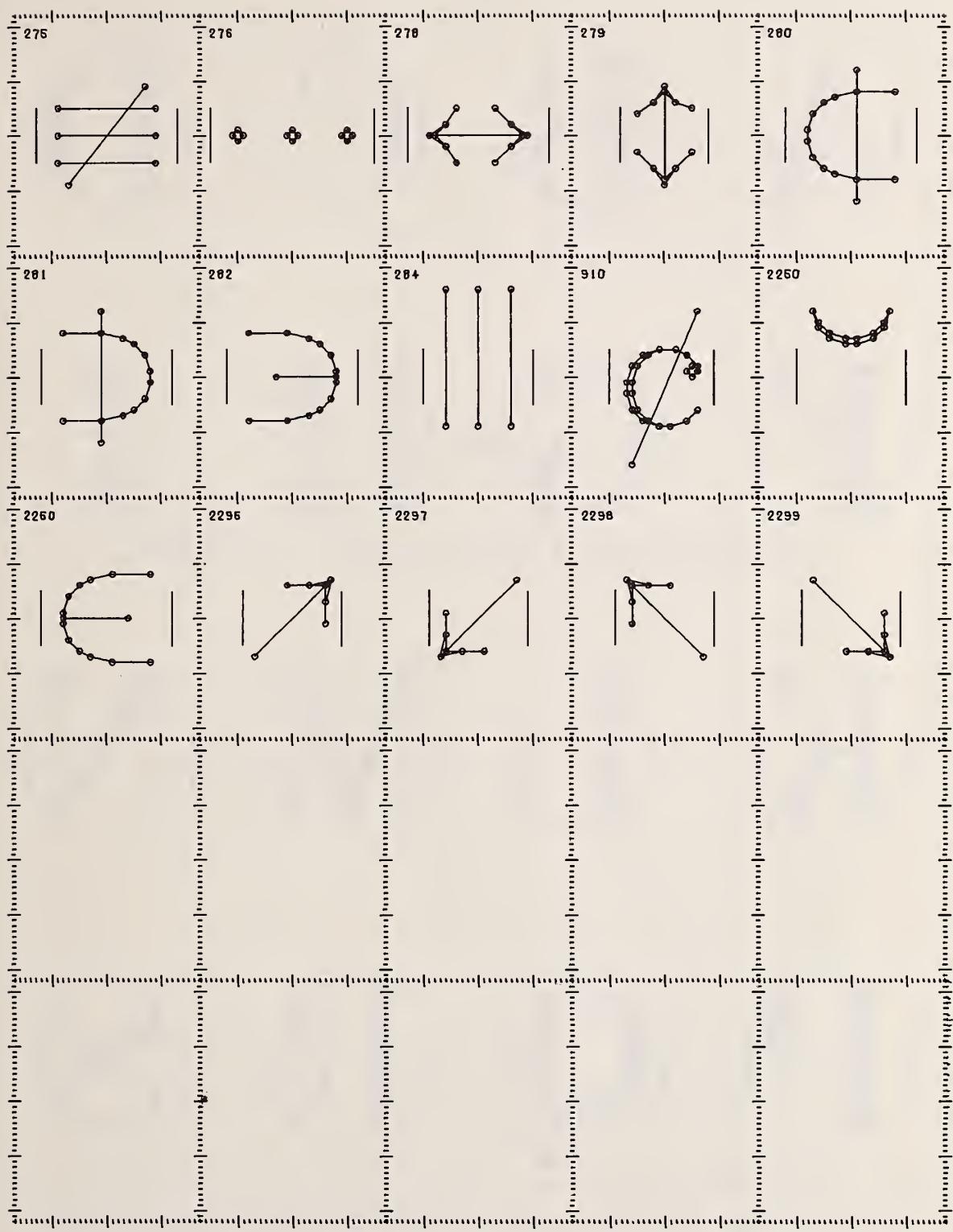


Figure 15. Concluded

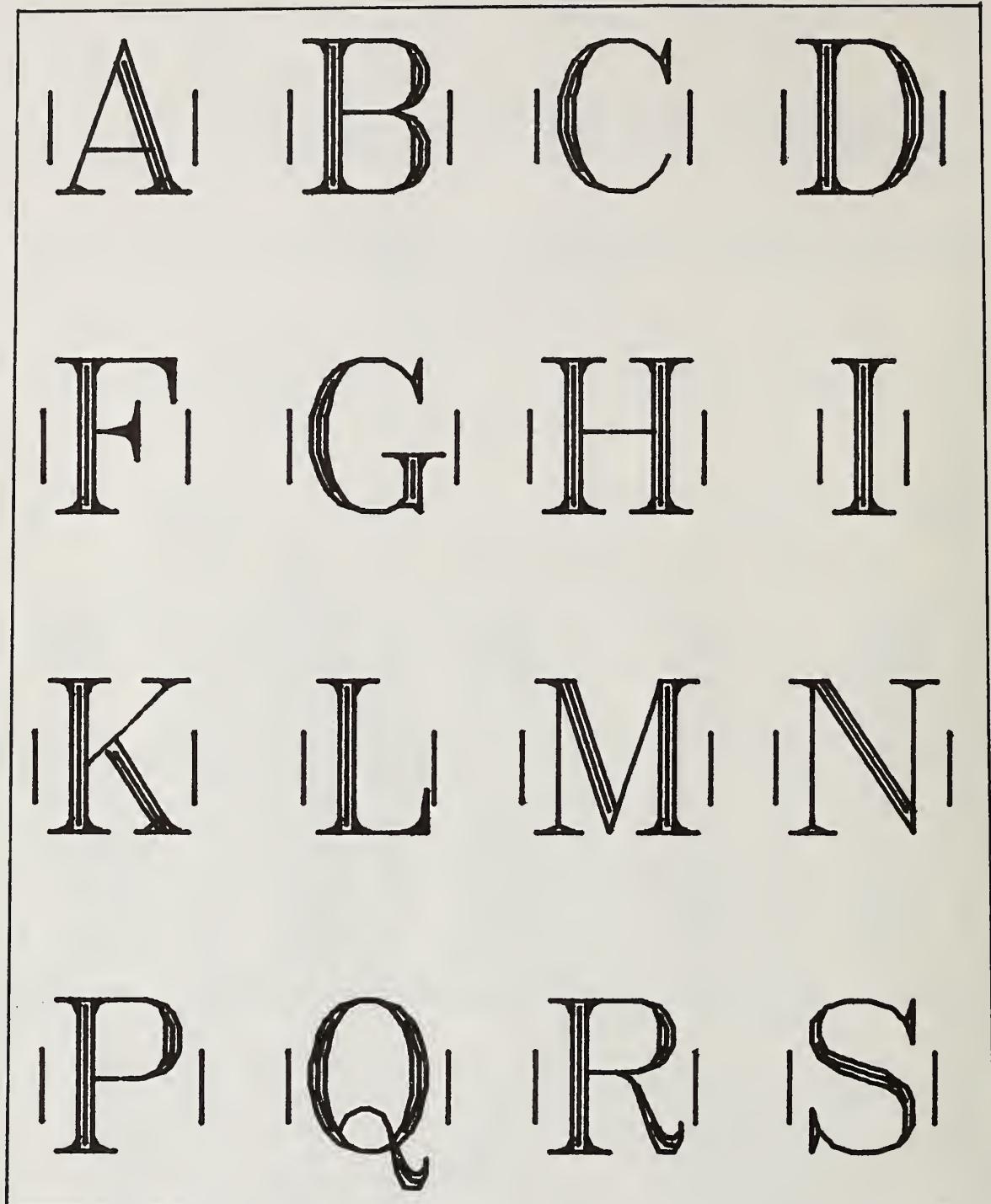
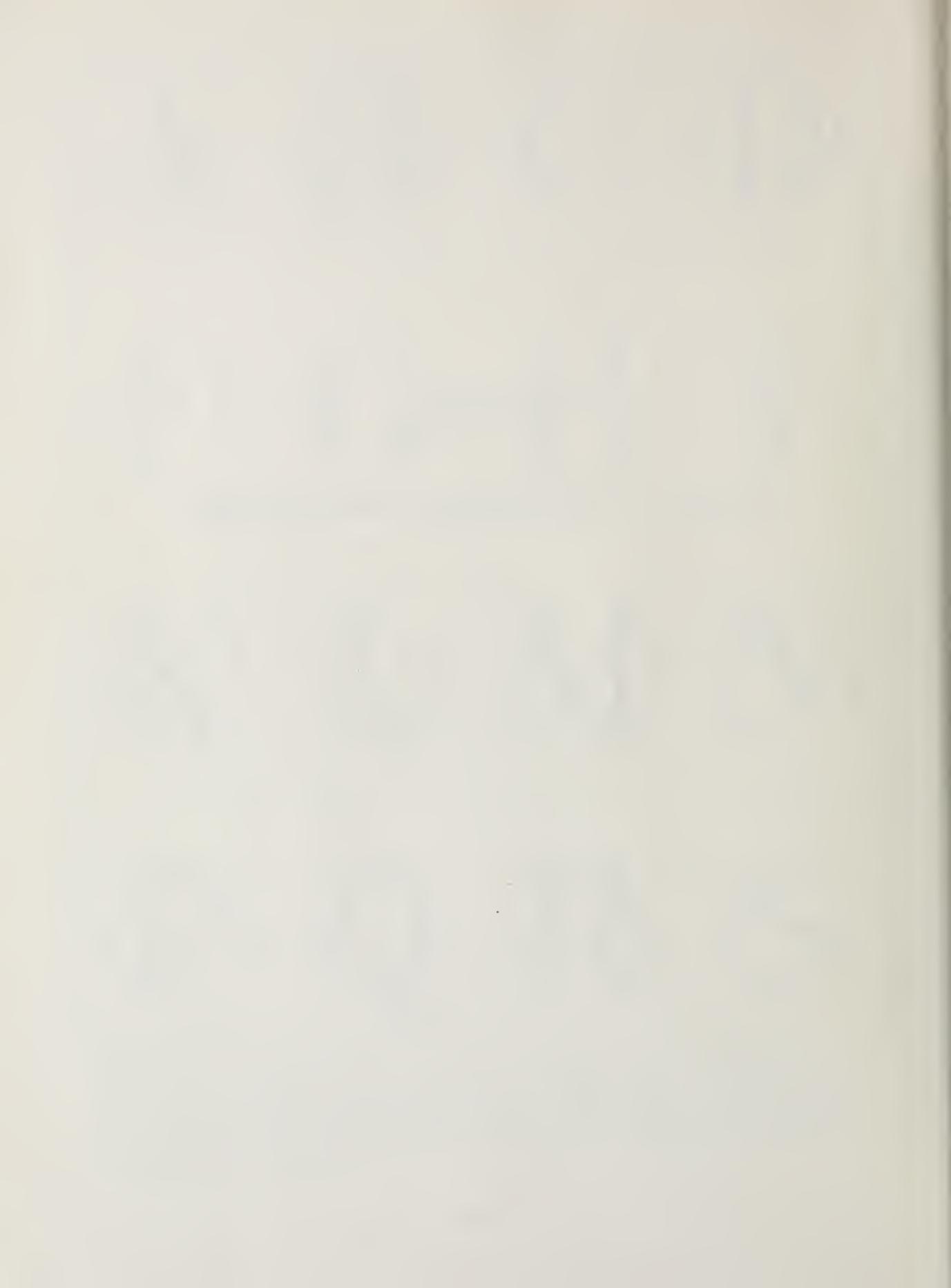


Figure 16. Here we see the use of the triplex mode to draw 72 point characters on a drum plotter (with a 0.4mm wide pen). Use of a wider pen would have removed the white spaces between all of the lines. Since spot size and intensity can be varied on a COM device, comparable results can be achieved.

APPENDIX A

TABLES OF CHARACTER DIGITIZATIONS



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680	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
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683	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
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708	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
709	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
710	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
711	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
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713	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
714	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
715	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	
716	-6	4:	-6	-9	5:	-9	5:	-8:	-6:	-1:	-6:	-9:	-3	9:	-1	8:	-64:	0:	-2	18:	-3	20:	-5	21:	0:	5	5:	

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1275	-6 -4 -6 4::
1276	-5 -4 -5 4::
1277	-3 -3 -3 3::
1278	-6 -4 -6 4::
1279	-5 -4 -5 4::
1280	-6 -4 -6 4::
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1283	-5 -4 -5 4::
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1287	-5 -4 -5 4::
1288	-6 -4 -6 4::
1289	-5 -4 -5 4::
1290	-6 -4 -6 4::
1291	-5 -4 -5 4::
1292	-6 -4 -6 4::
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1294	-6 -4 -6 4::
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1402	-5 -4 -5 4::
1403	-6 -4 -6 4::
1404	-5 -4 -5 4::
1405	-6 -4 -6 4::

2045	-6	-9	-4	-10	-4	-6	-9	-6	-12	-7	-6	-7	-12	8	-6	7	-12	-64	0	-3	9			
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2049	-6	-7	-6	-12	-1	-5	-6	-5	-9	-5	-6	-6	-5	-7	-7	-3	-7	-1	-4	-1	-4	-1	-4	-1
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2052	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2053	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2054	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
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2056	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2057	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2058	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2059	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2060	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2061	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2062	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
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2064	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
2065	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1
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2067	-6	-7	-12	-7	-9	-6	-4	-4	-7	-12	-7	-9	-6	-7	-6	-5	-6	-5	-3	-7	-1	-1	-1	-1

This block contains the first 1000 digits of pi.

2575	-3:-
2576	-3:-
2601	-2:-
2602	-2:-
2603	-2:-
2604	-2:-
2605	-2:-
2606	-2:-
2607	-2:-
2608	-2:-
2609	-2:-
2610	-2:-
2611	-2:-
2612	-2:-
2613	-2:-
2614	-2:-
2615	-2:-
2616	-2:-
2617	-2:-
2618	-2:-
2619	-2:-
2620	-2:-
2621	-2:-

2713 -6 10 0 9 1 13 -64 1 -3 0 1 -7 0 1 -7 0
 2714 -6 12 0 -1 12 -64 0 1 9 1 9 2 8 0 -5 -9 0
 2715 -6 7 -6 0 5 -3 3 -2 0 0 0 0 0 0 0 0 0 0 0
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 2717 -6 7 -6 0 5 -3 3 -2 0 0 0 0 0 0 0 0 0 0 0
 2718 -6 7 -6 0 5 -3 3 -2 0 0 0 0 0 0 0 0 0 0 0
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 2720 -6 7 -6 0 5 -3 3 -2 0 0 0 0 0 0 0 0 0 0 0
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 2755 -6 7 -6 0 5 -3 3 -2 0 0 0 0 0 0 0 0 0 0 0

This block contains a single character, the letter 'A', repeated 1000 times across all 1000 columns of the grid.

3109	-5::	-1	-5::	-1	-2	-1	-2	-5::
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3111	-1	-1	-1	-1	-1	-1	-1	-1
3112	-2	-1	-2	-1	-2	-1	-2	-1
3113	-1	-1	-1	-1	-1	-1	-1	-1
3114	-6::	-1	-6::	-1	-6::	-1	-6::	-1
3115	-6::	-1	-6::	-1	-6::	-1	-6::	-1
3116	-1	-1	-1	-1	-1	-1	-1	-1
3117	-6::	-1	-6::	-1	-6::	-1	-6::	-1
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3119	-6::	-1	-6::	-1	-6::	-1	-6::	-1
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3121	-1	-1	-1	-1	-1	-1	-1	-1
3122	-1	-1	-1	-1	-1	-1	-1	-1
3123	-1	-1	-1	-1	-1	-1	-1	-1
3124	-6::	-1	-6::	-1	-6::	-1	-6::	-1

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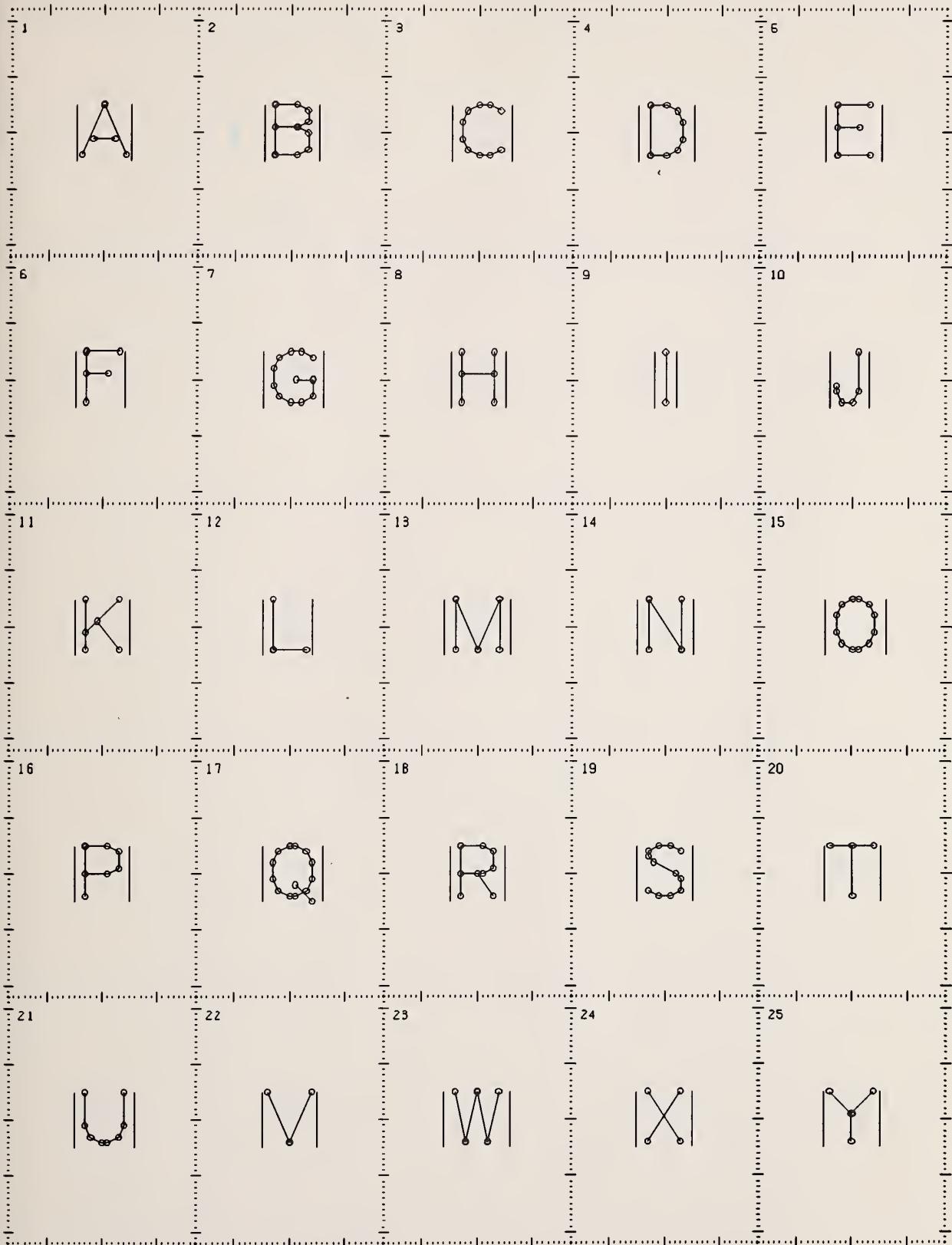
This block contains the first 13 pages of a large document, likely a technical report or manual, with content spanning from page 1 to page 13. The text is organized into several sections, each with a title and detailed descriptions. The content includes various tables, figures, and mathematical expressions, such as the Ramanujan-like identity for π and the Rogers-Ramanujan identities. The document is highly technical and requires a deep understanding of number theory and combinatorics to fully appreciate.

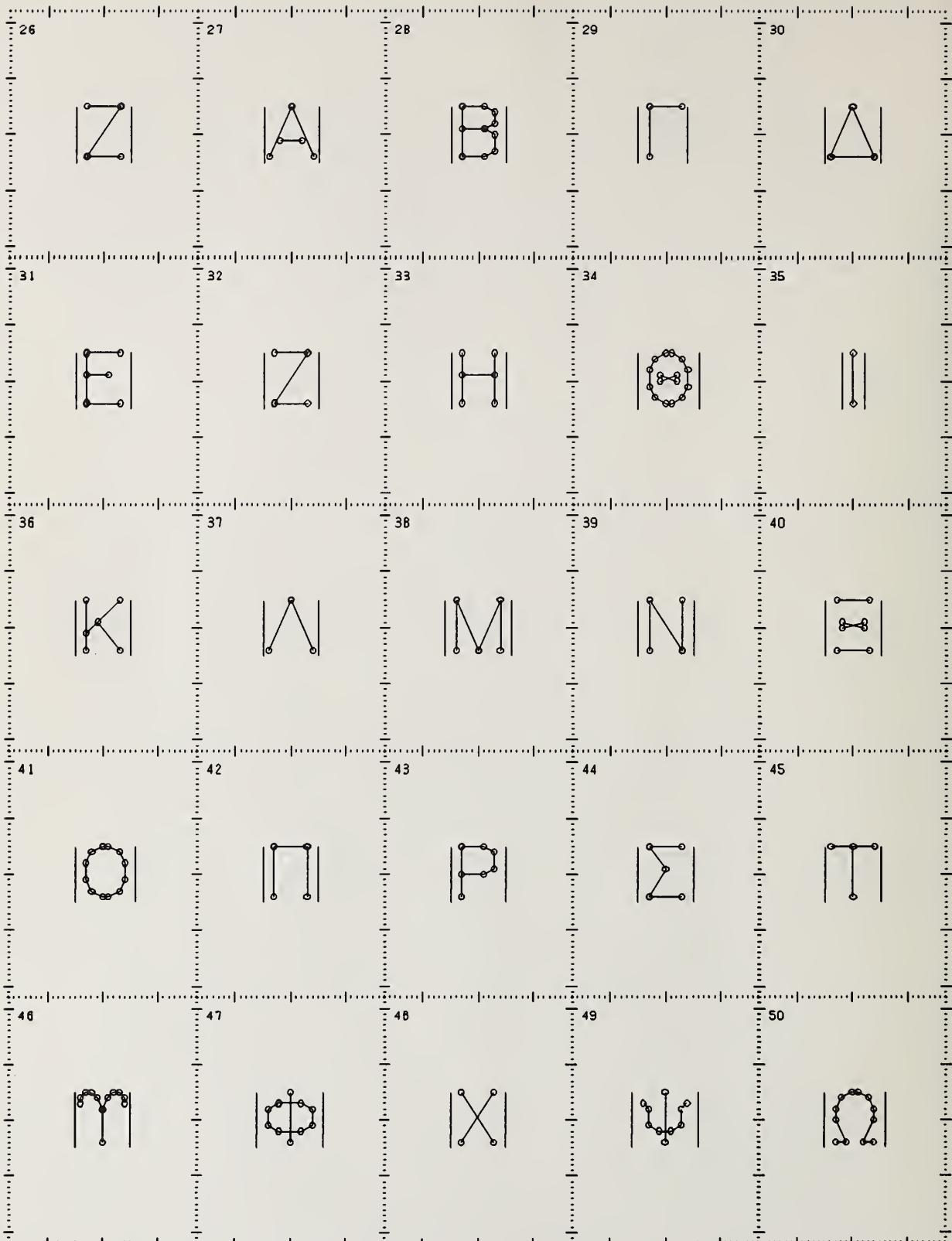
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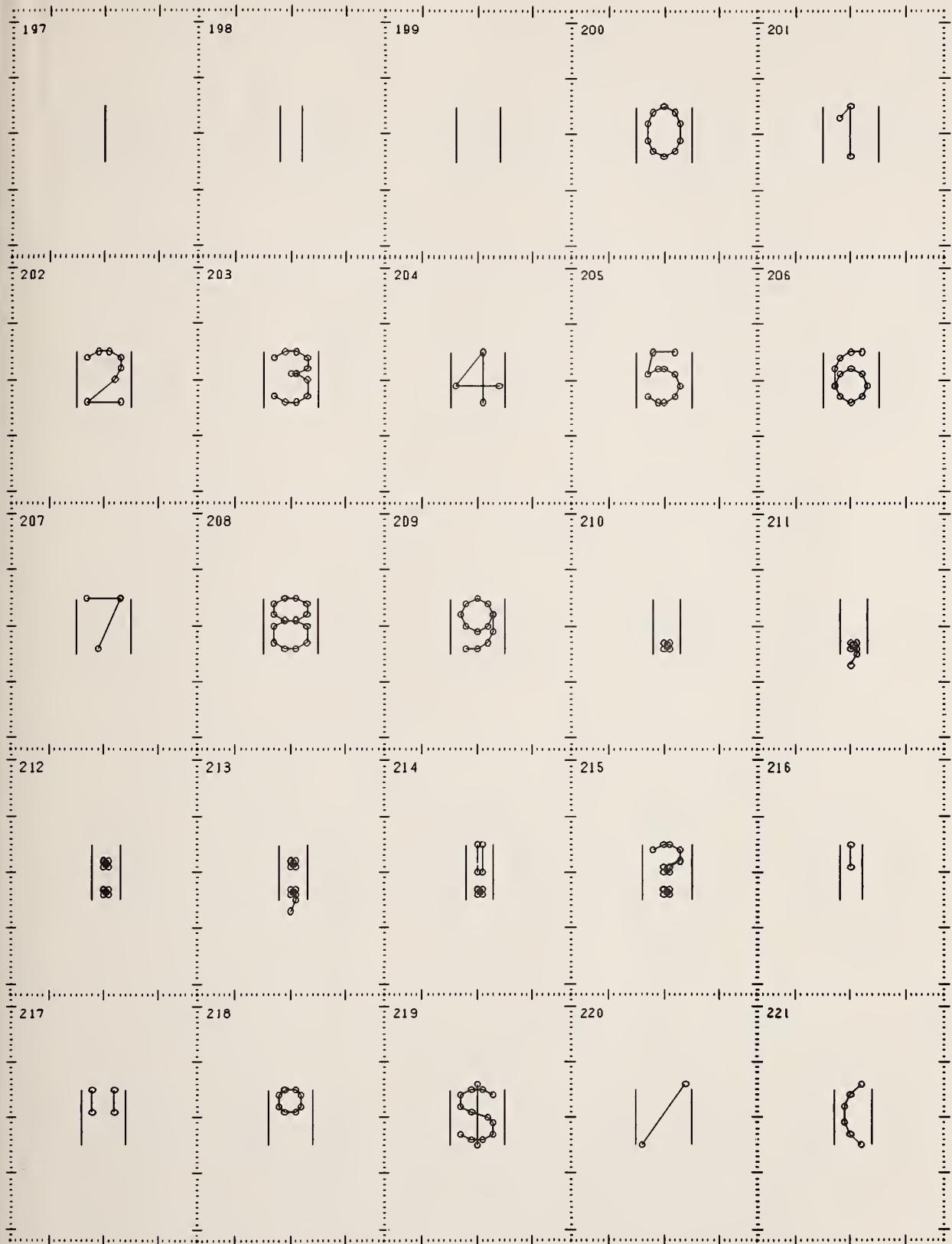
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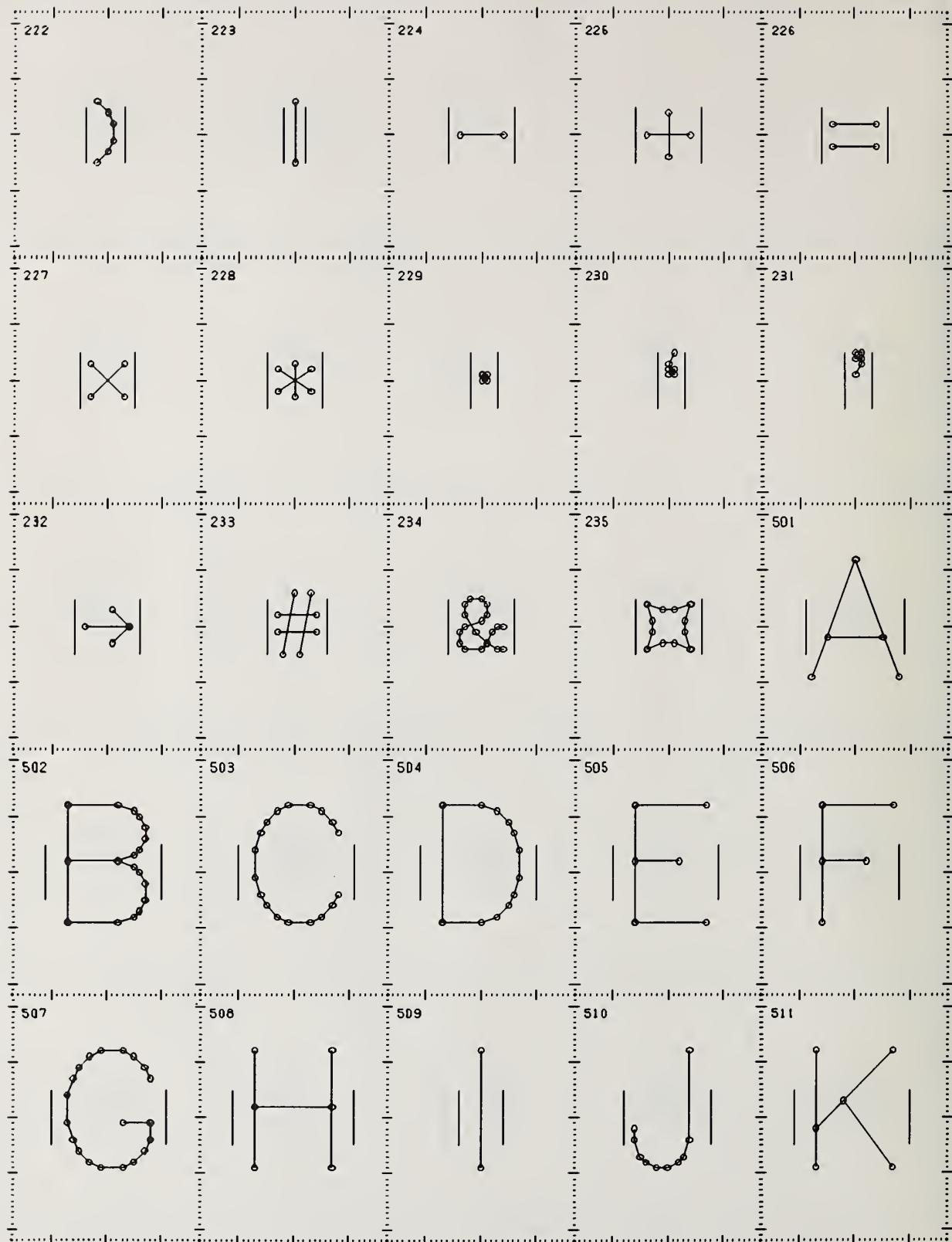
APPENDIX B

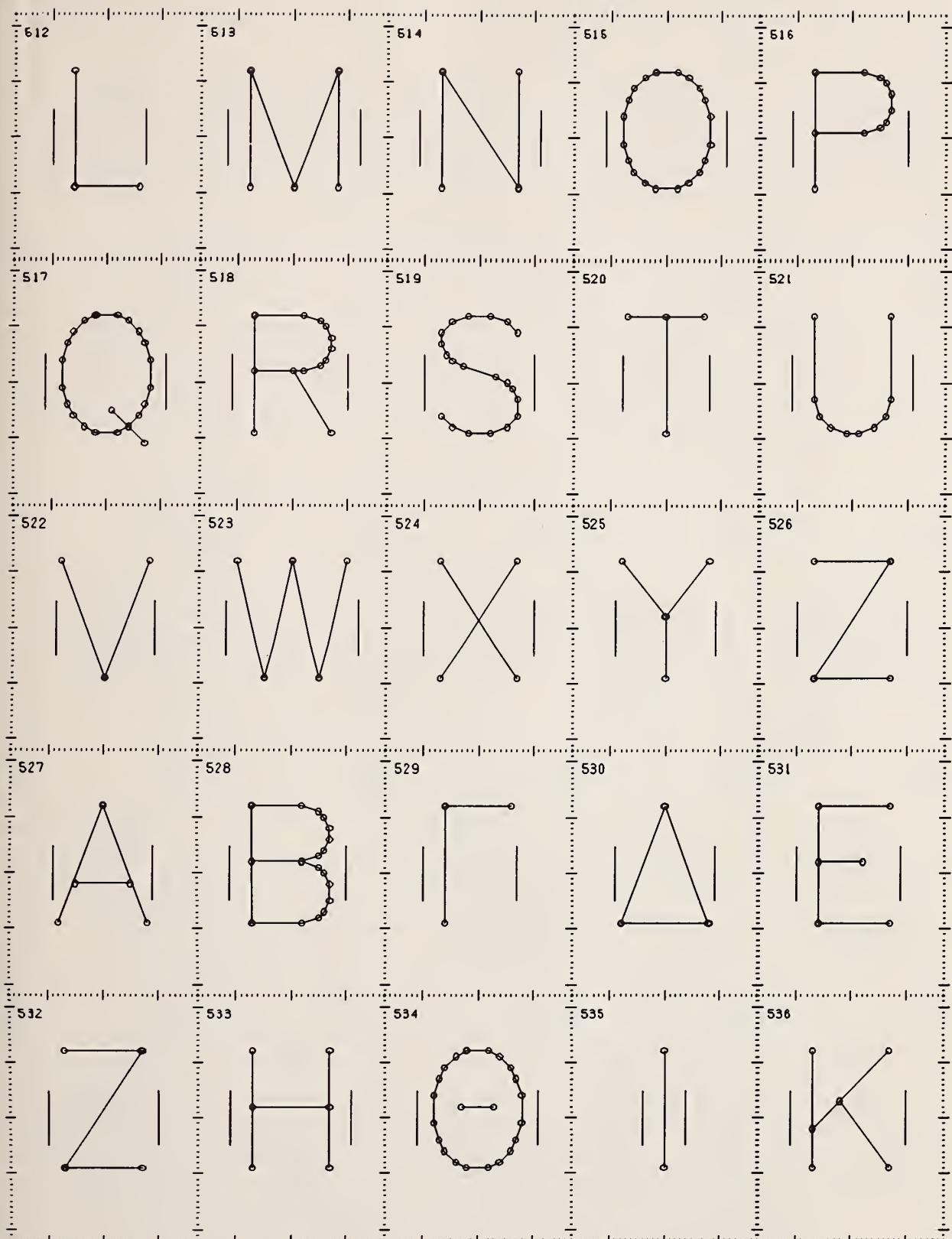
GRAPHIC REPRESENTATIONS OF CHARACTERS

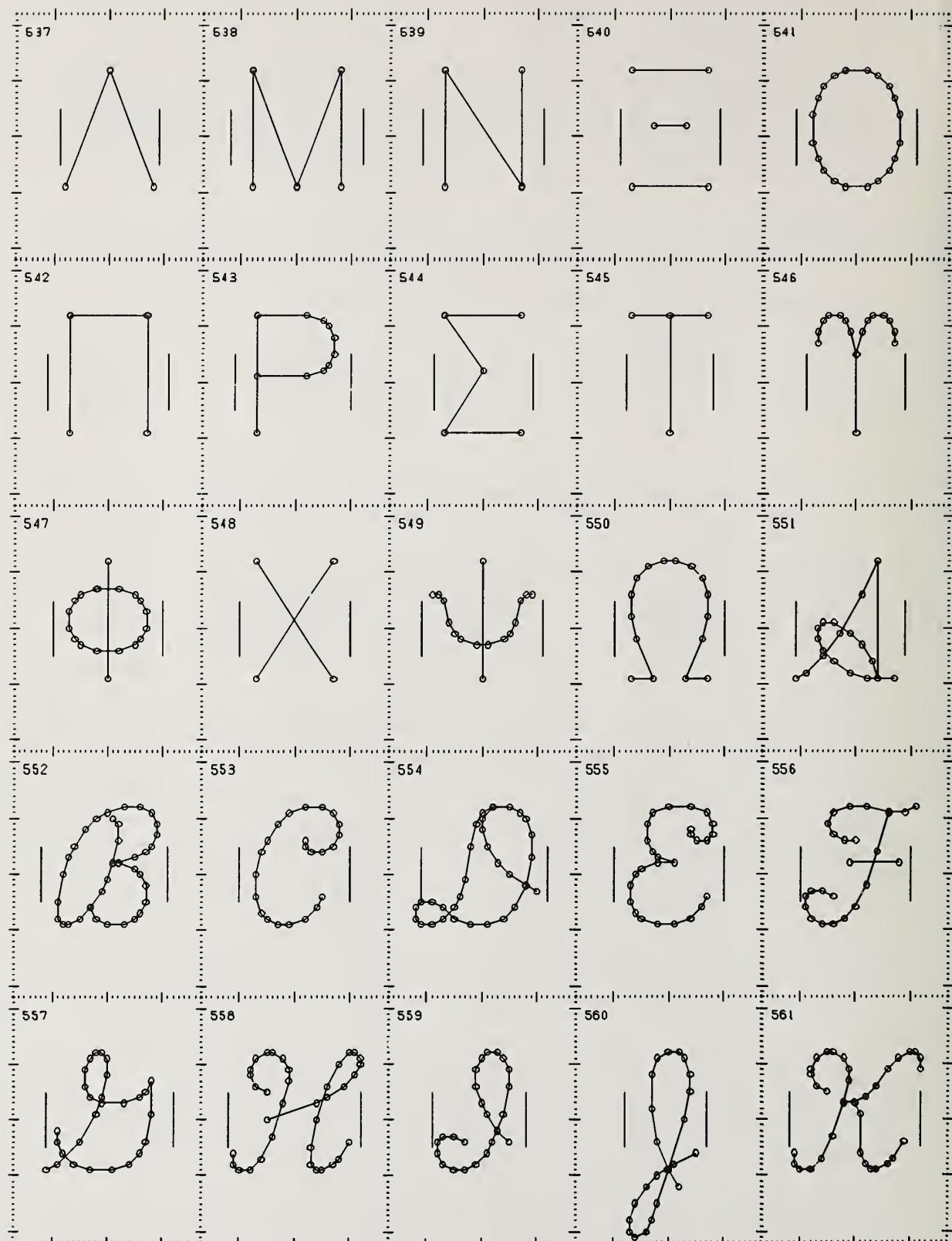


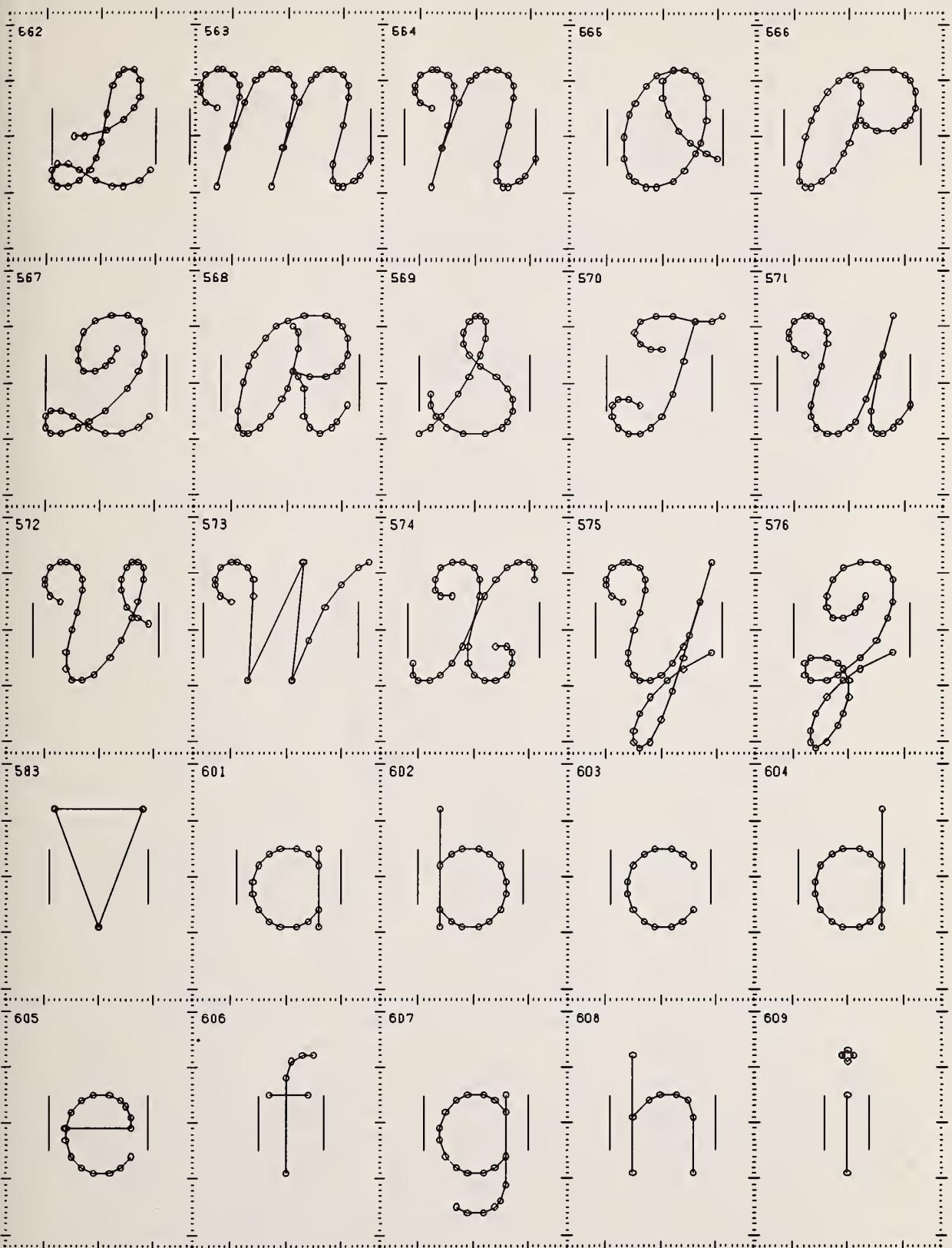


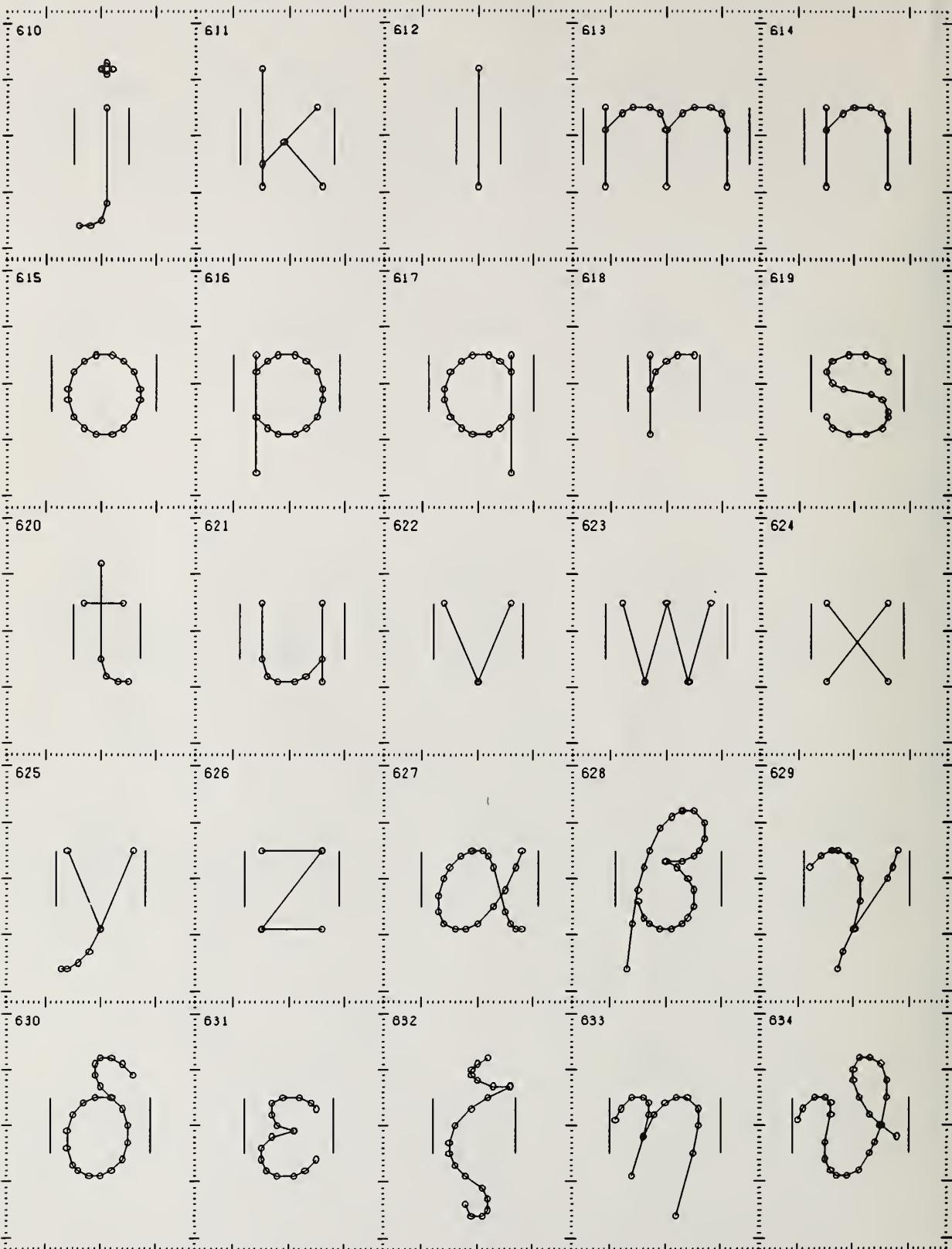


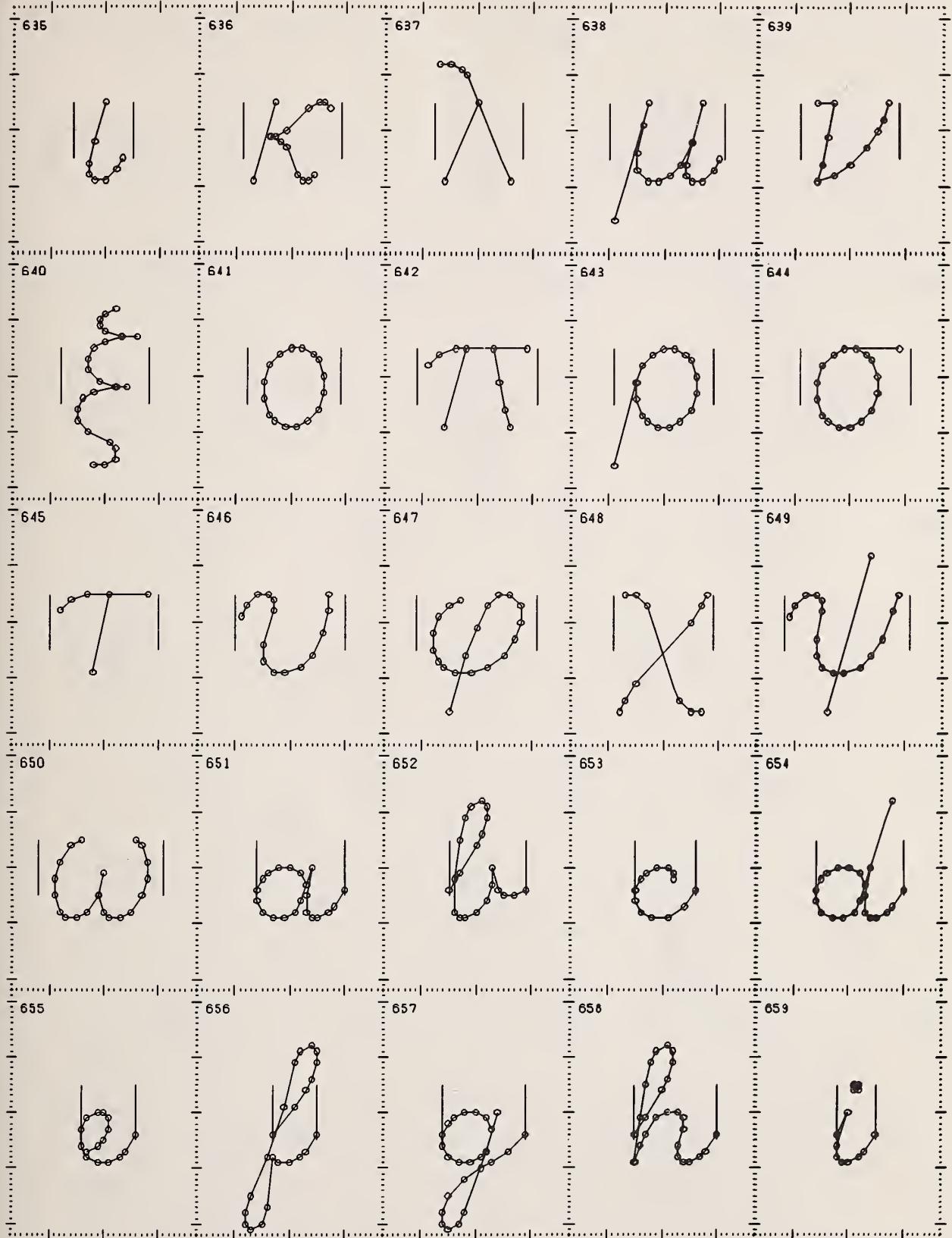


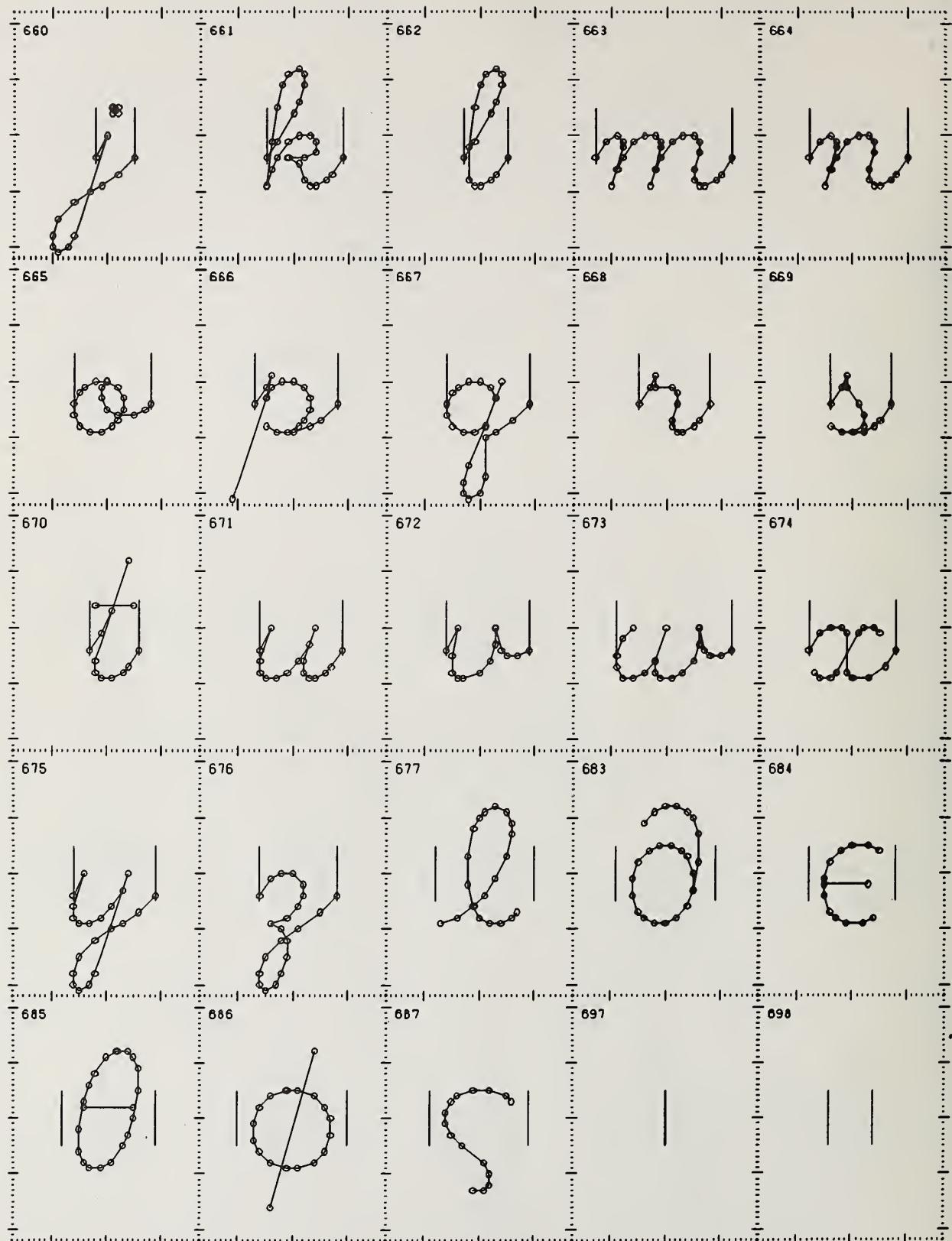


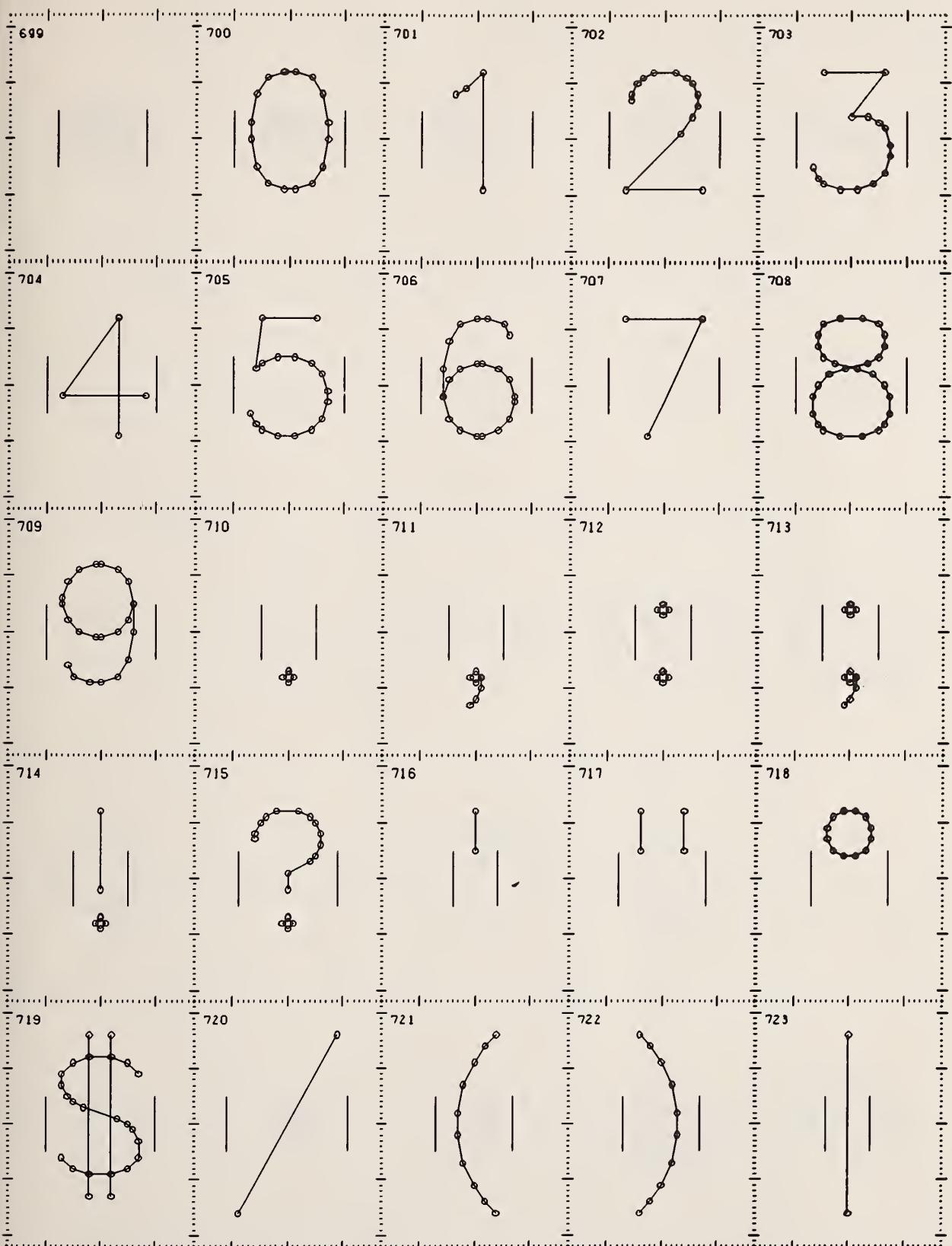


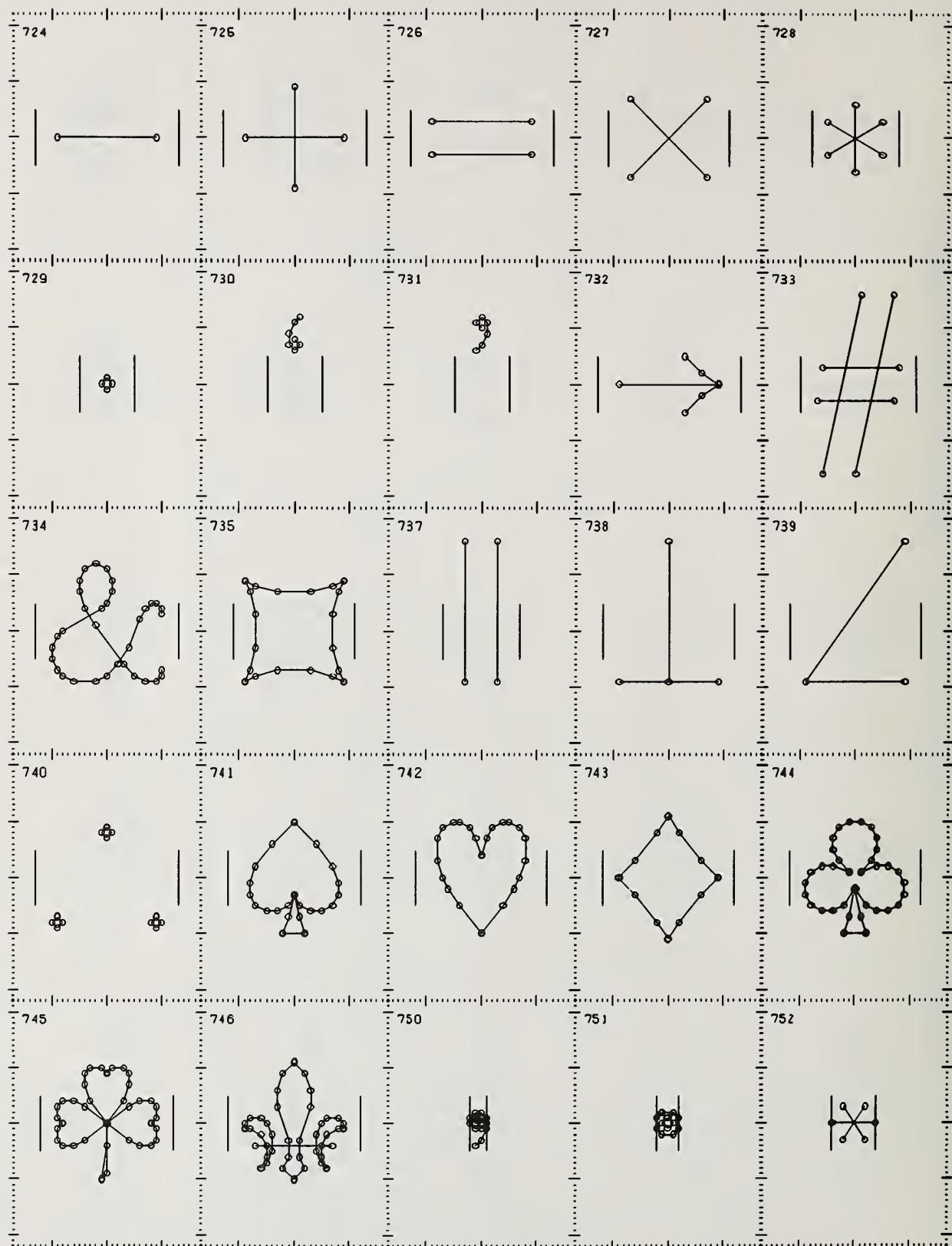


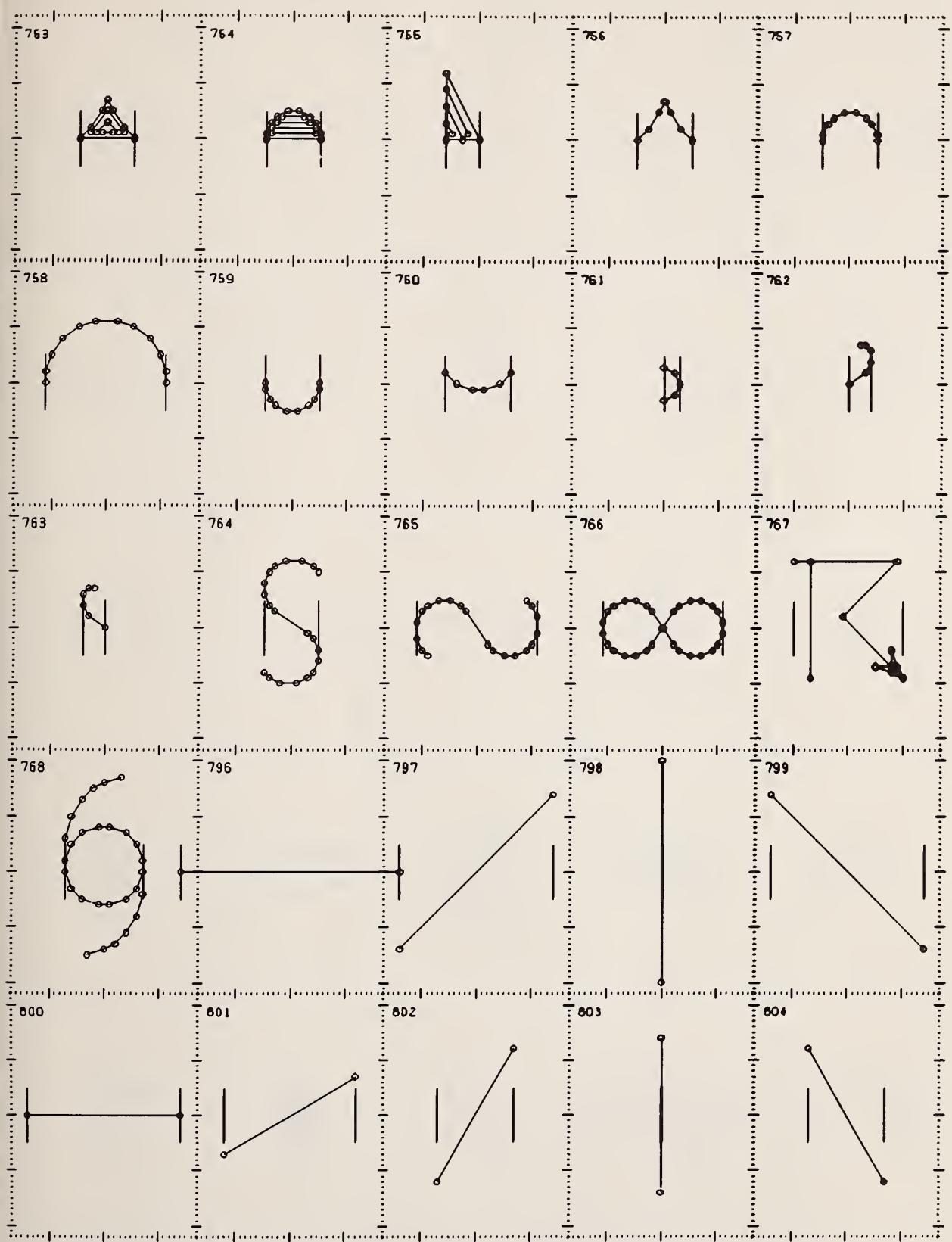


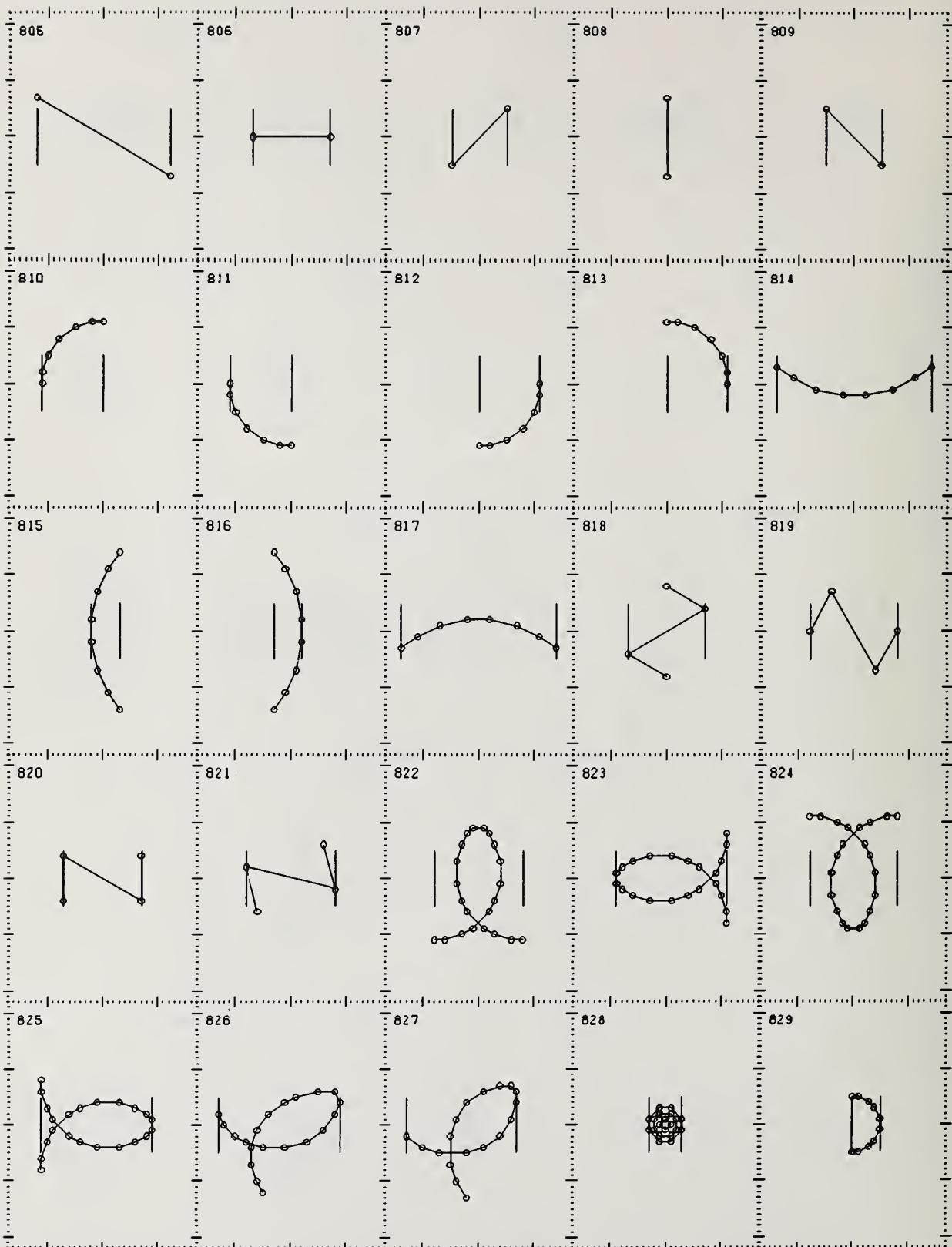


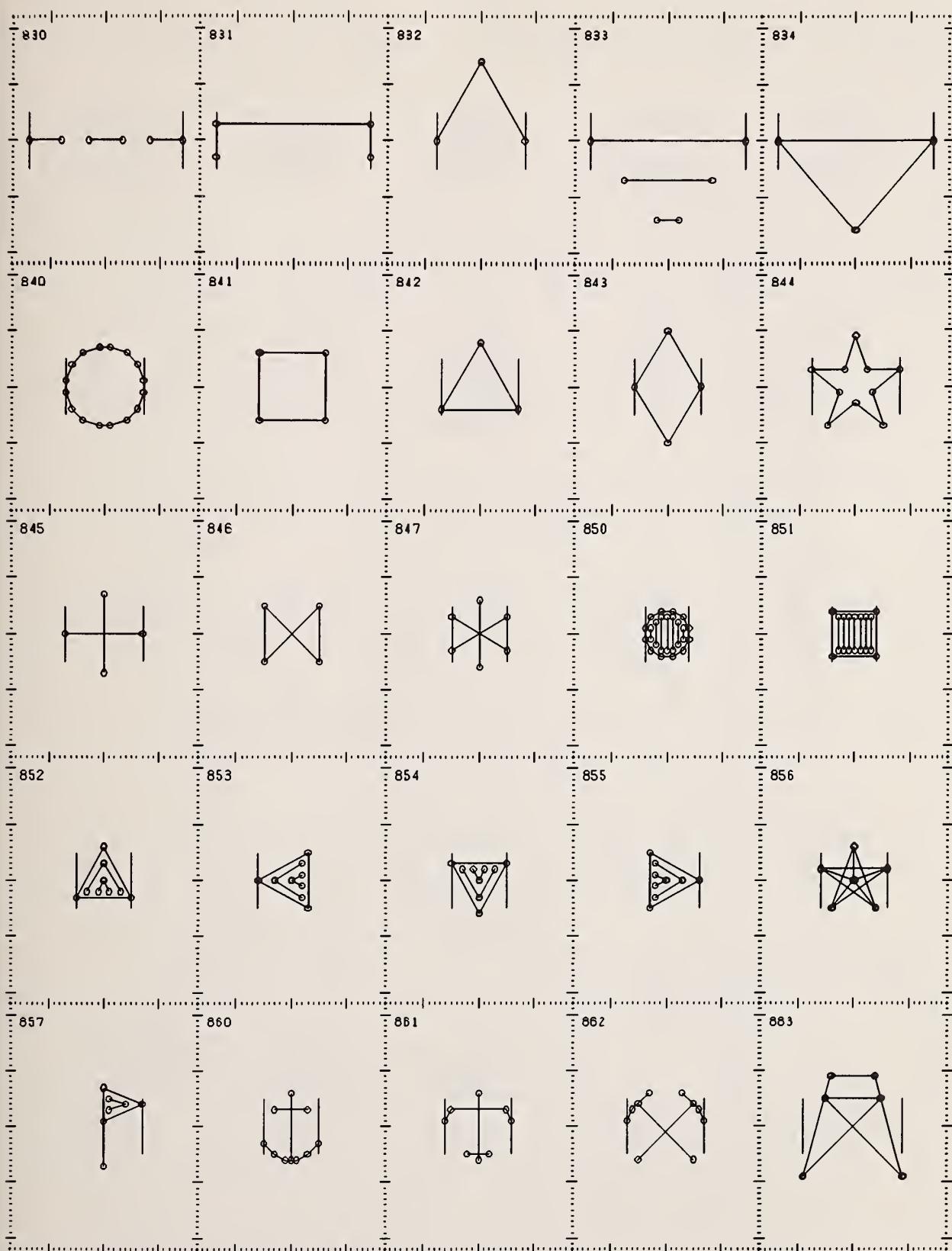


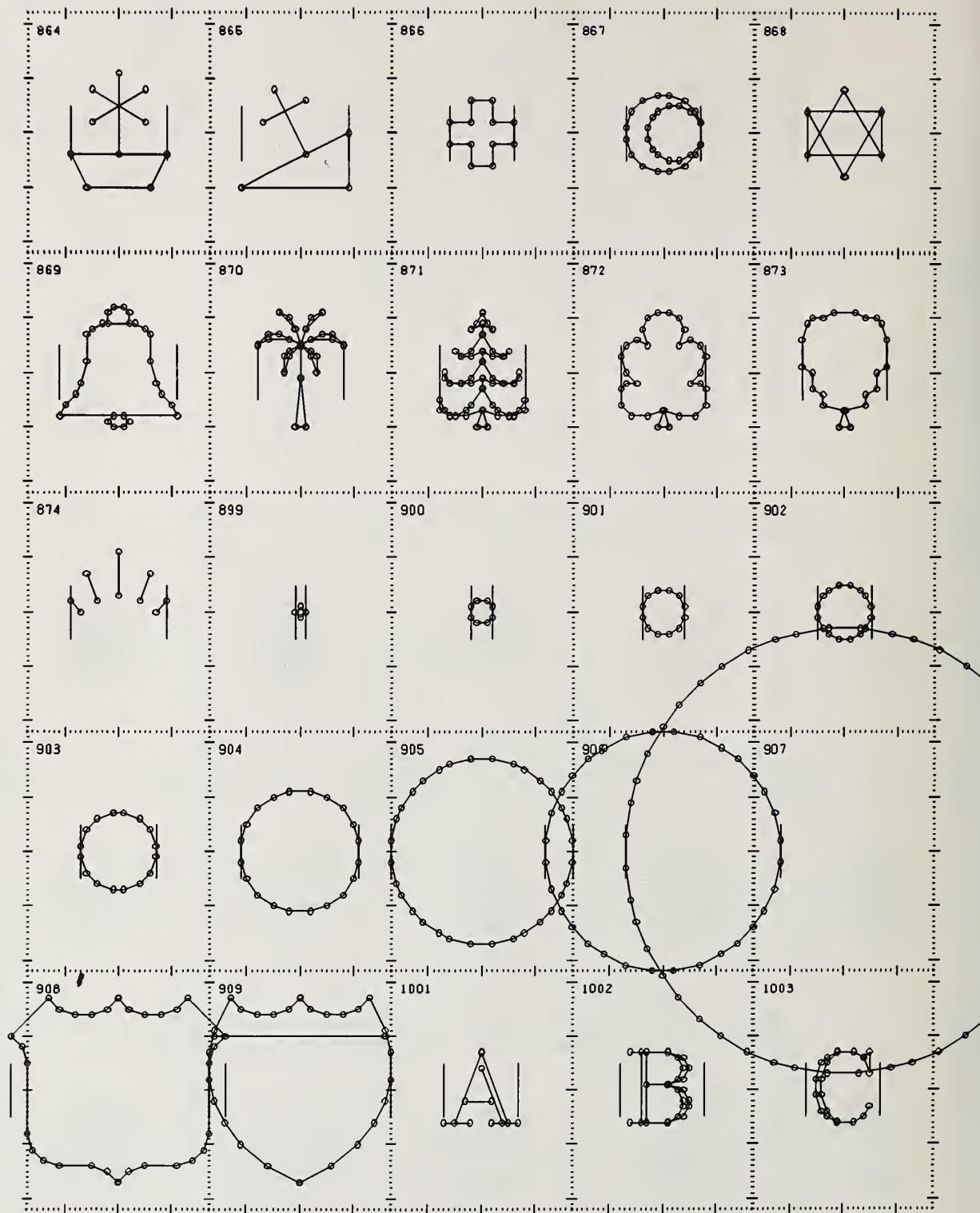


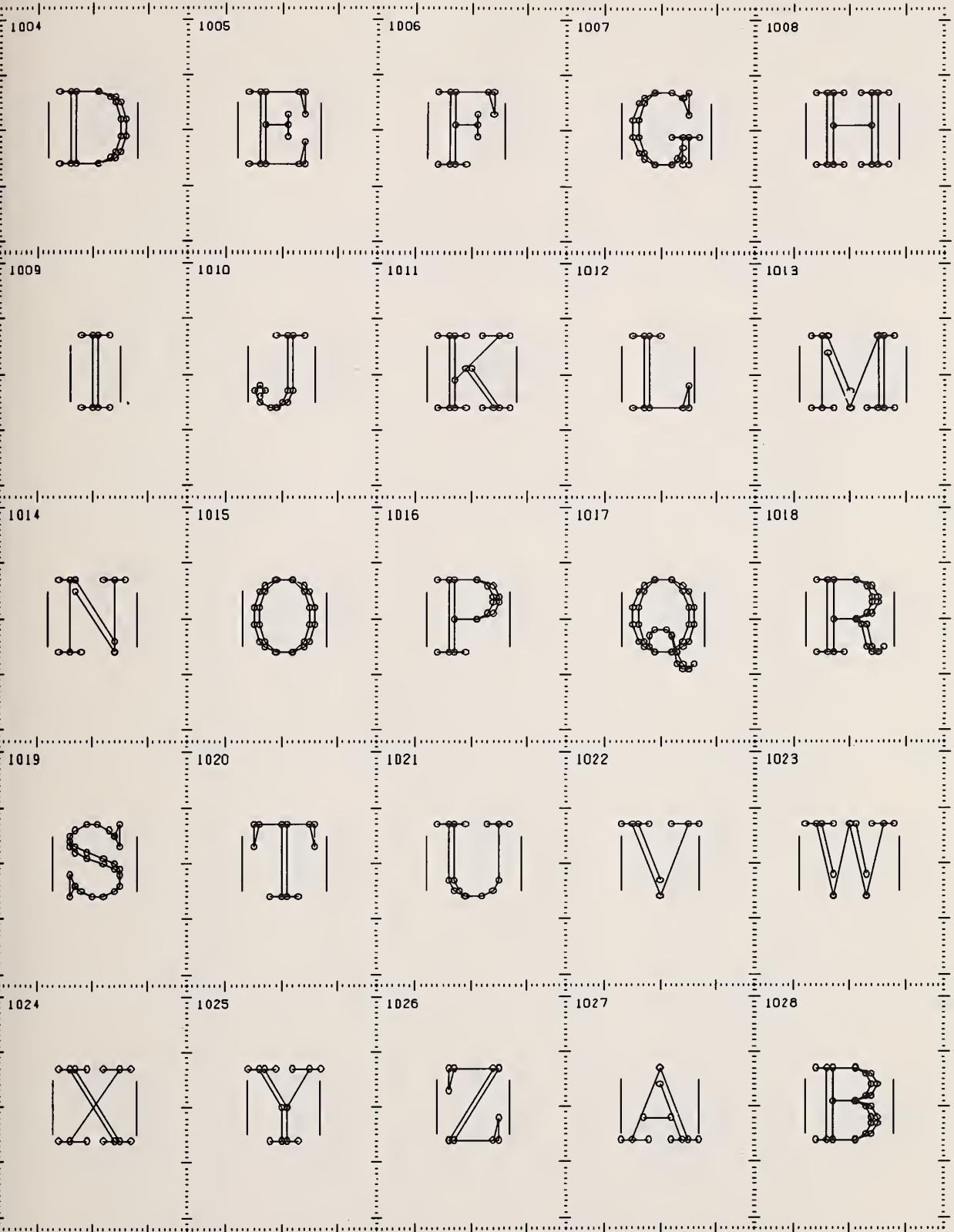




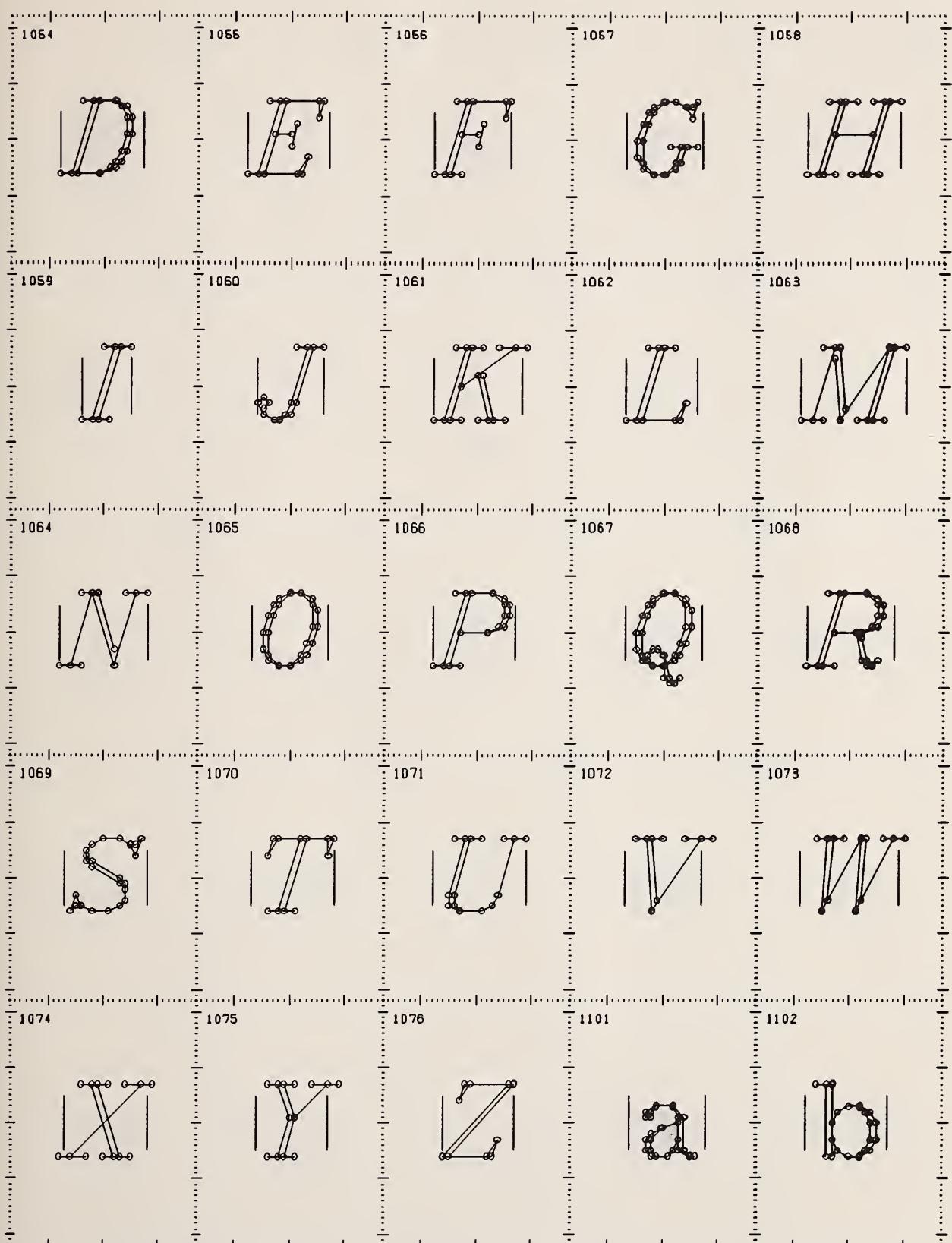


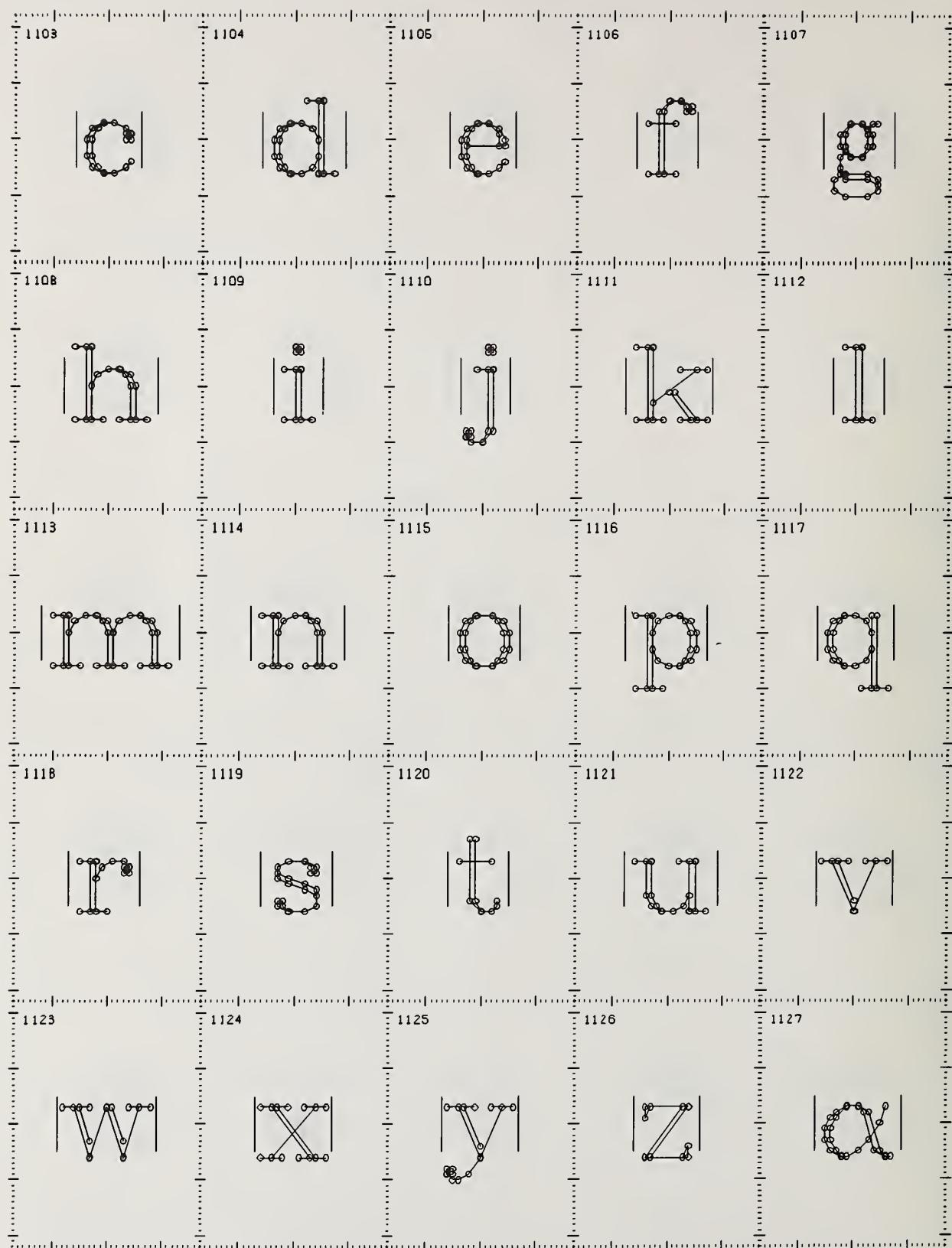


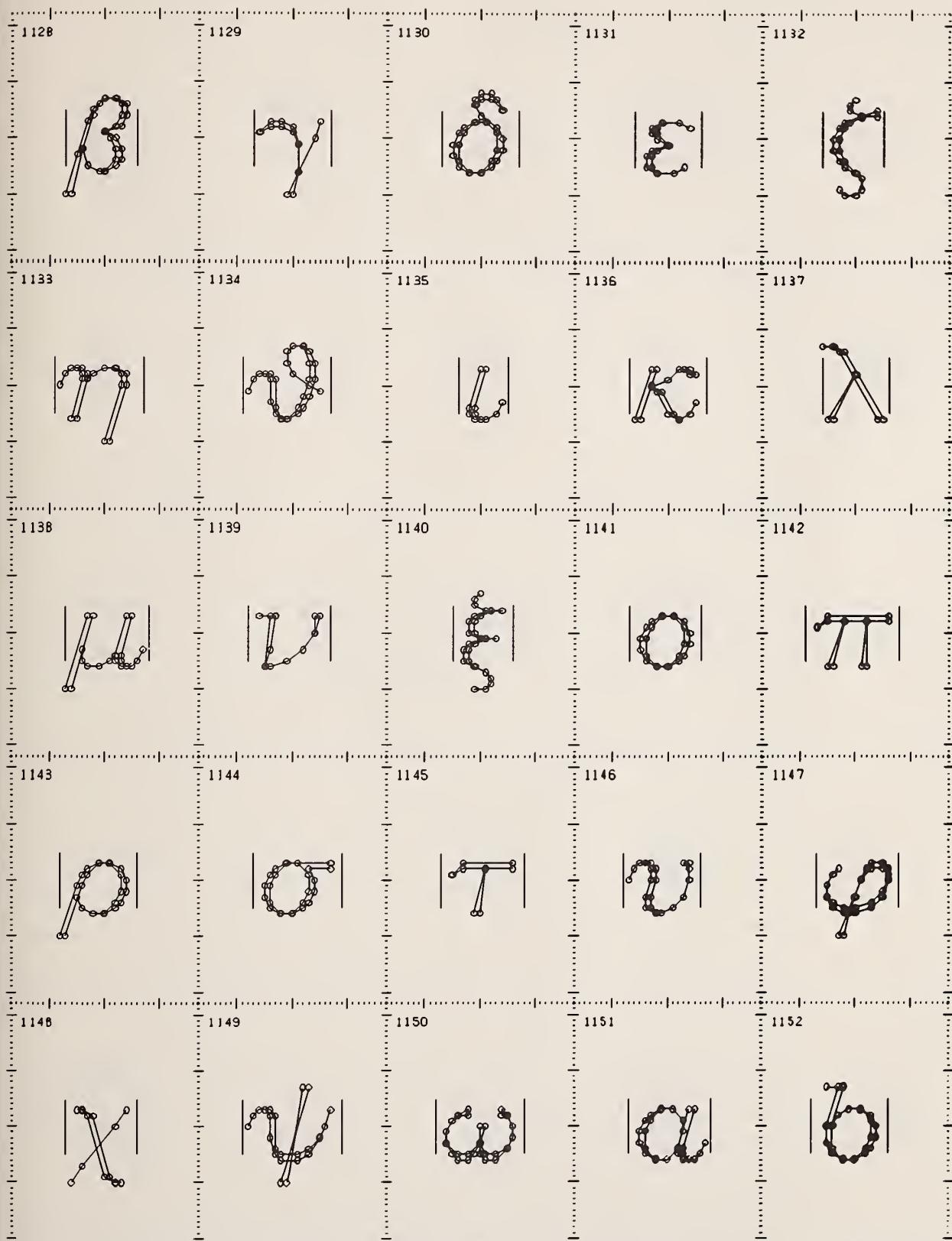


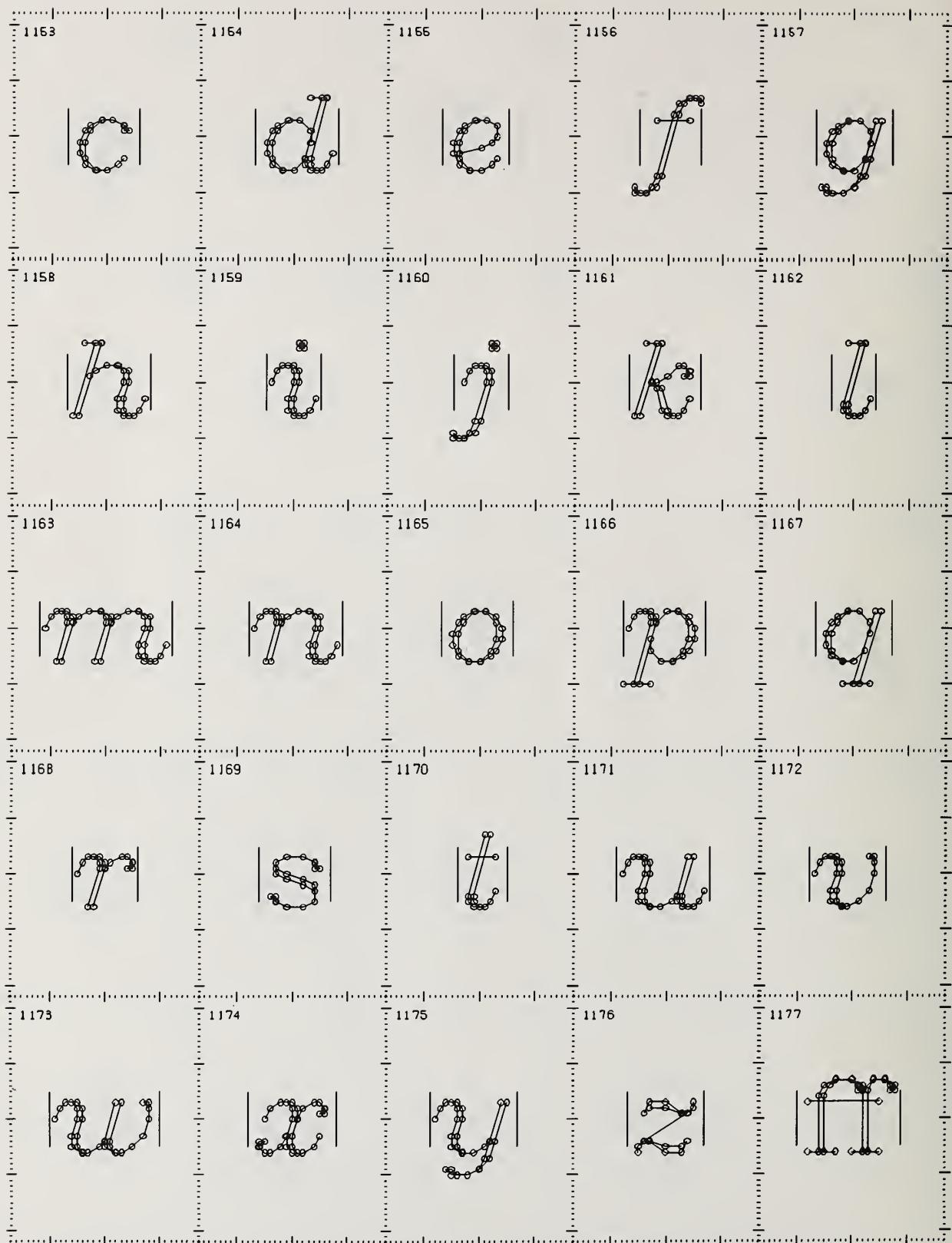


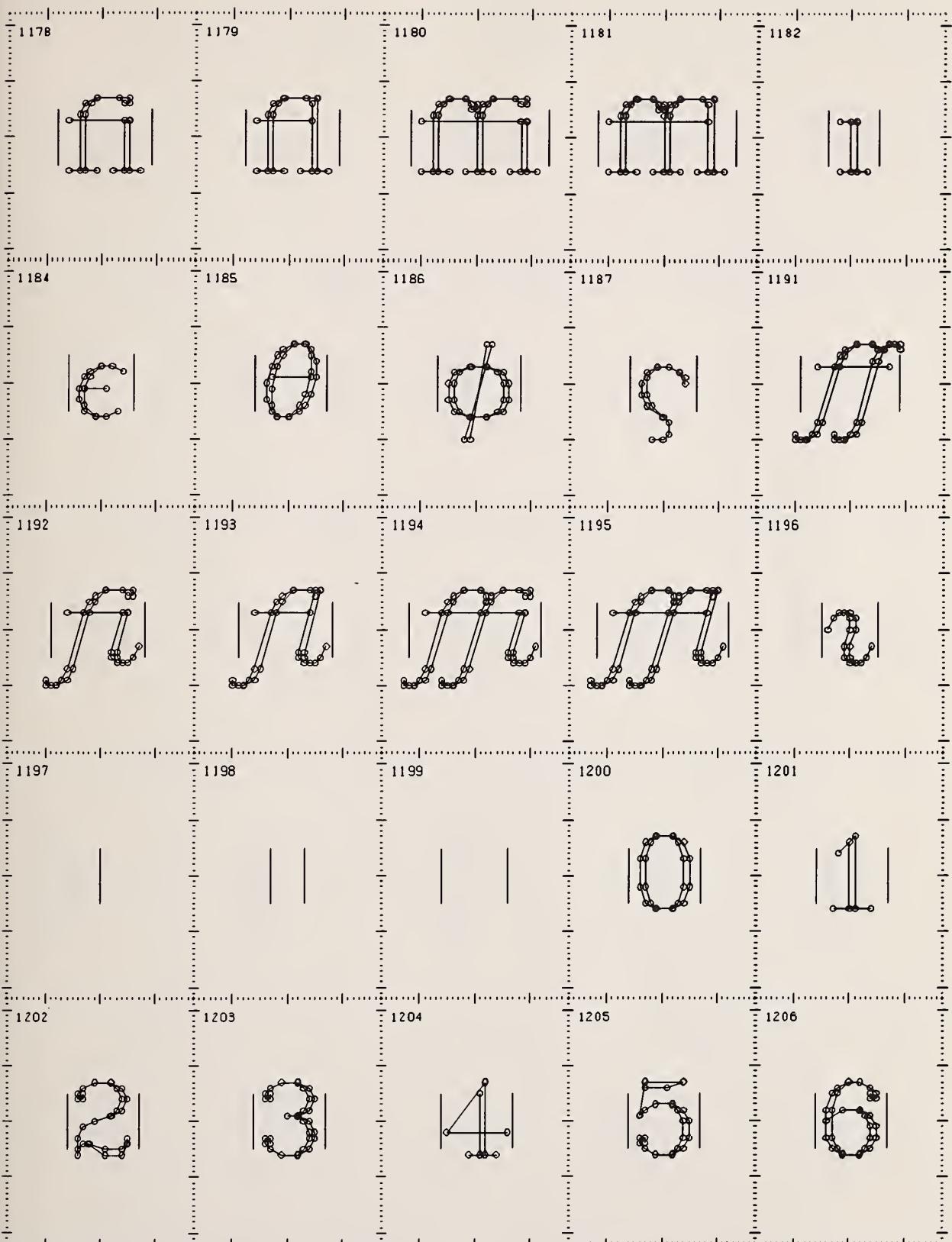


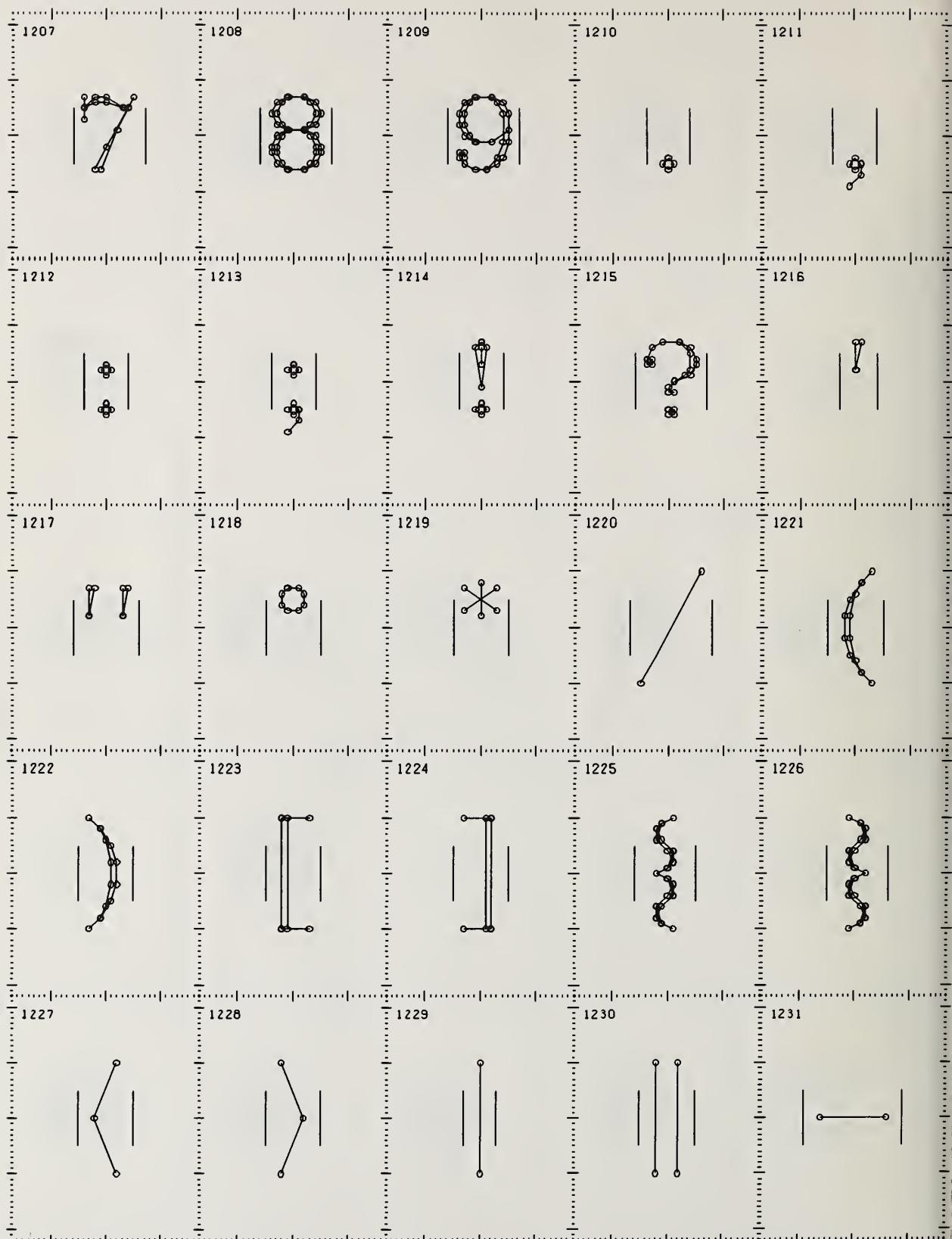


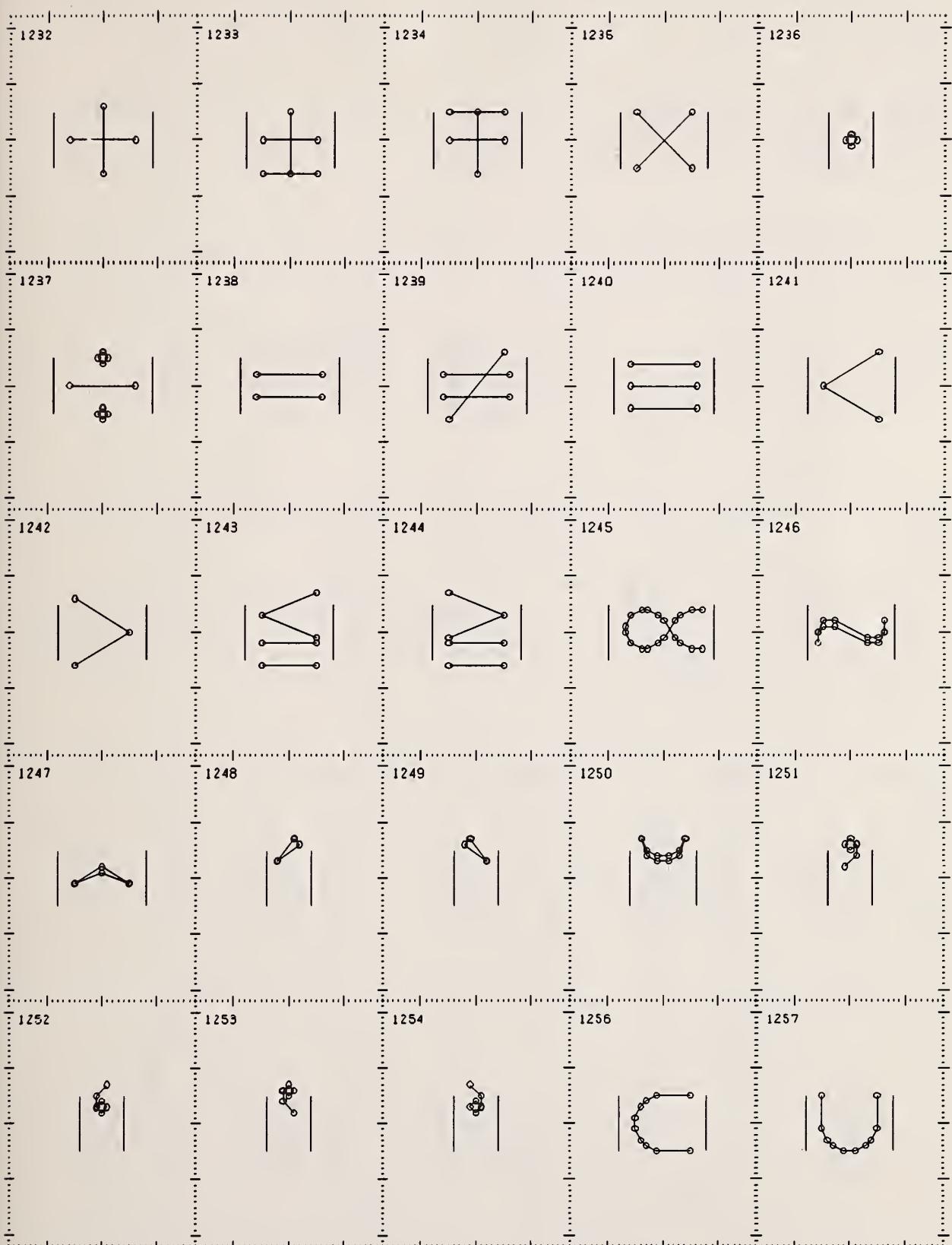


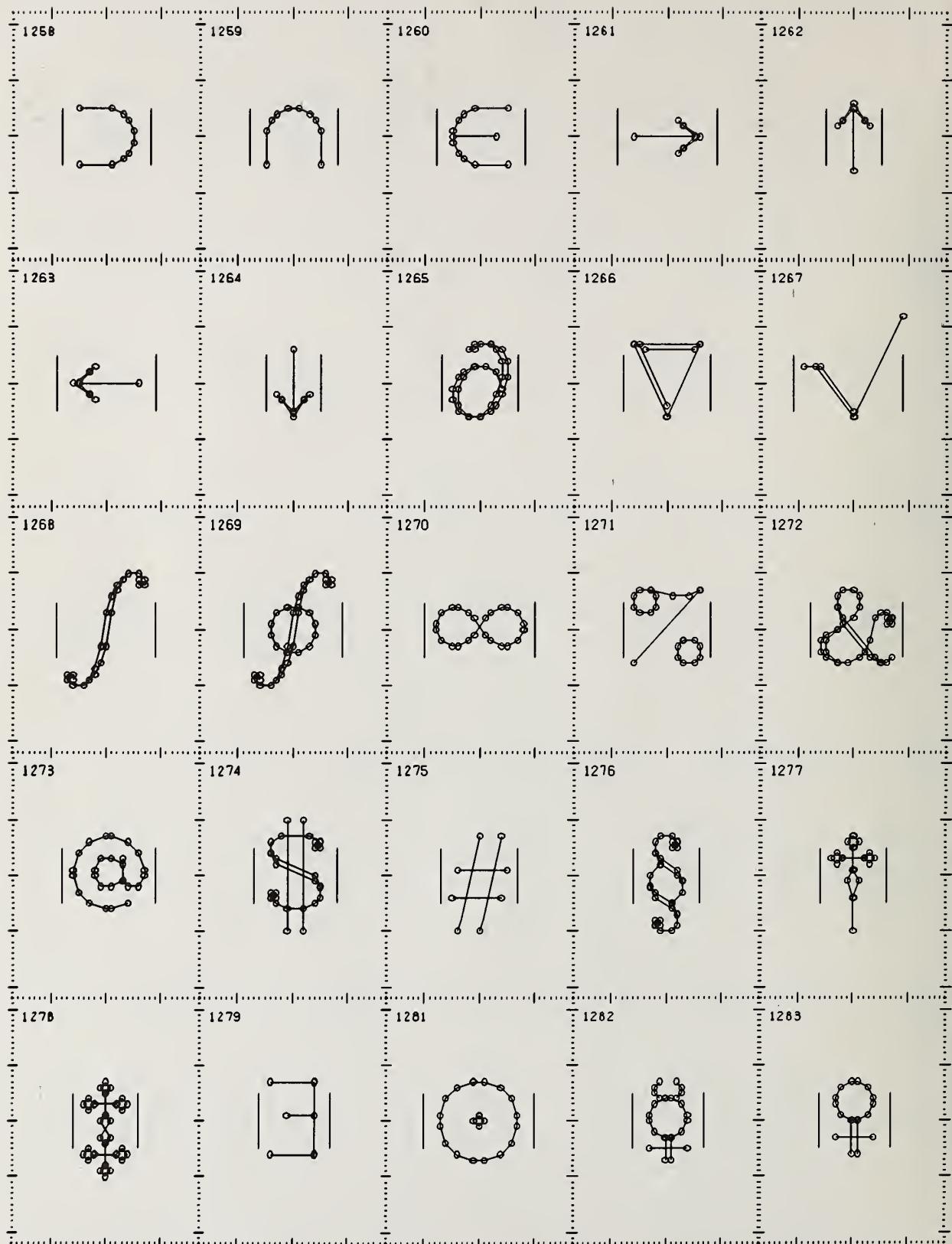


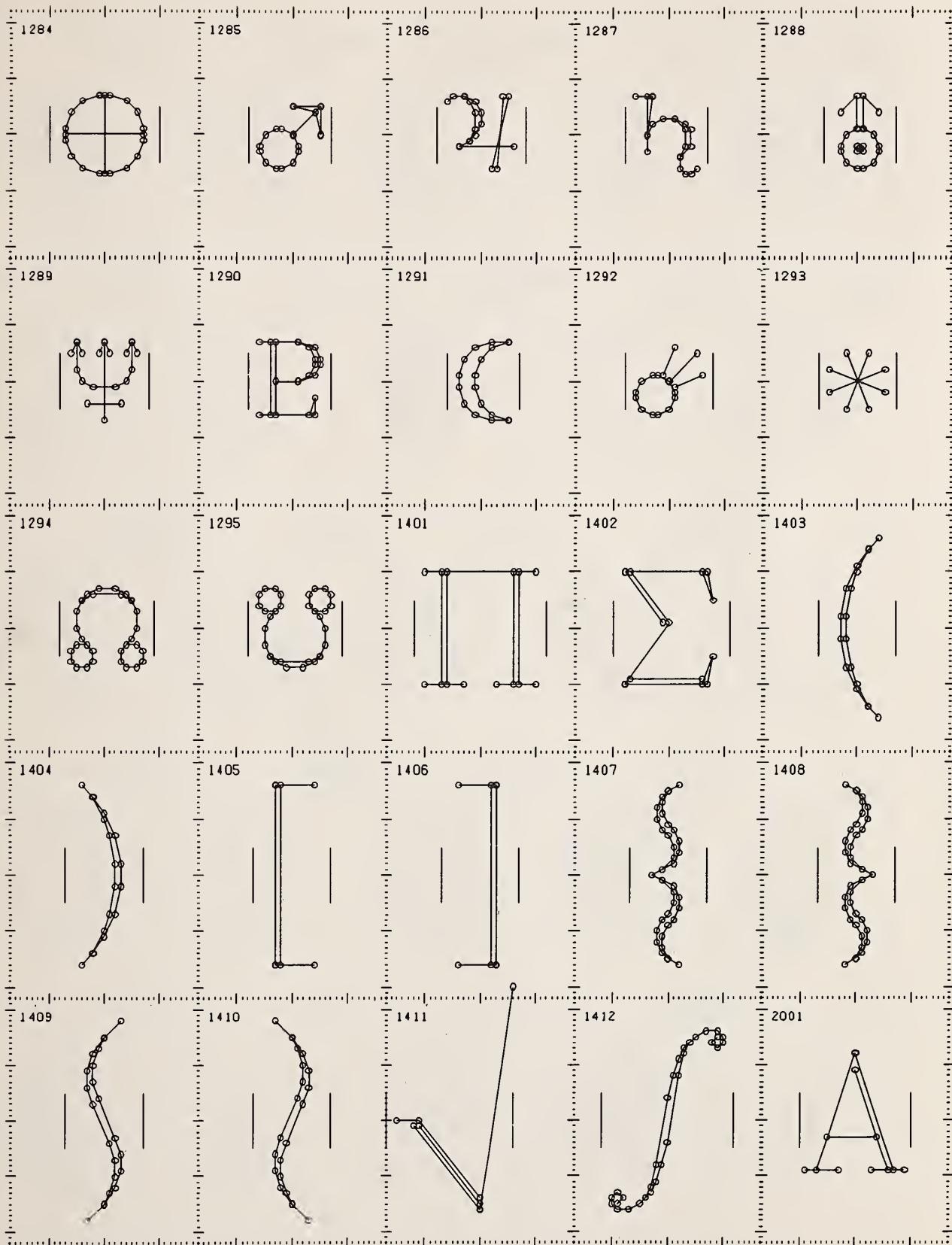






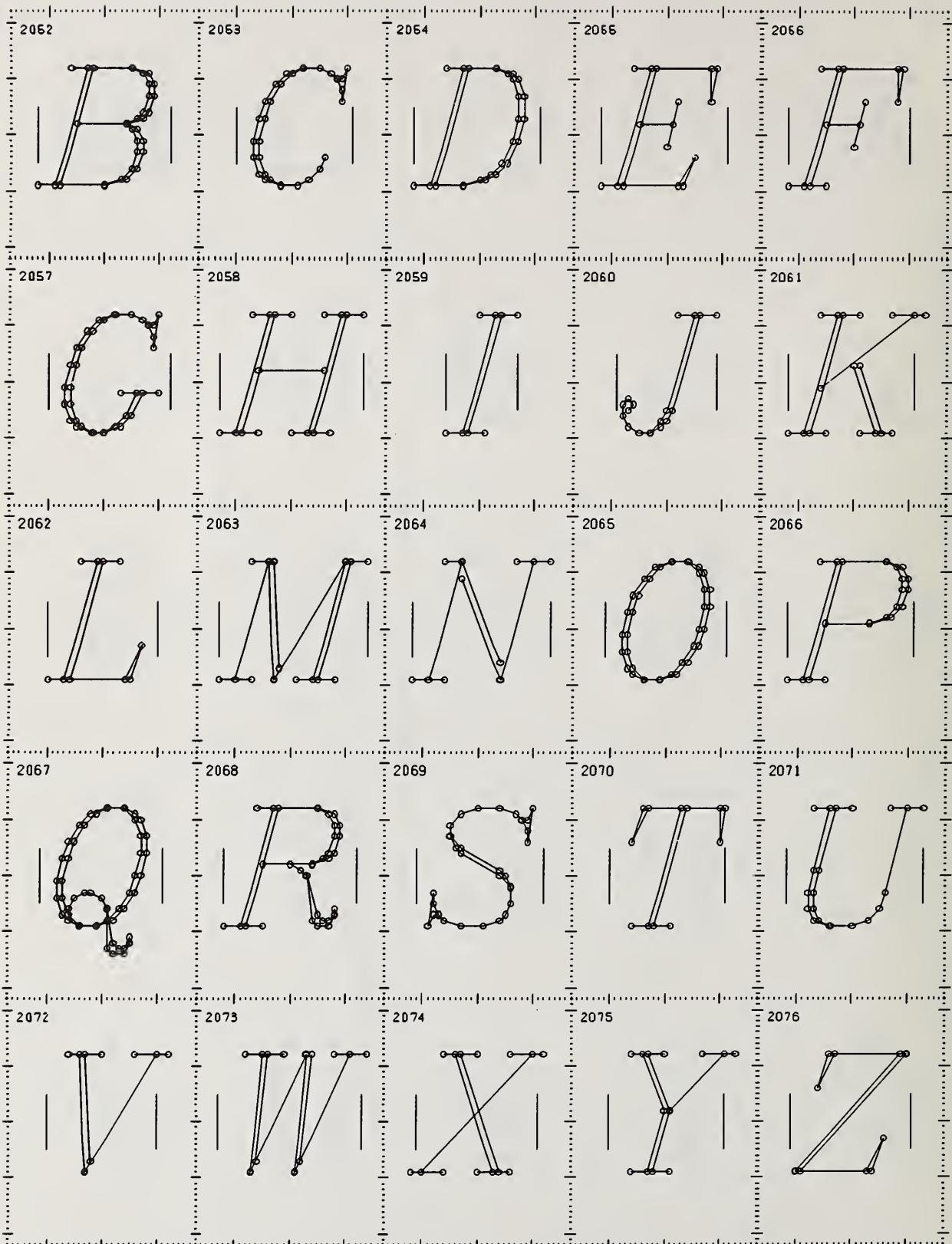


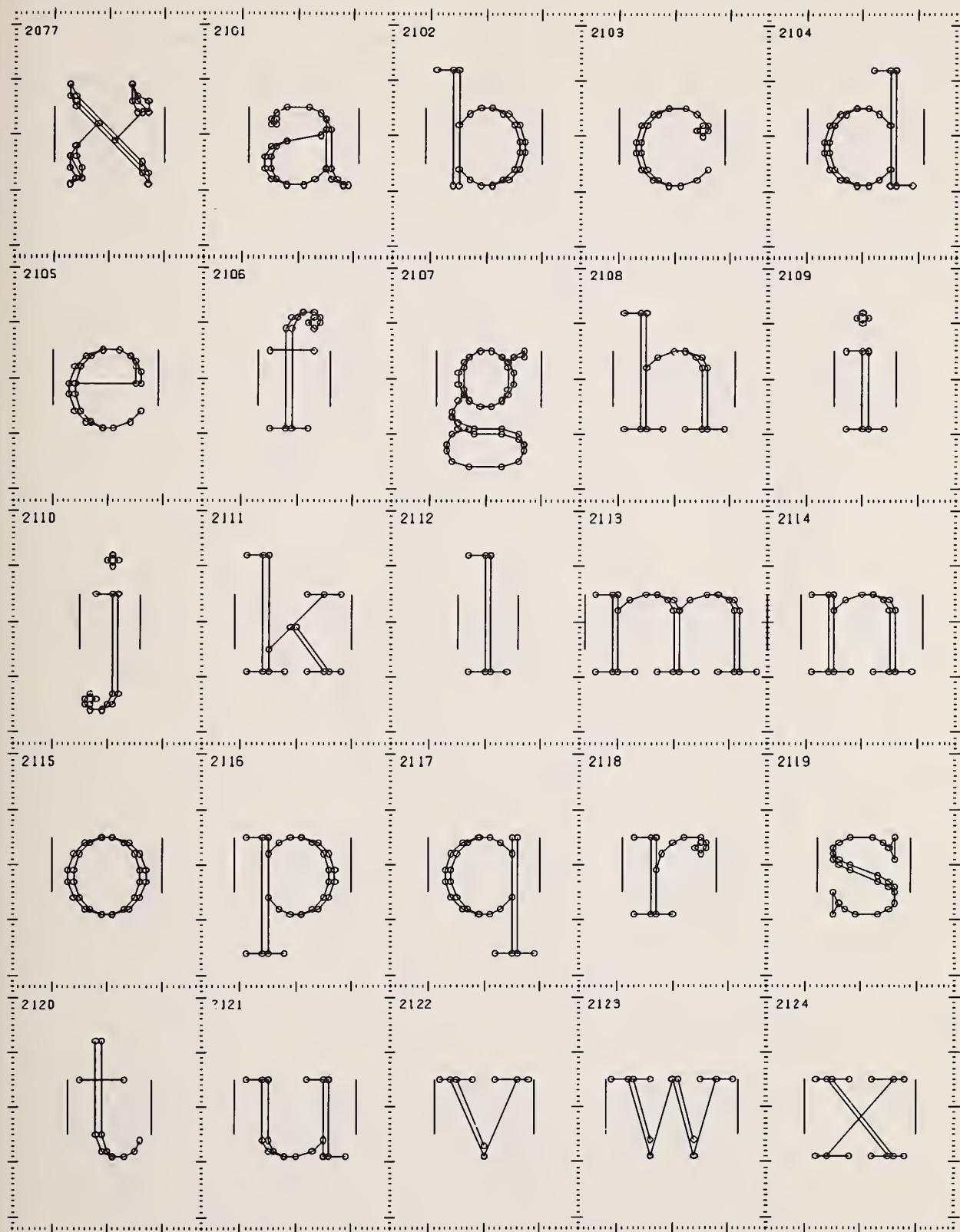


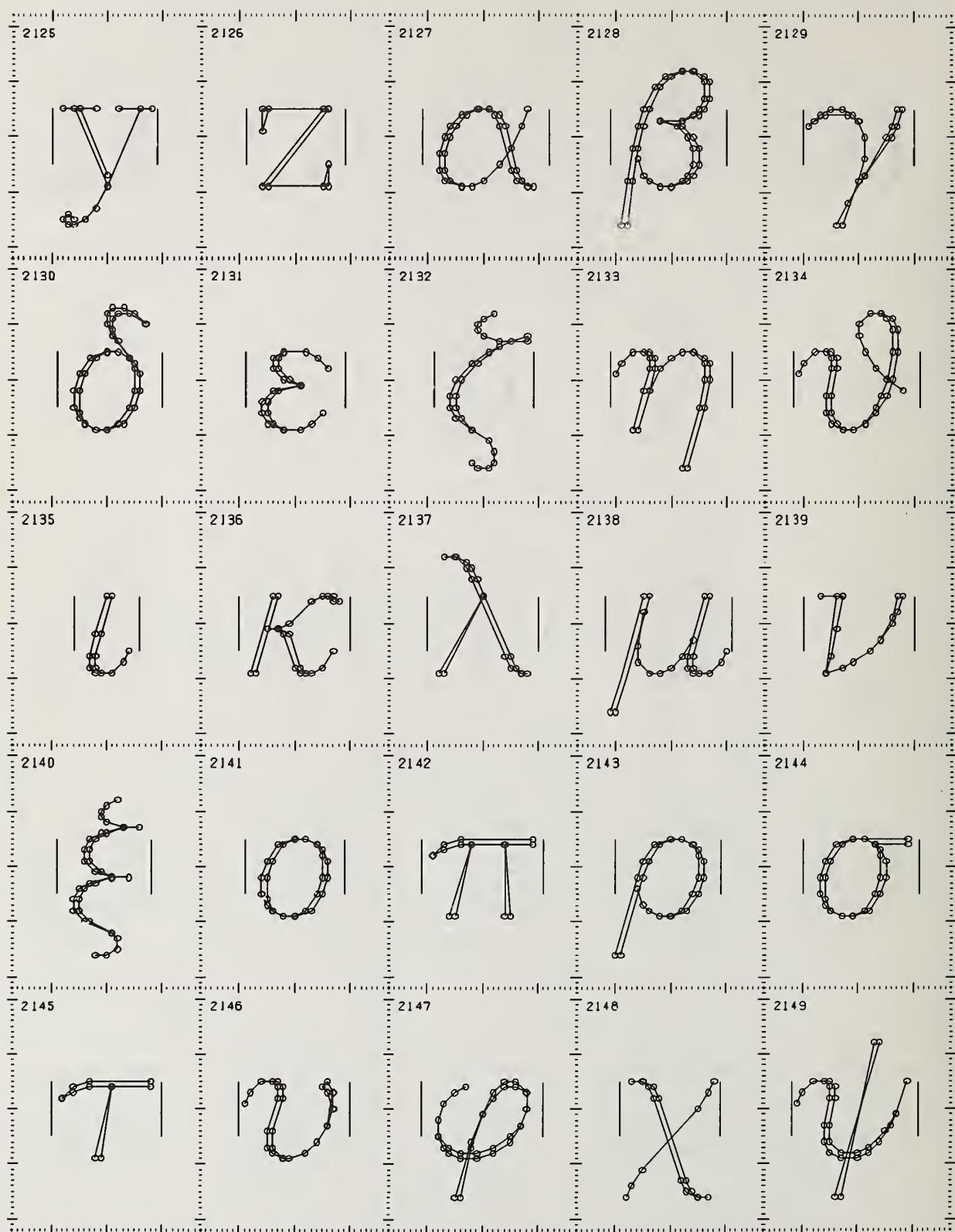


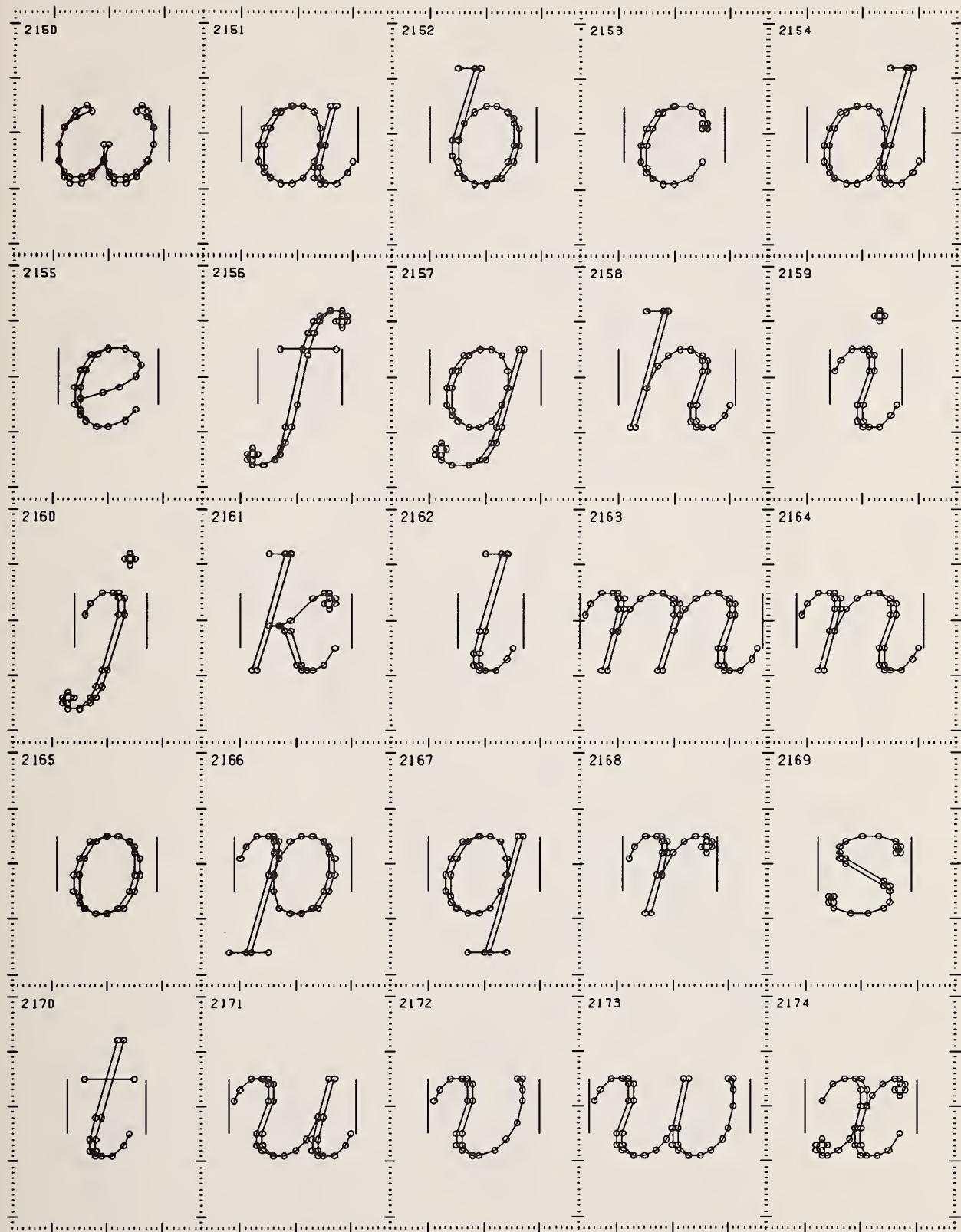


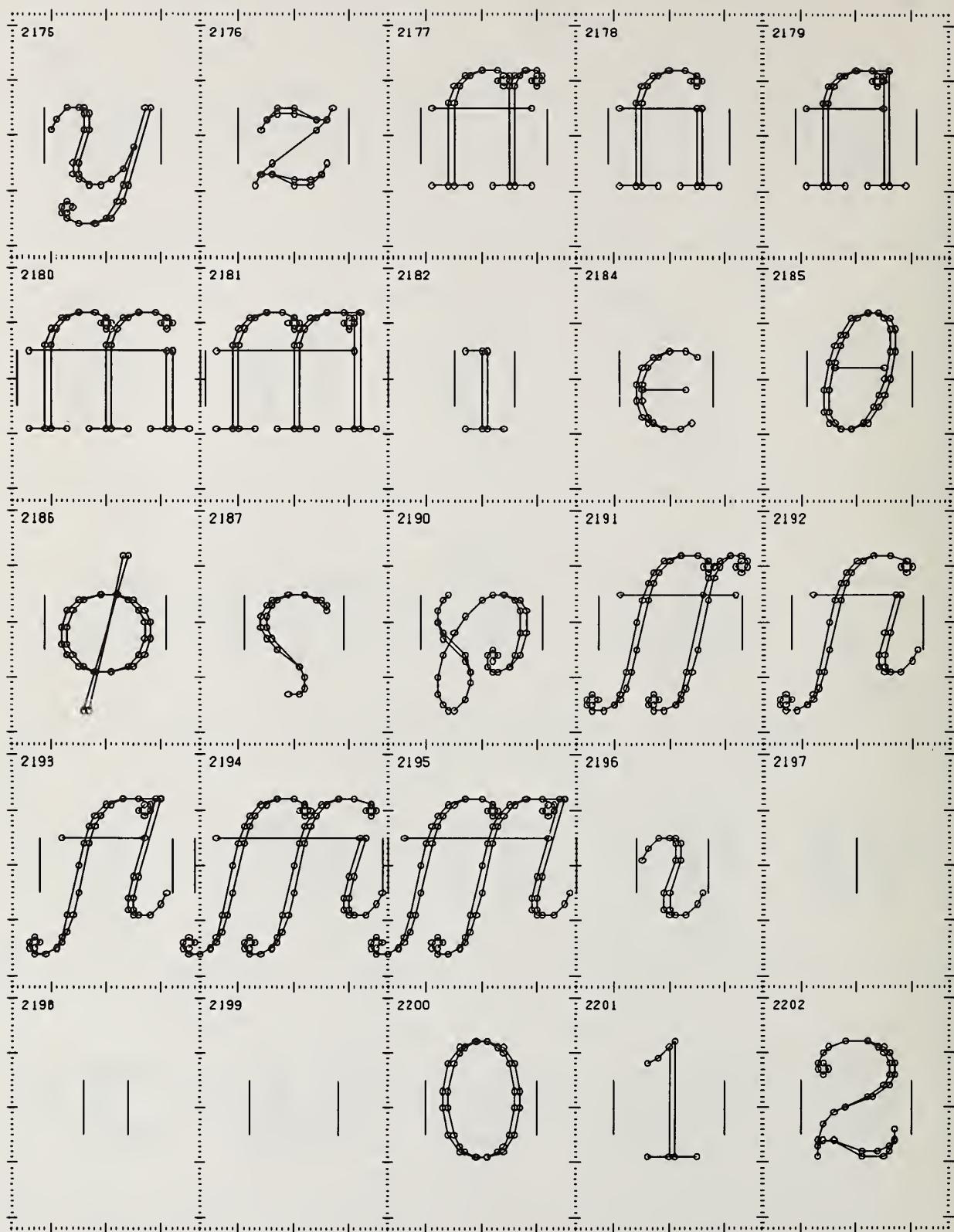


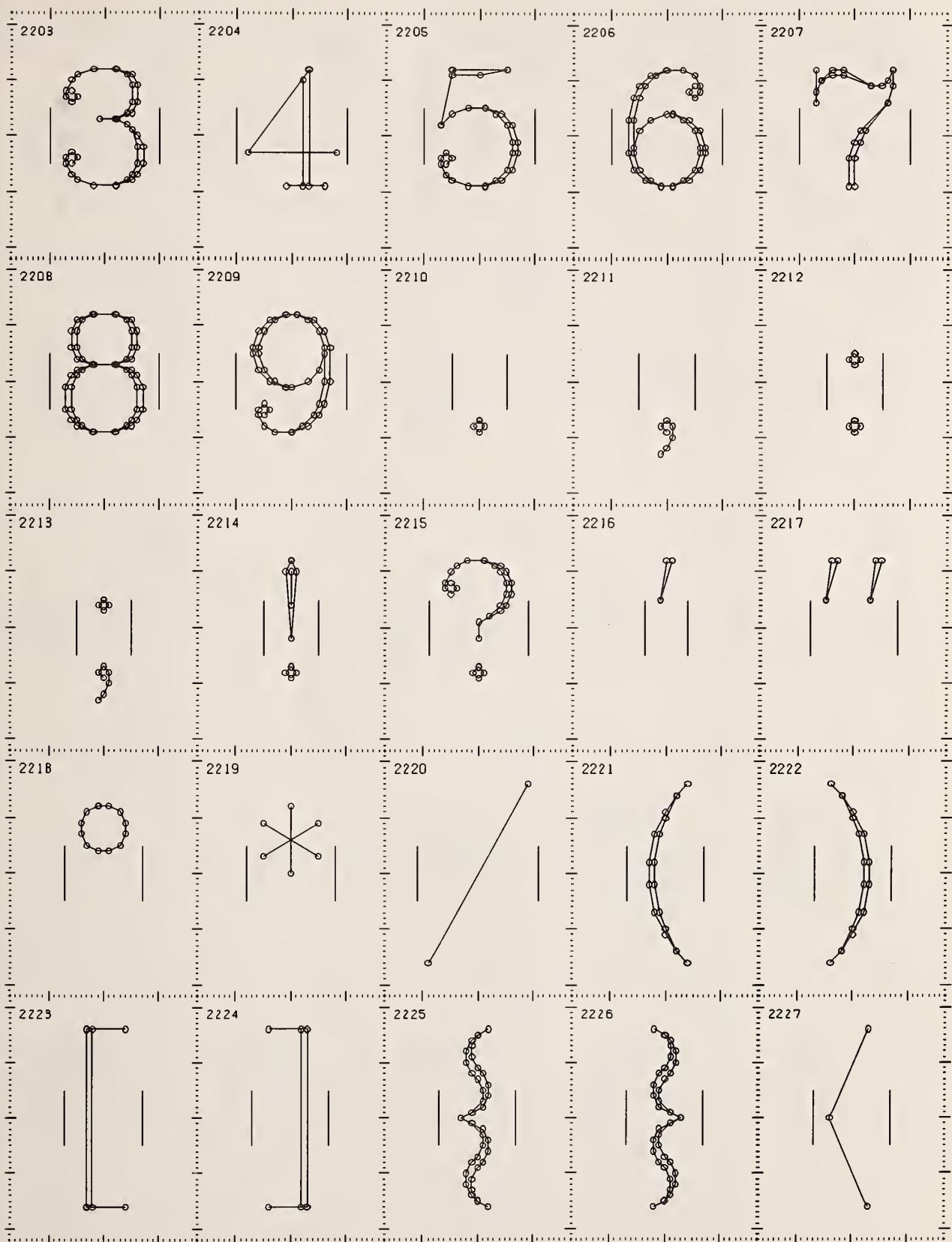


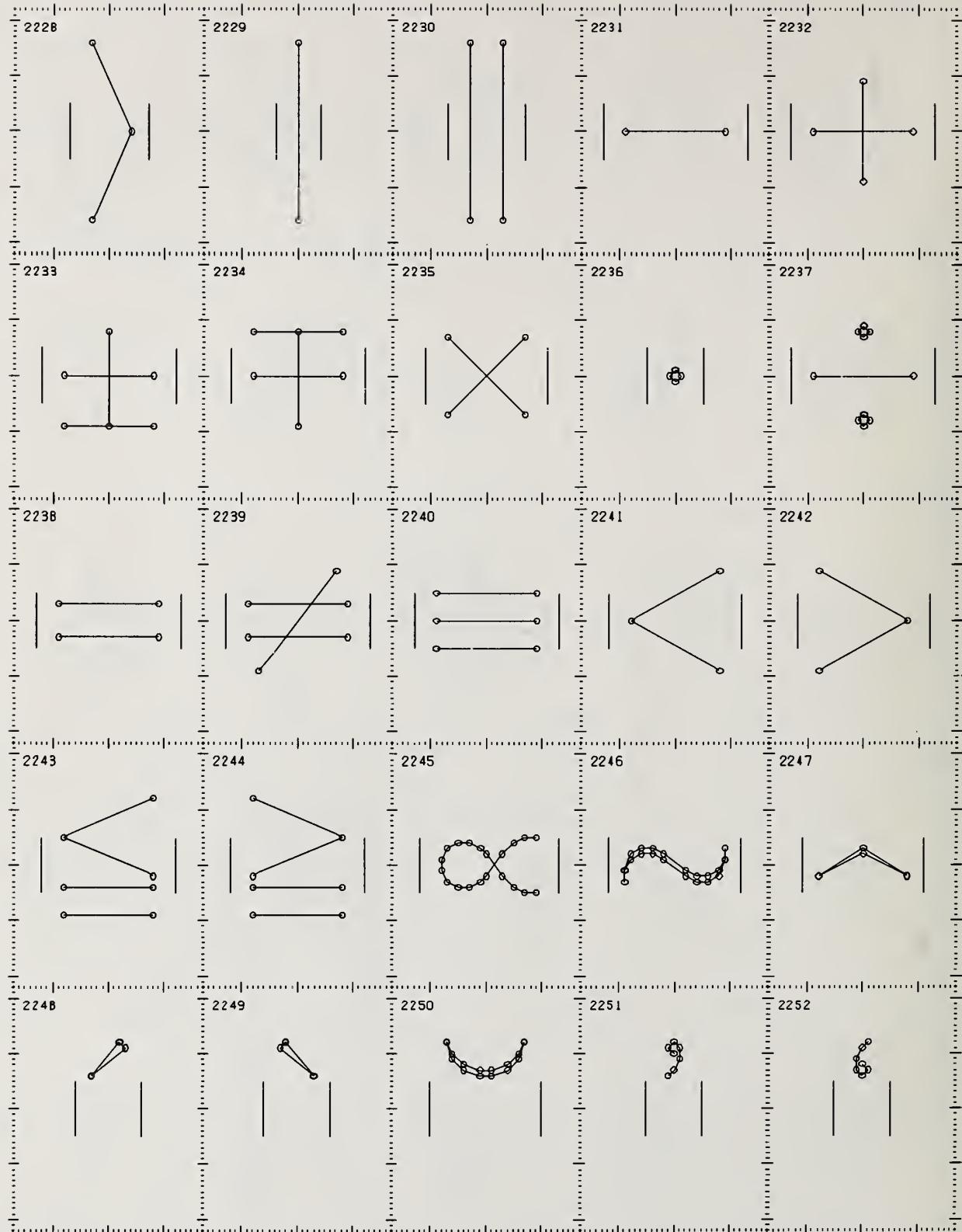


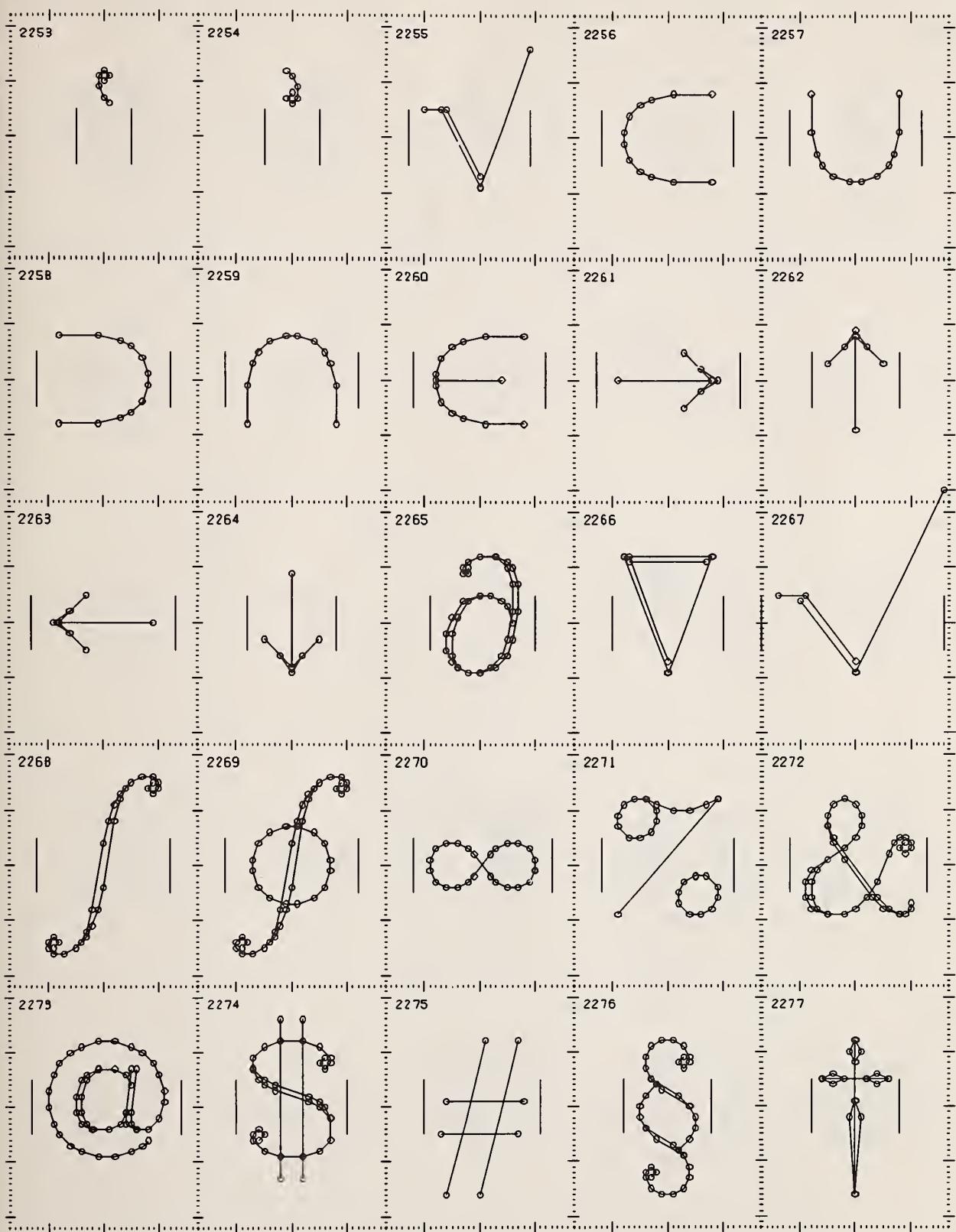


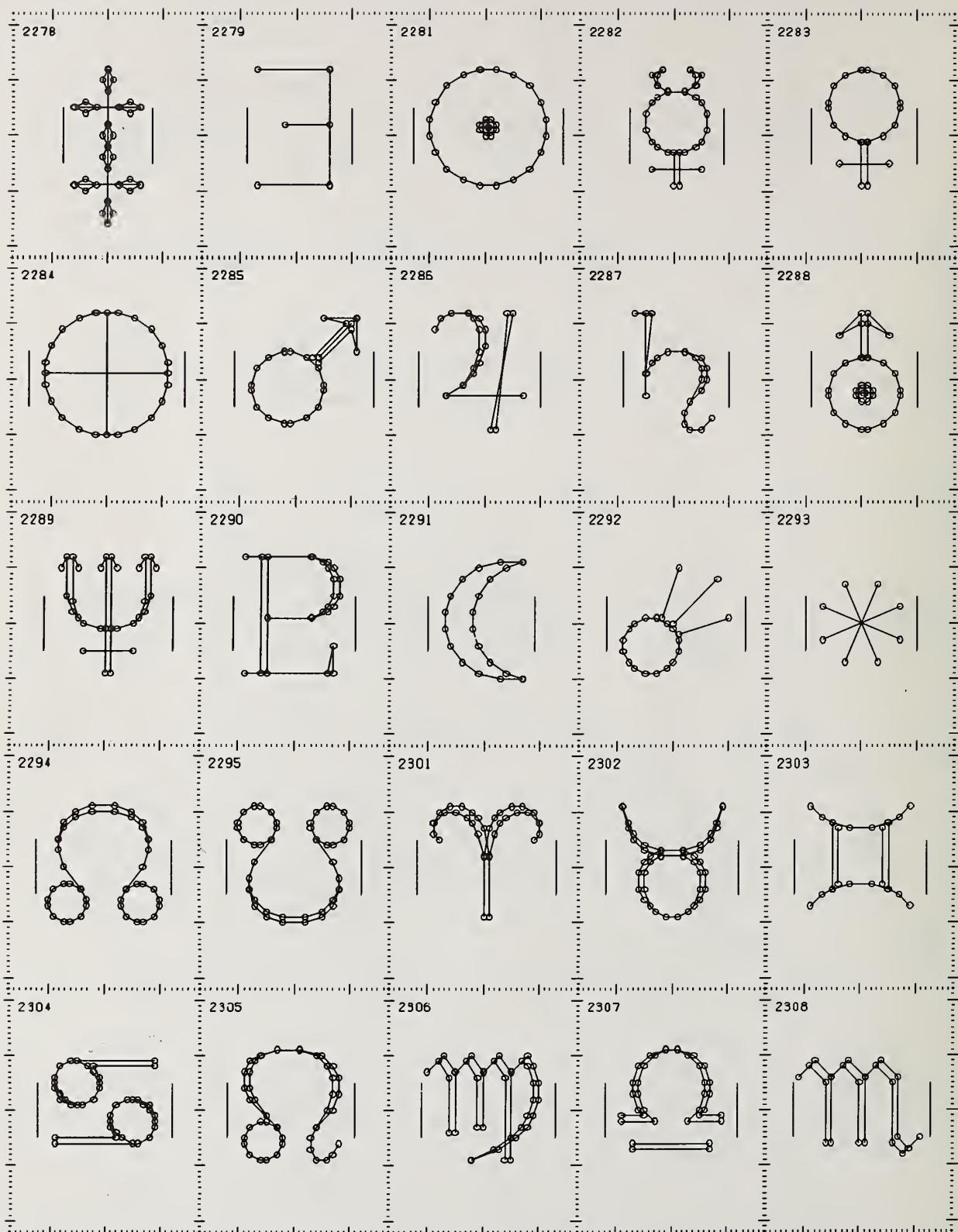


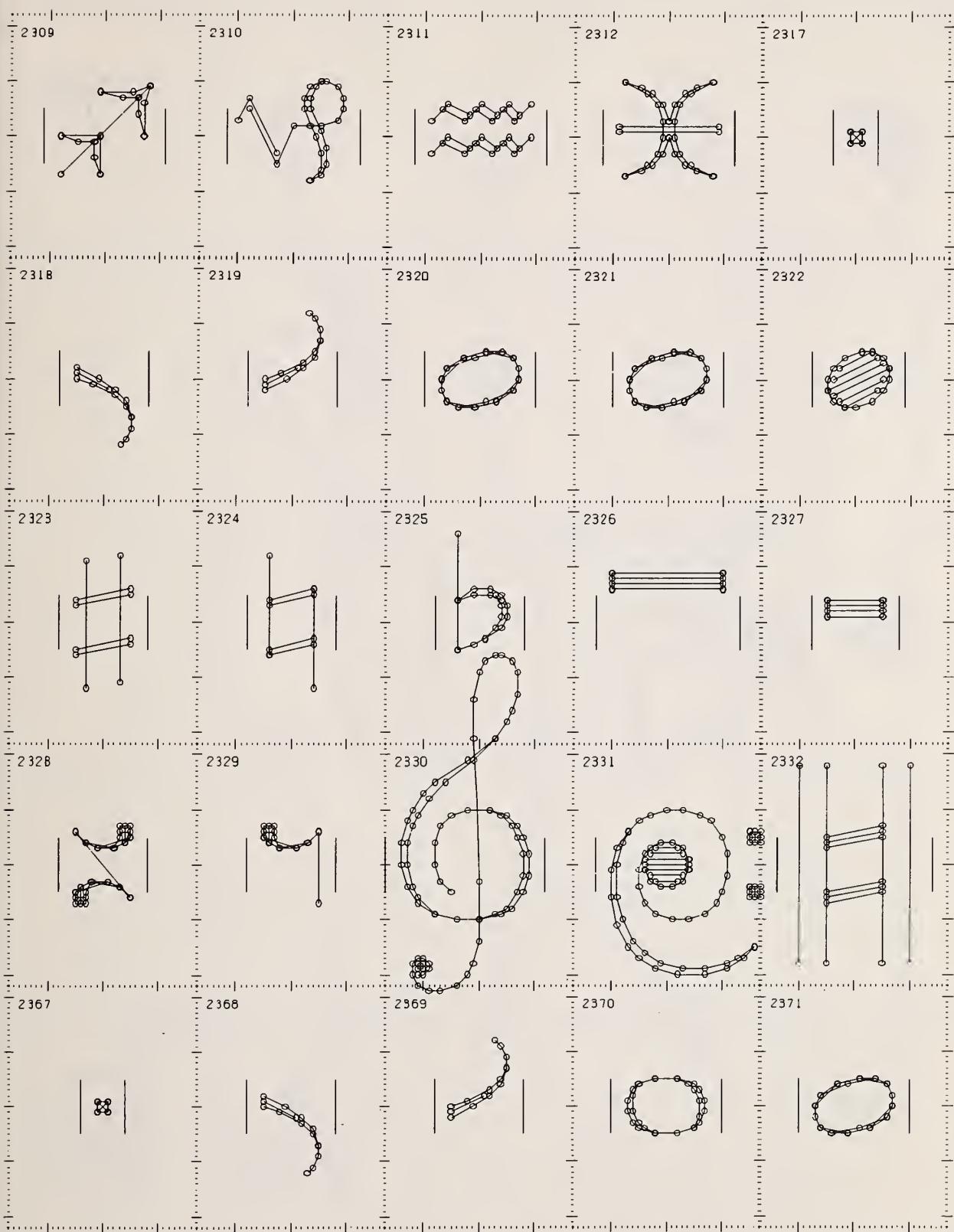


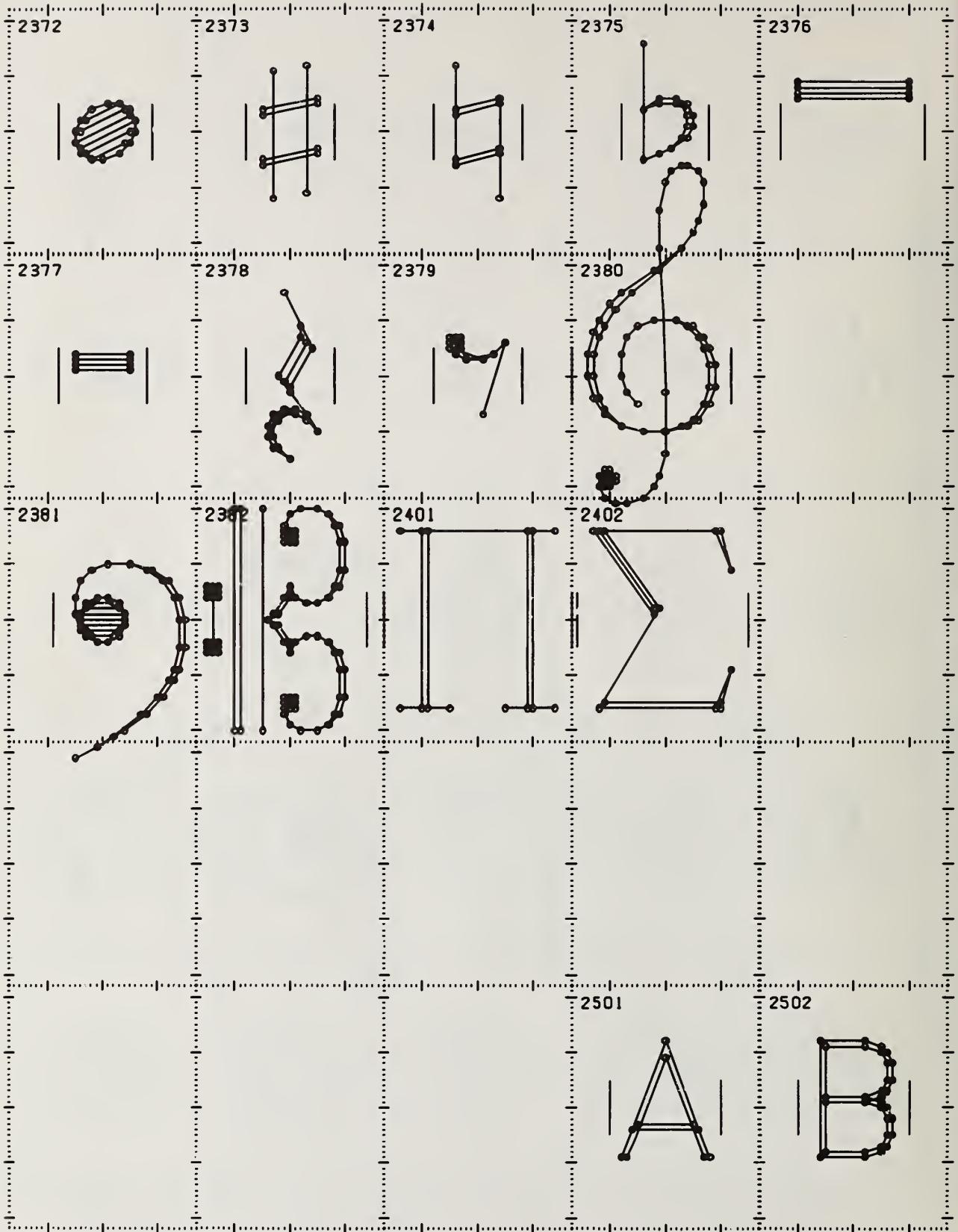


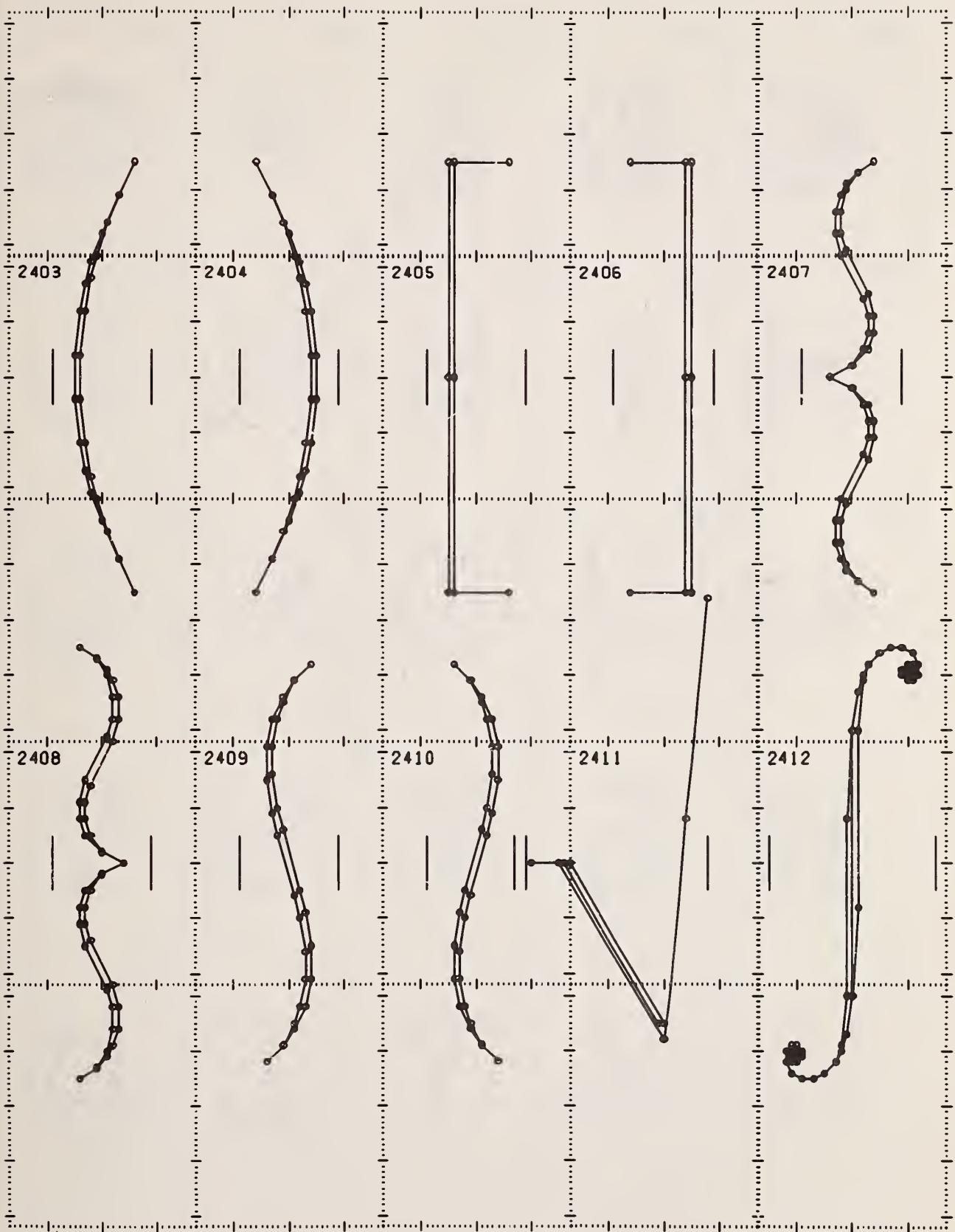




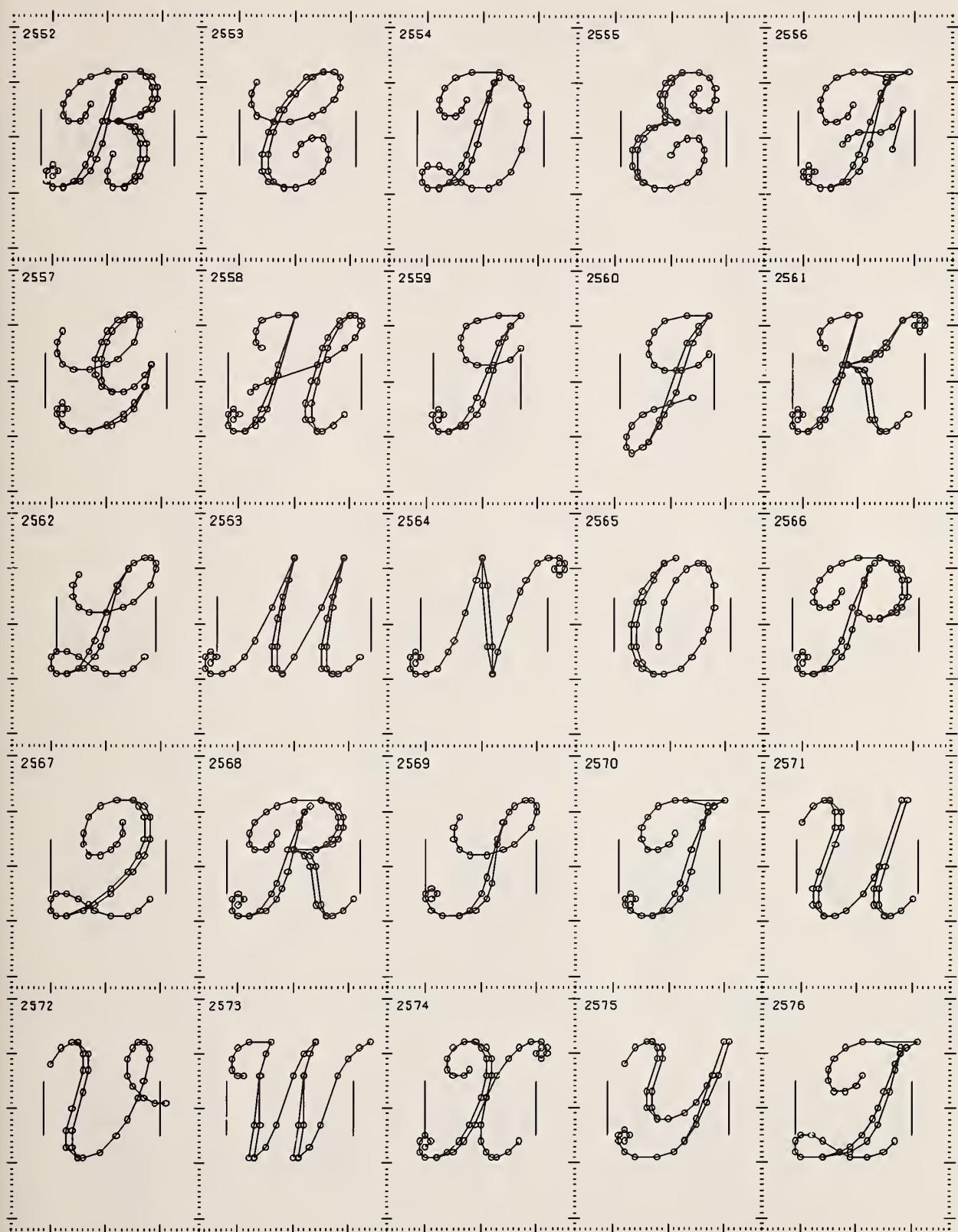


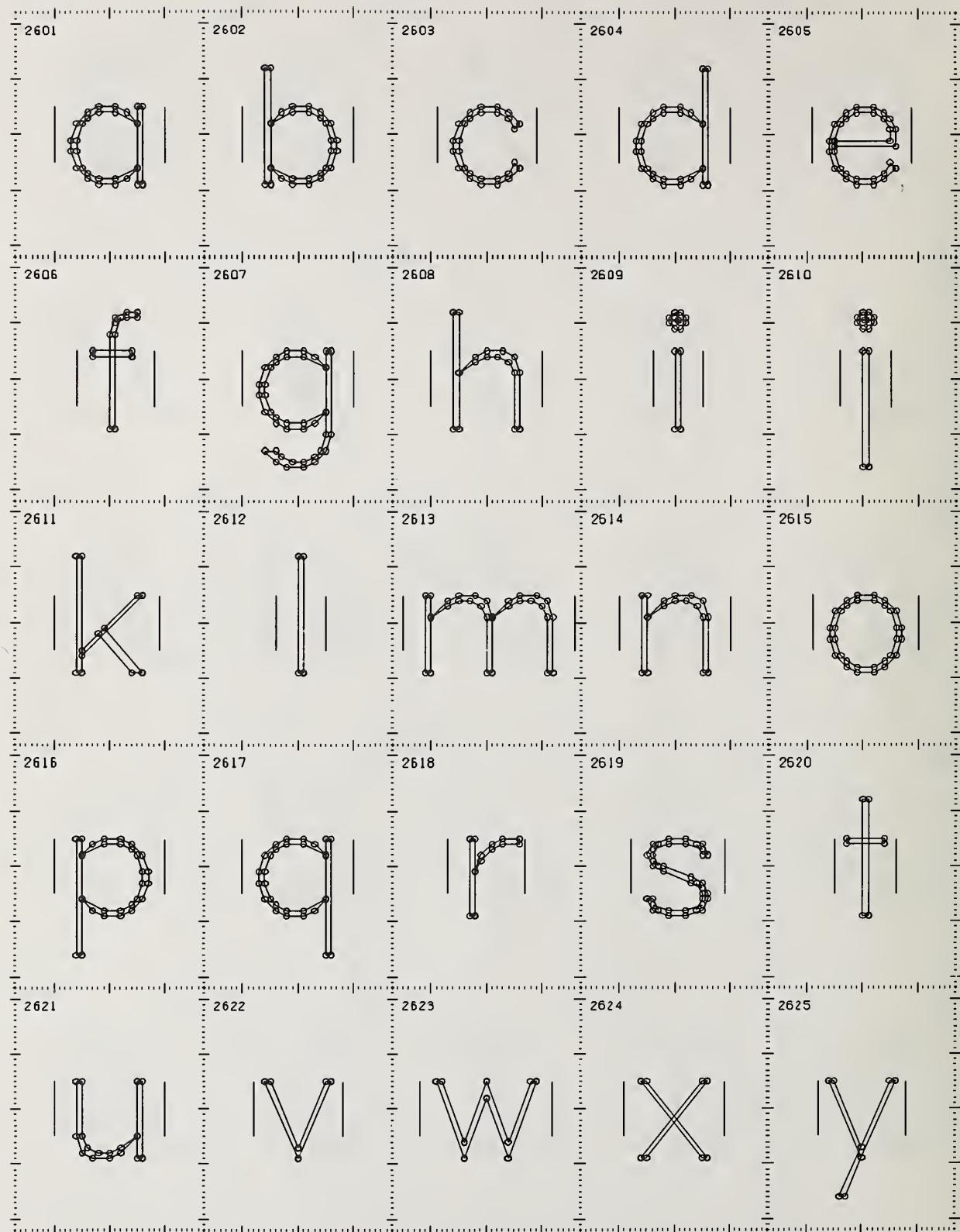


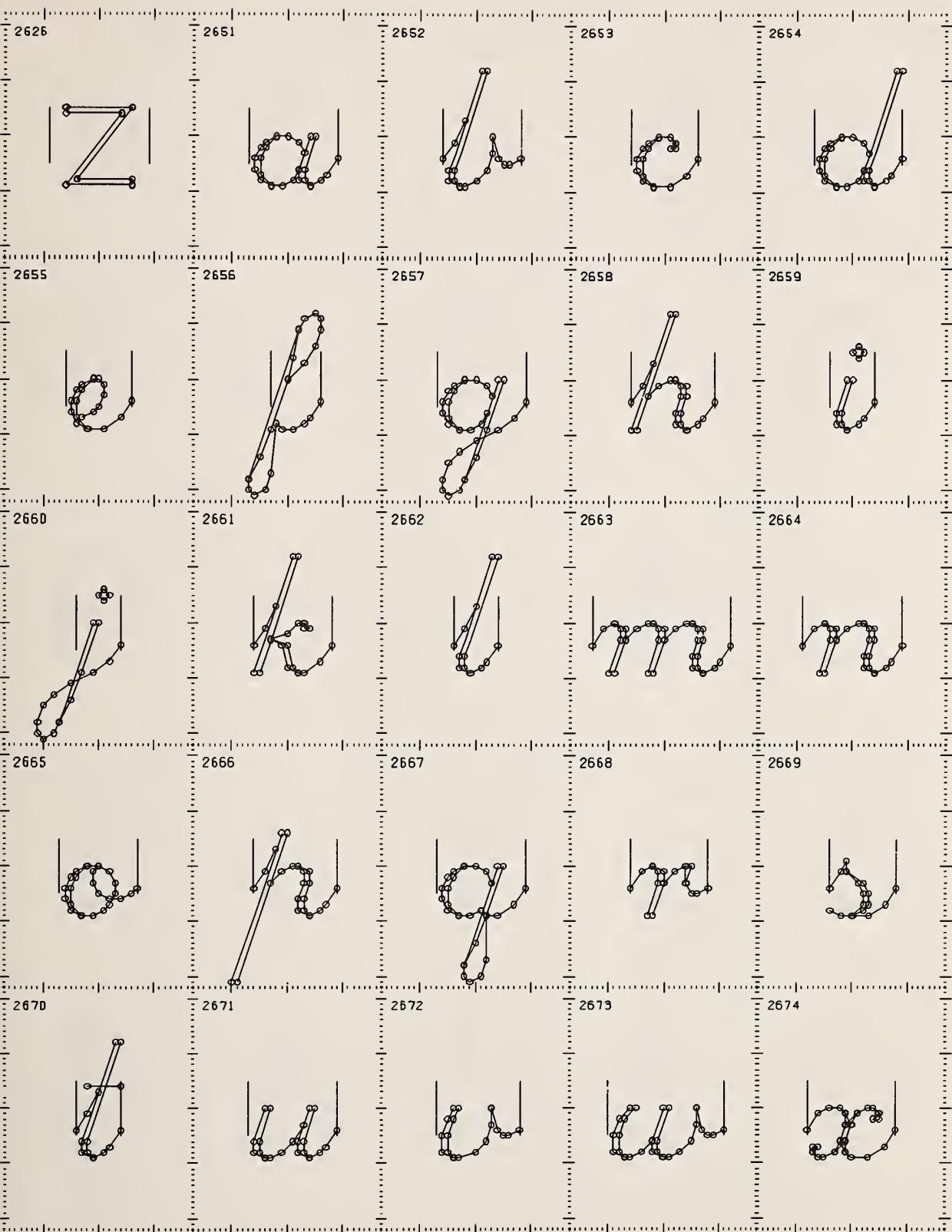


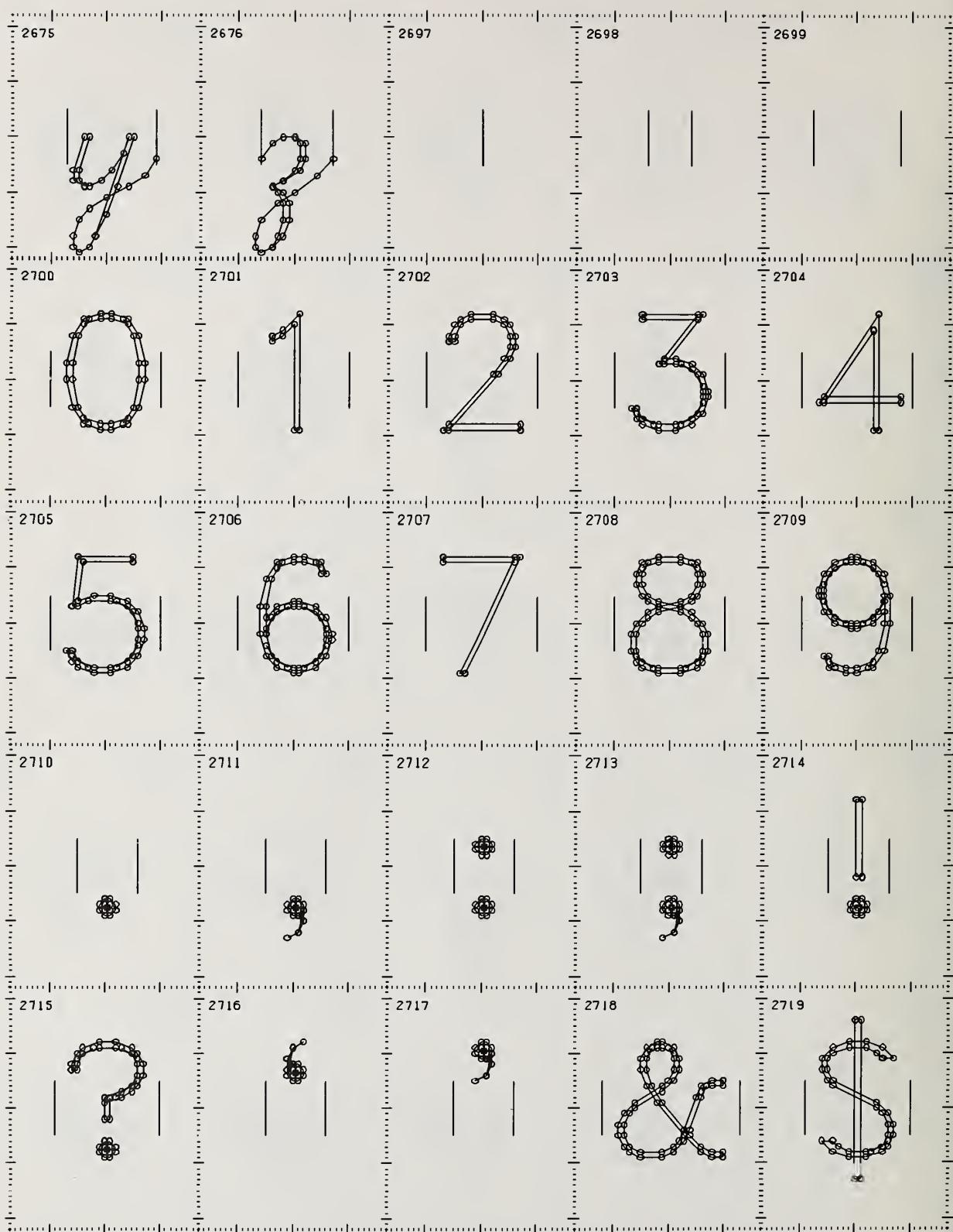


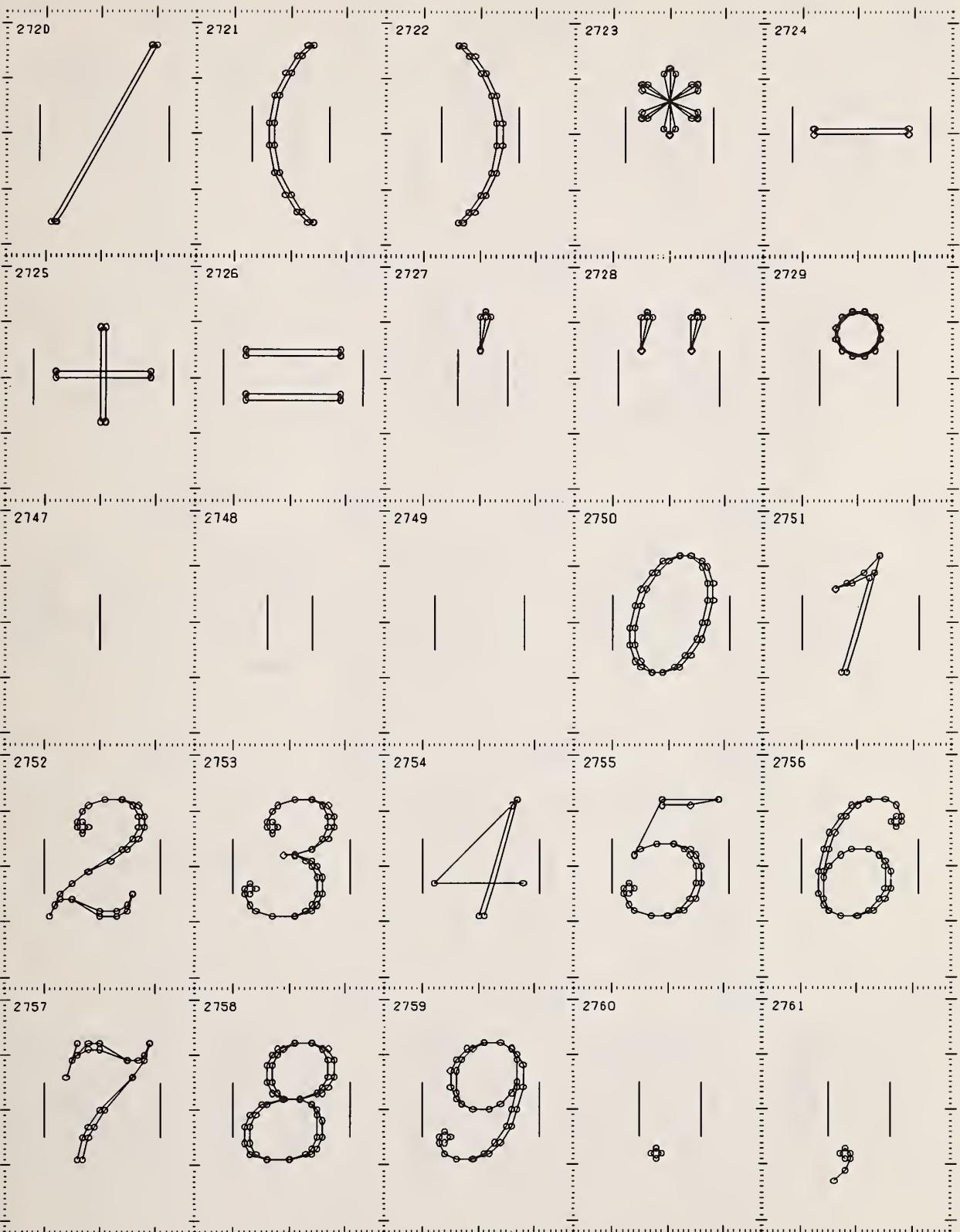


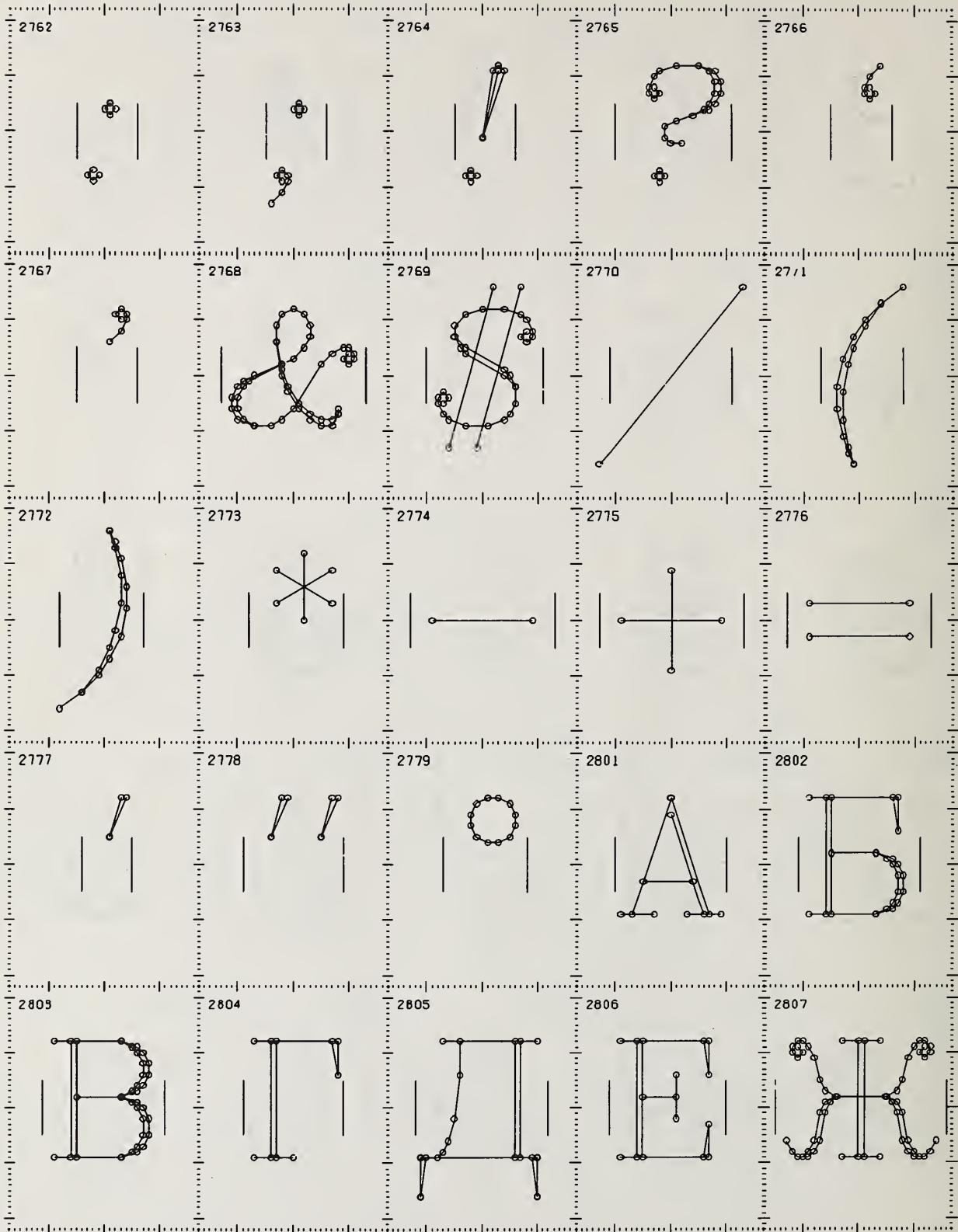


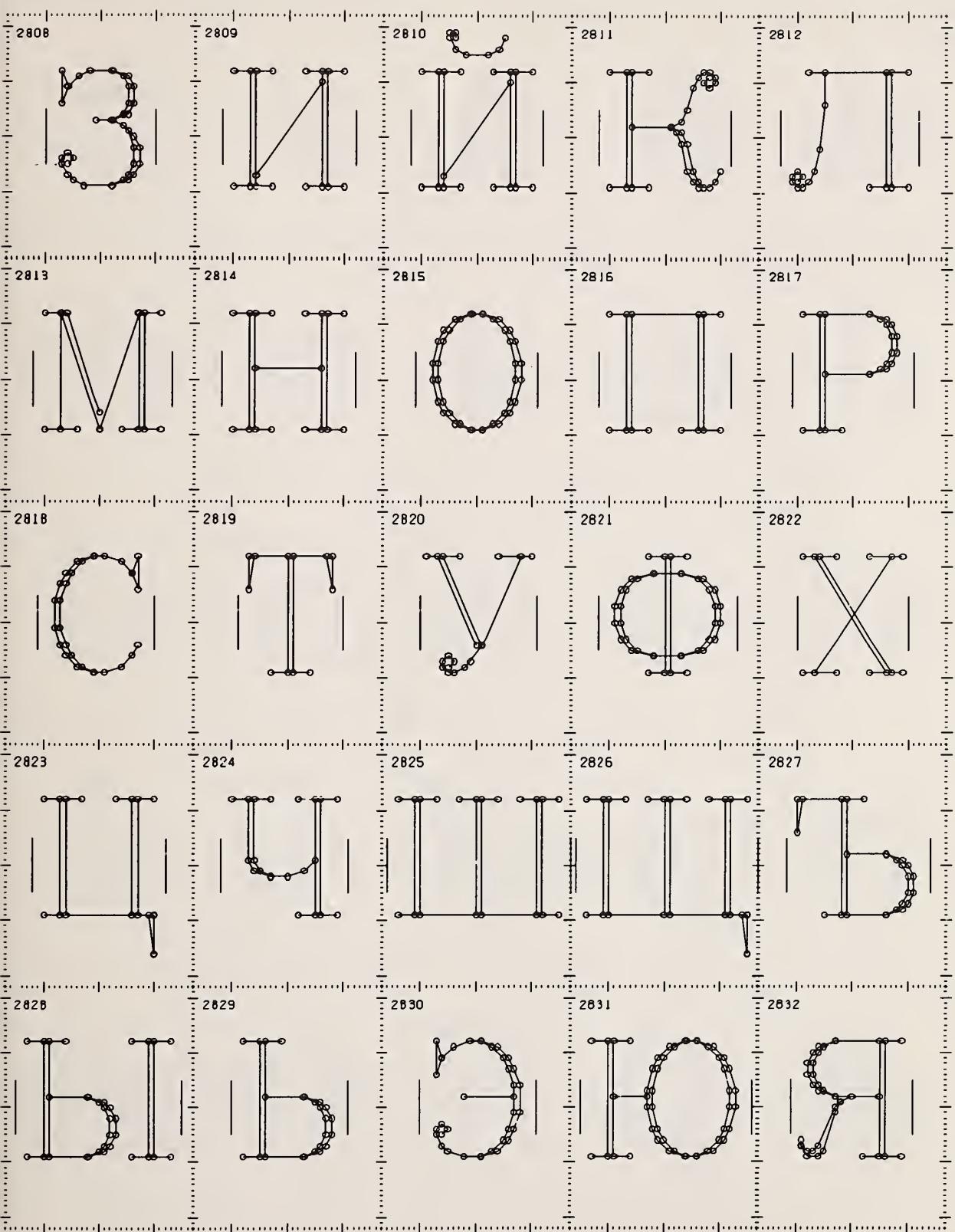




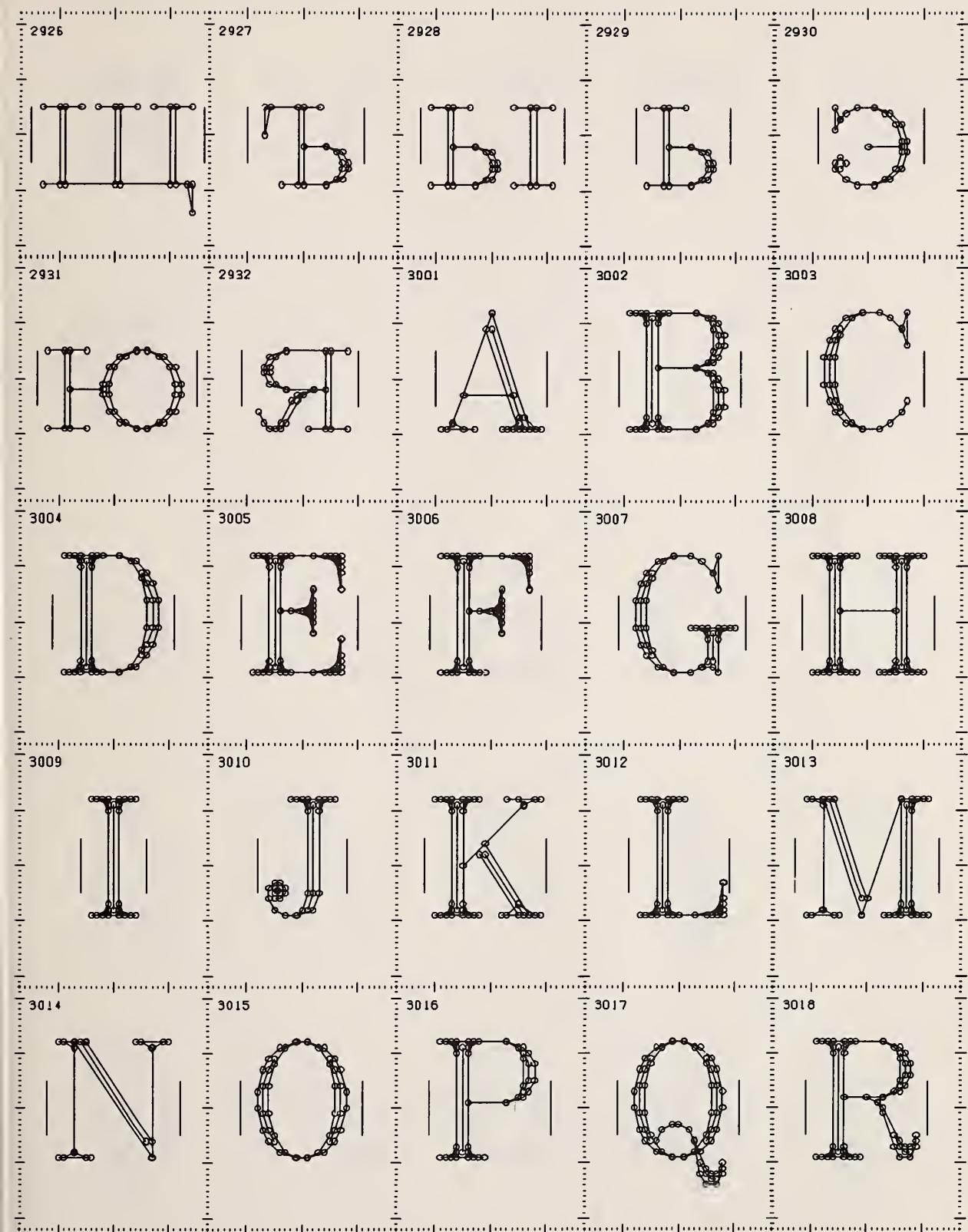






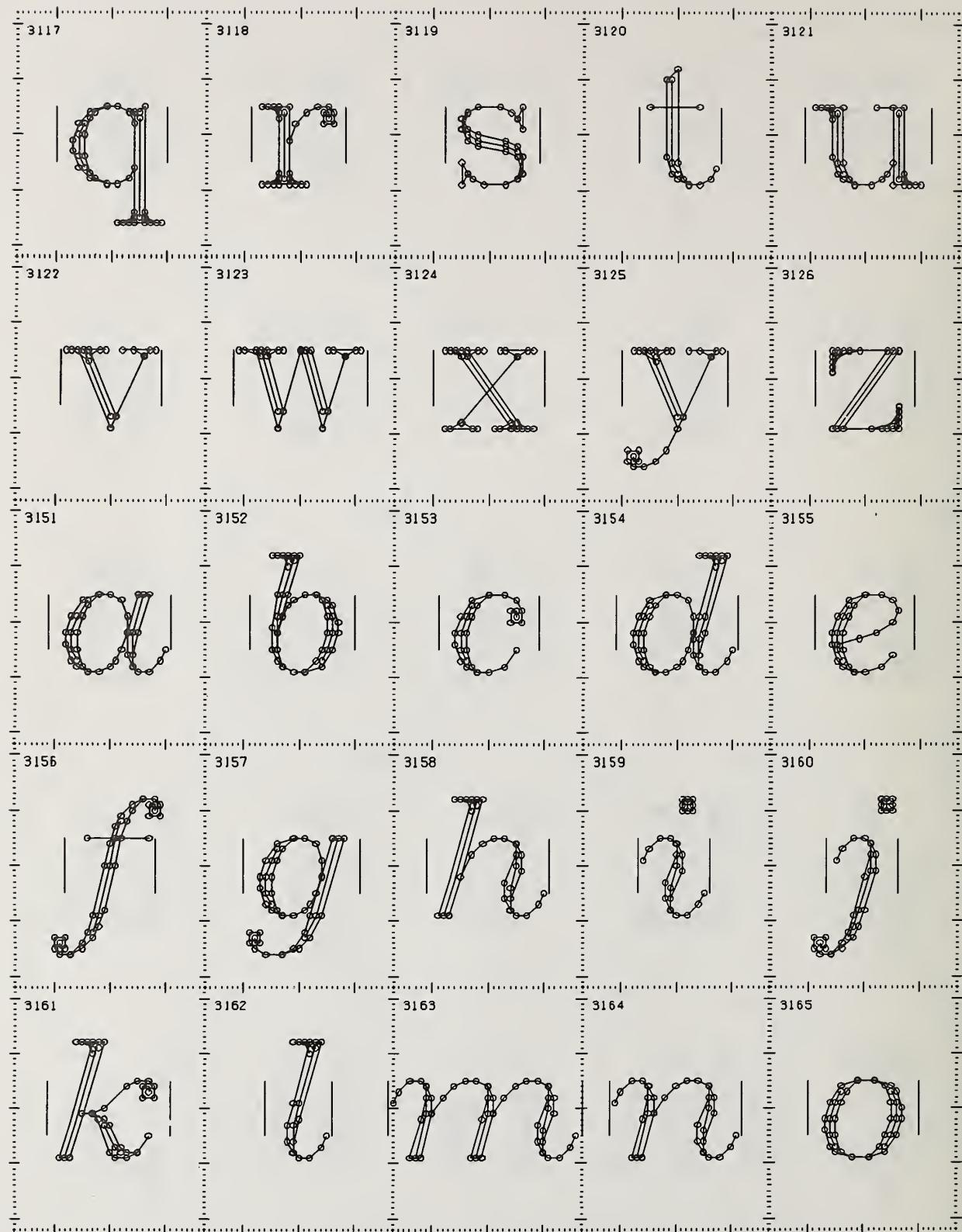


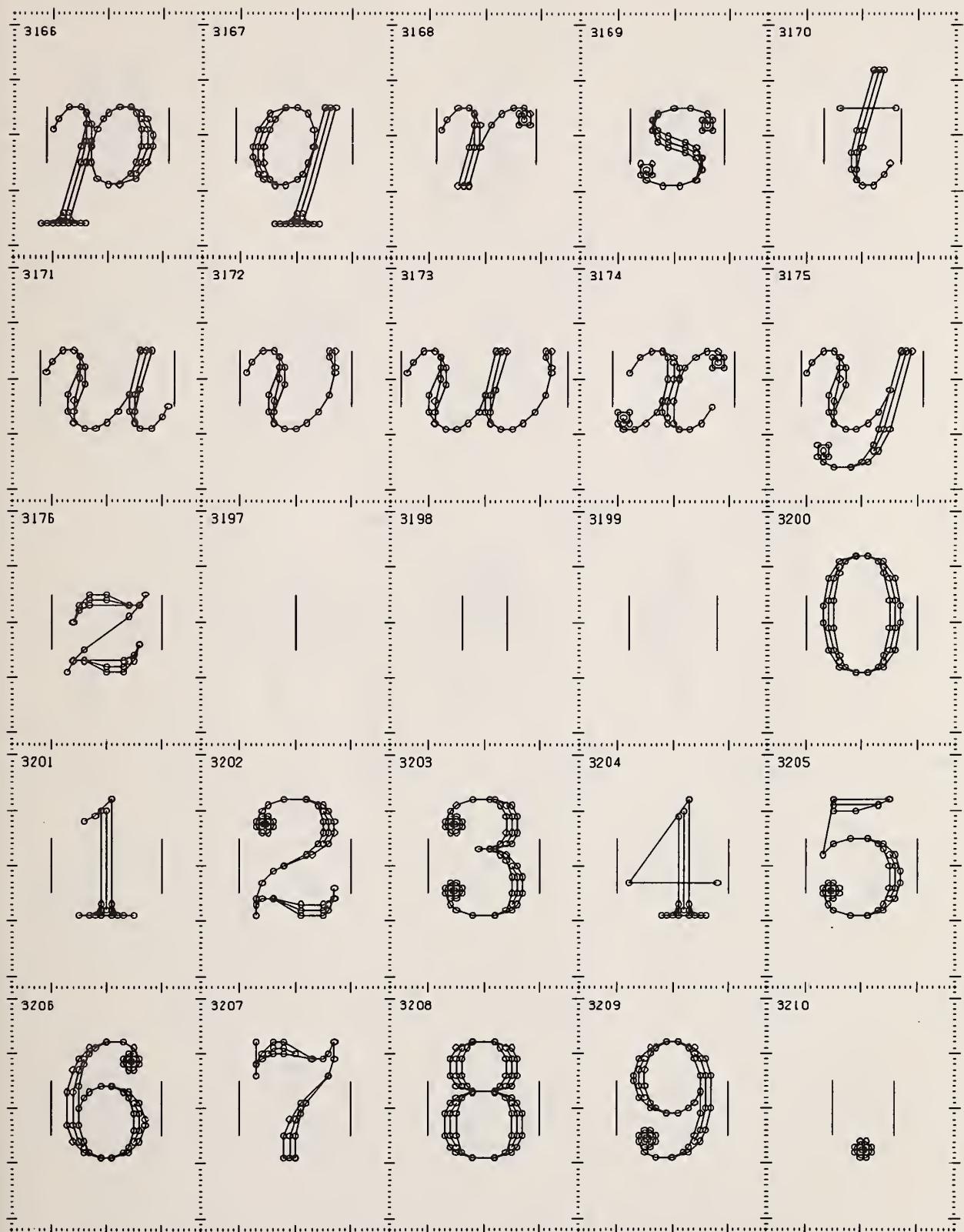


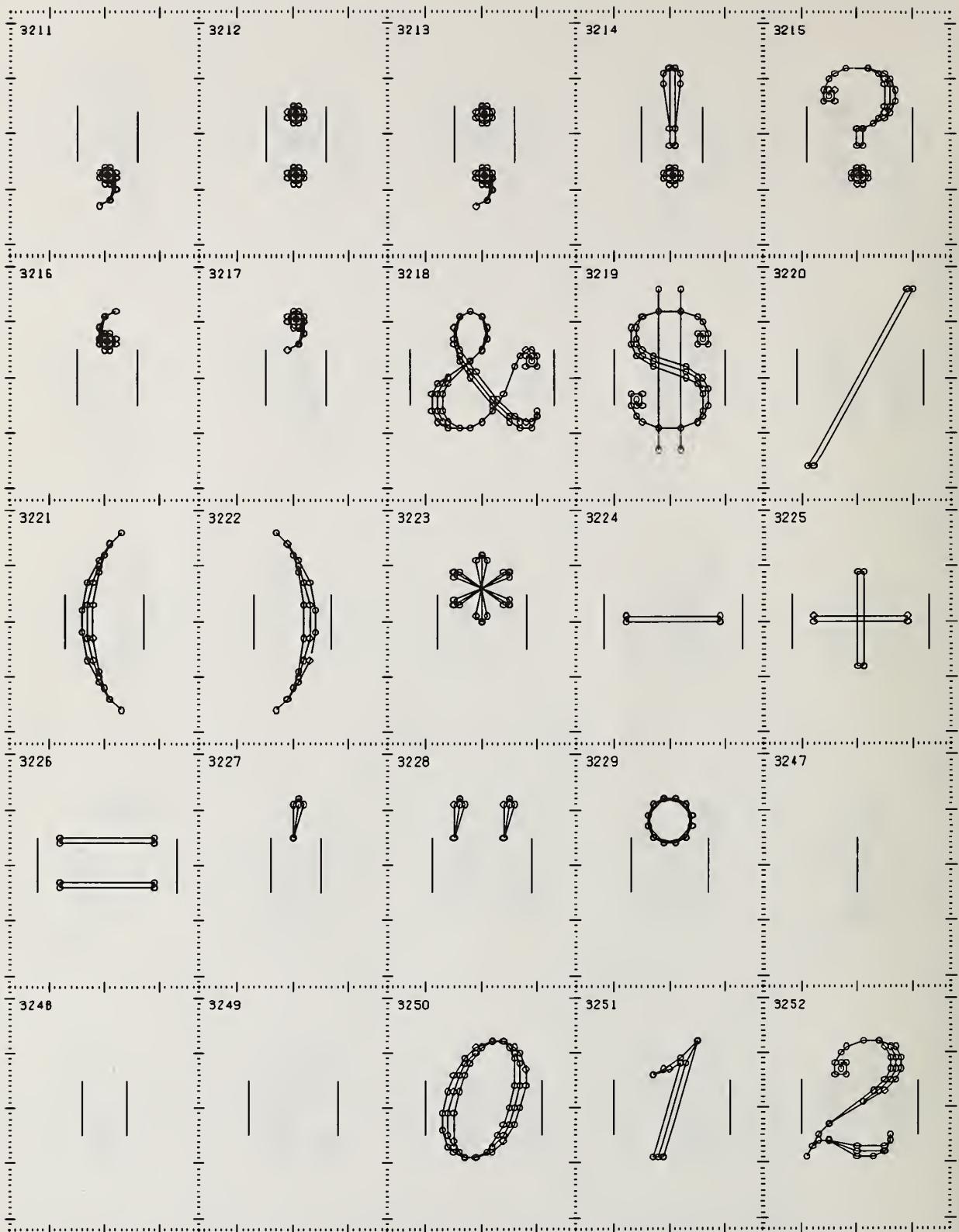


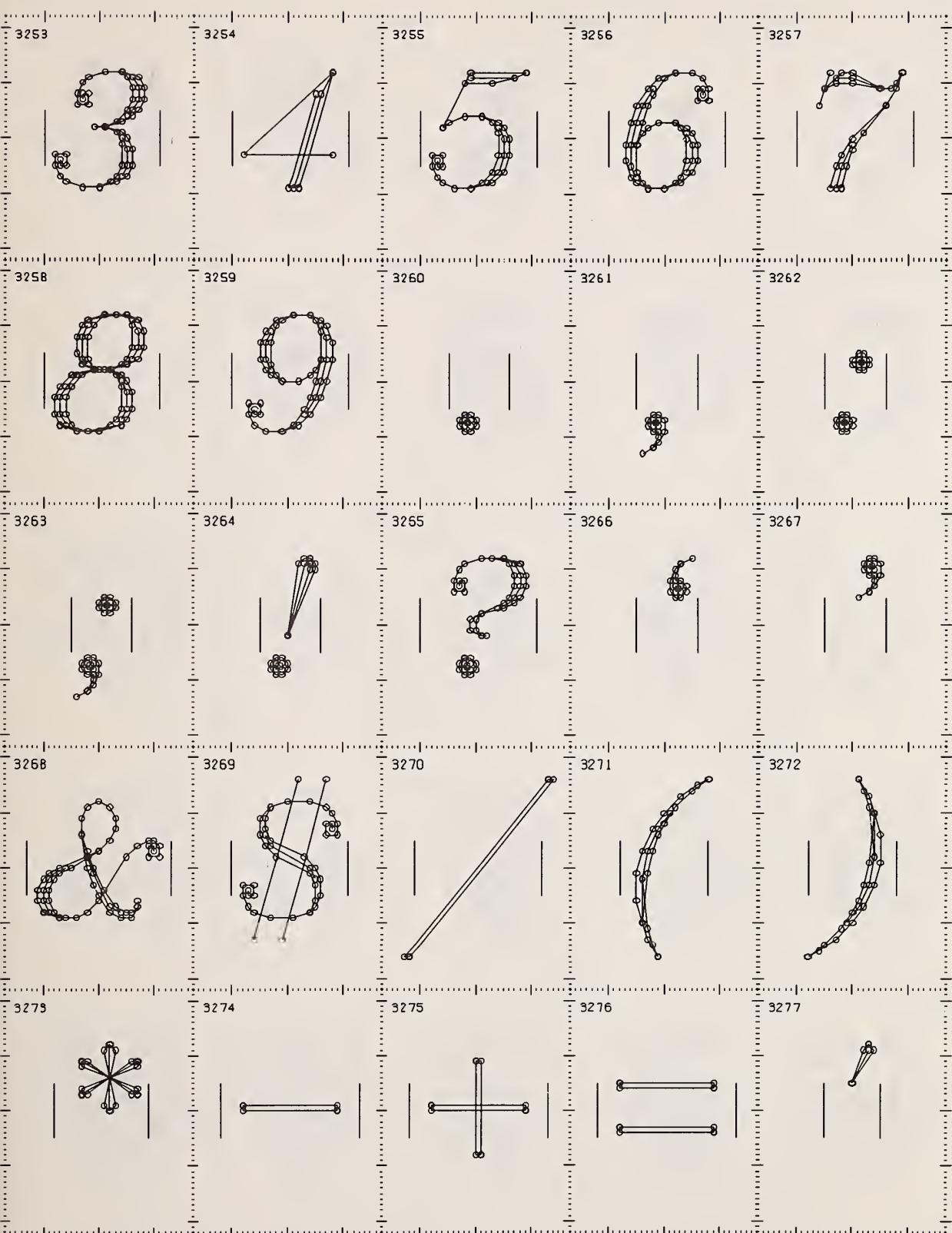


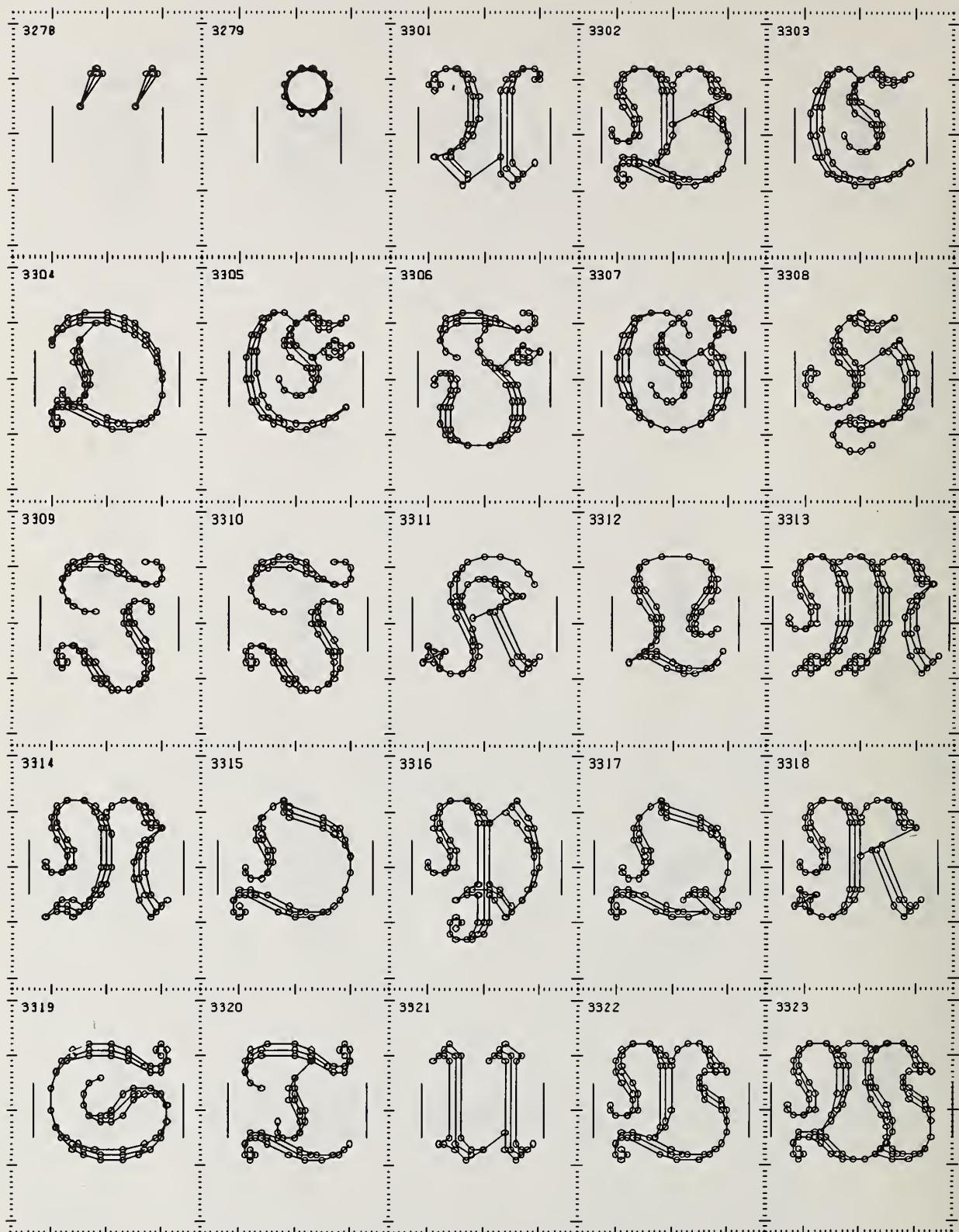


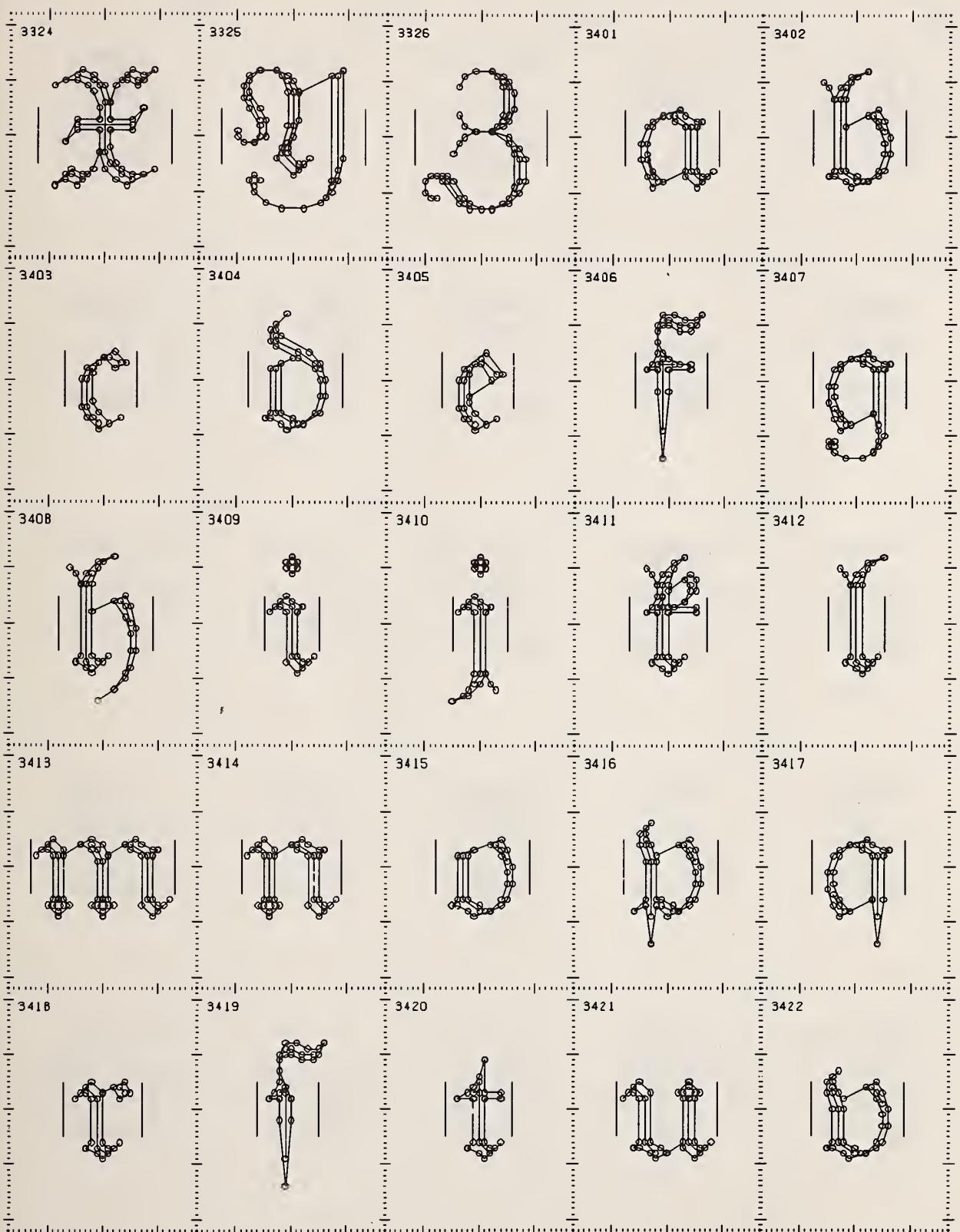


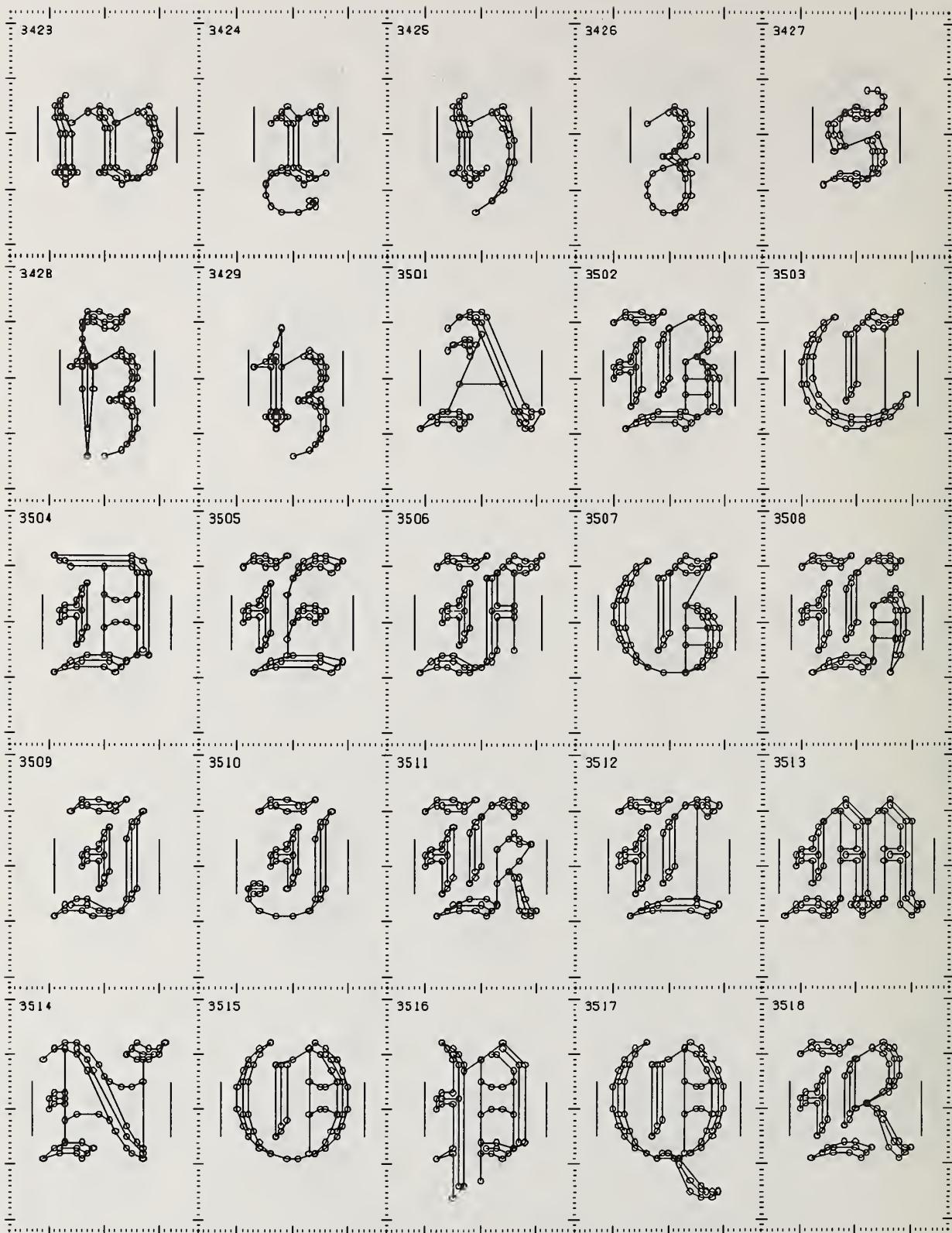


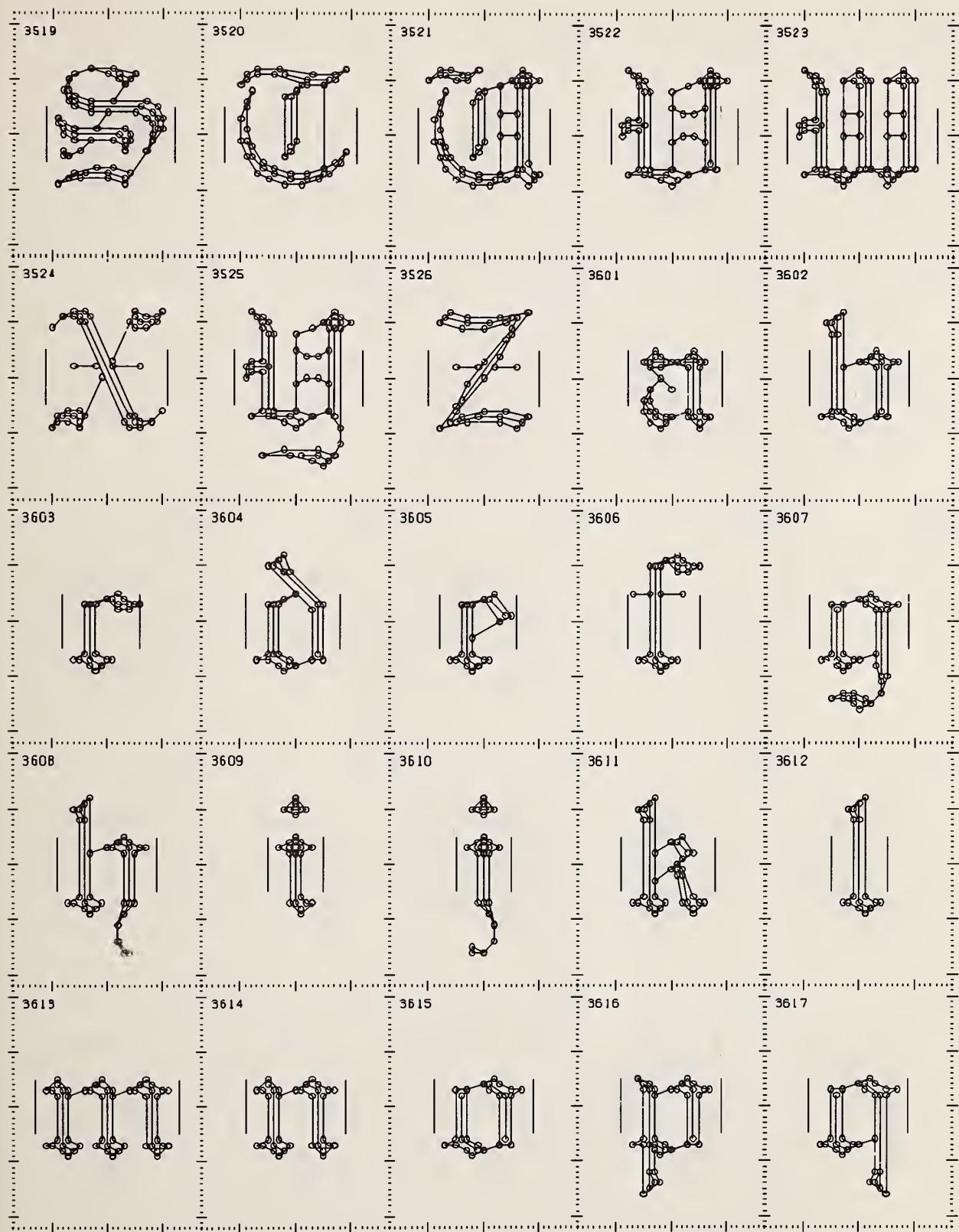


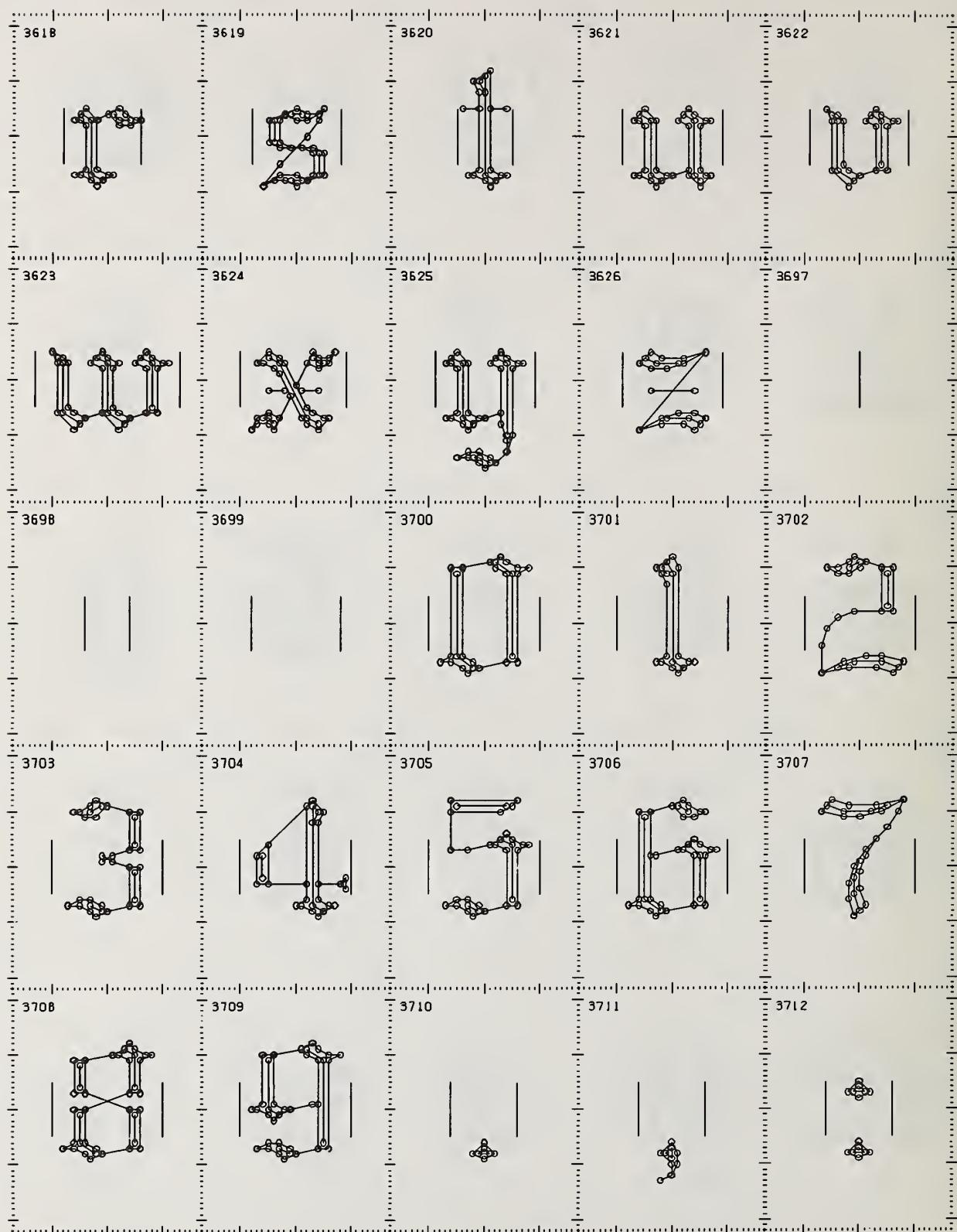


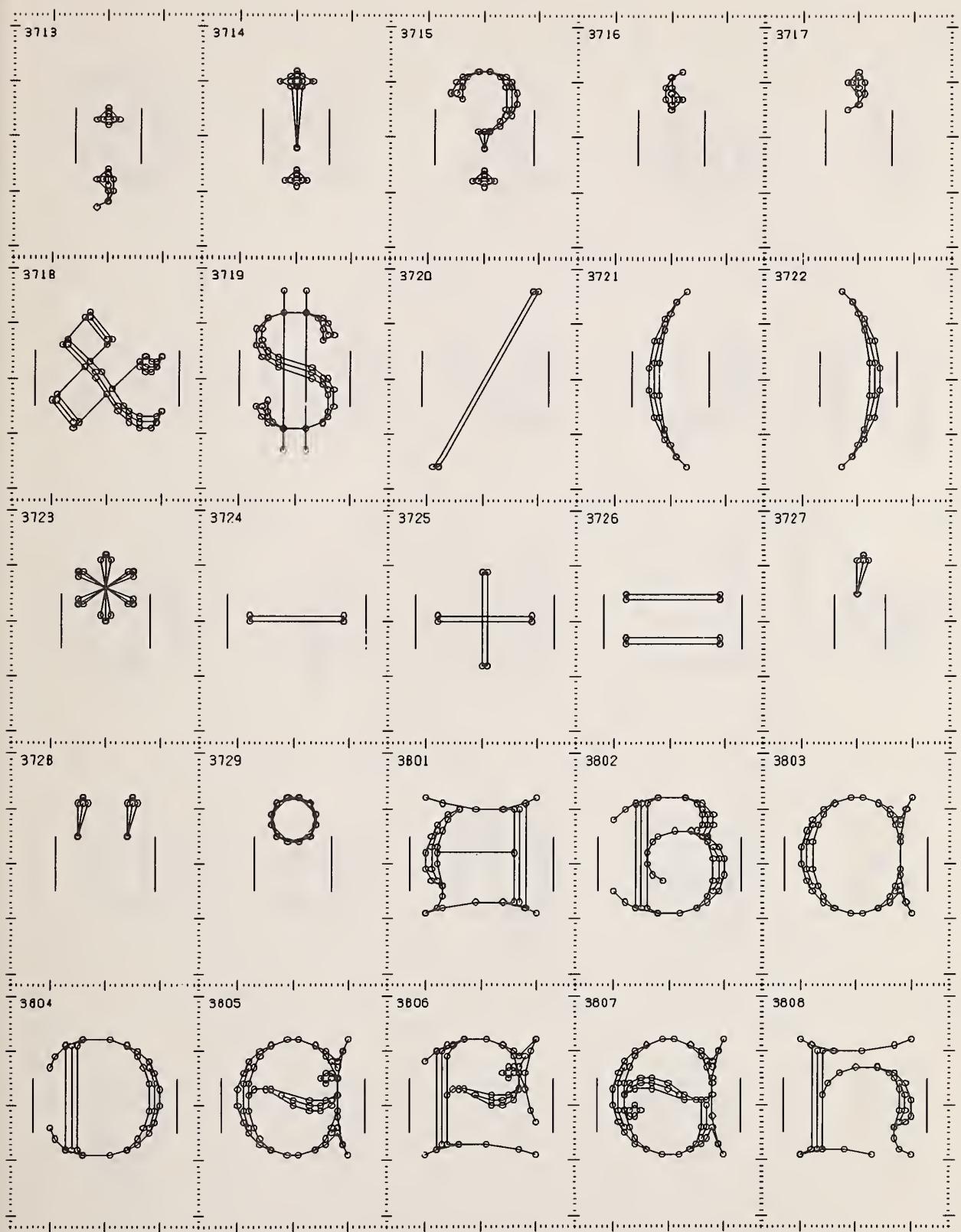


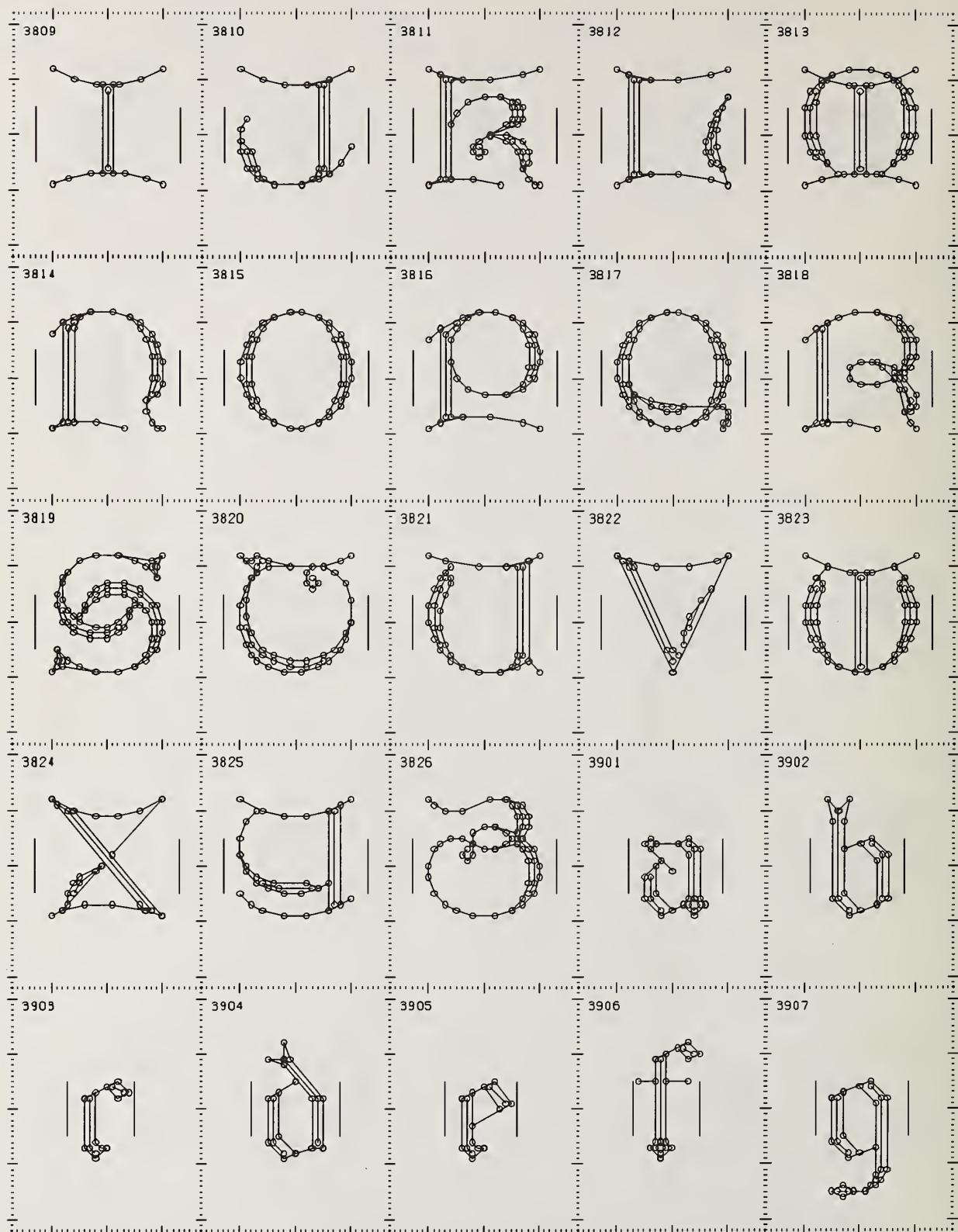


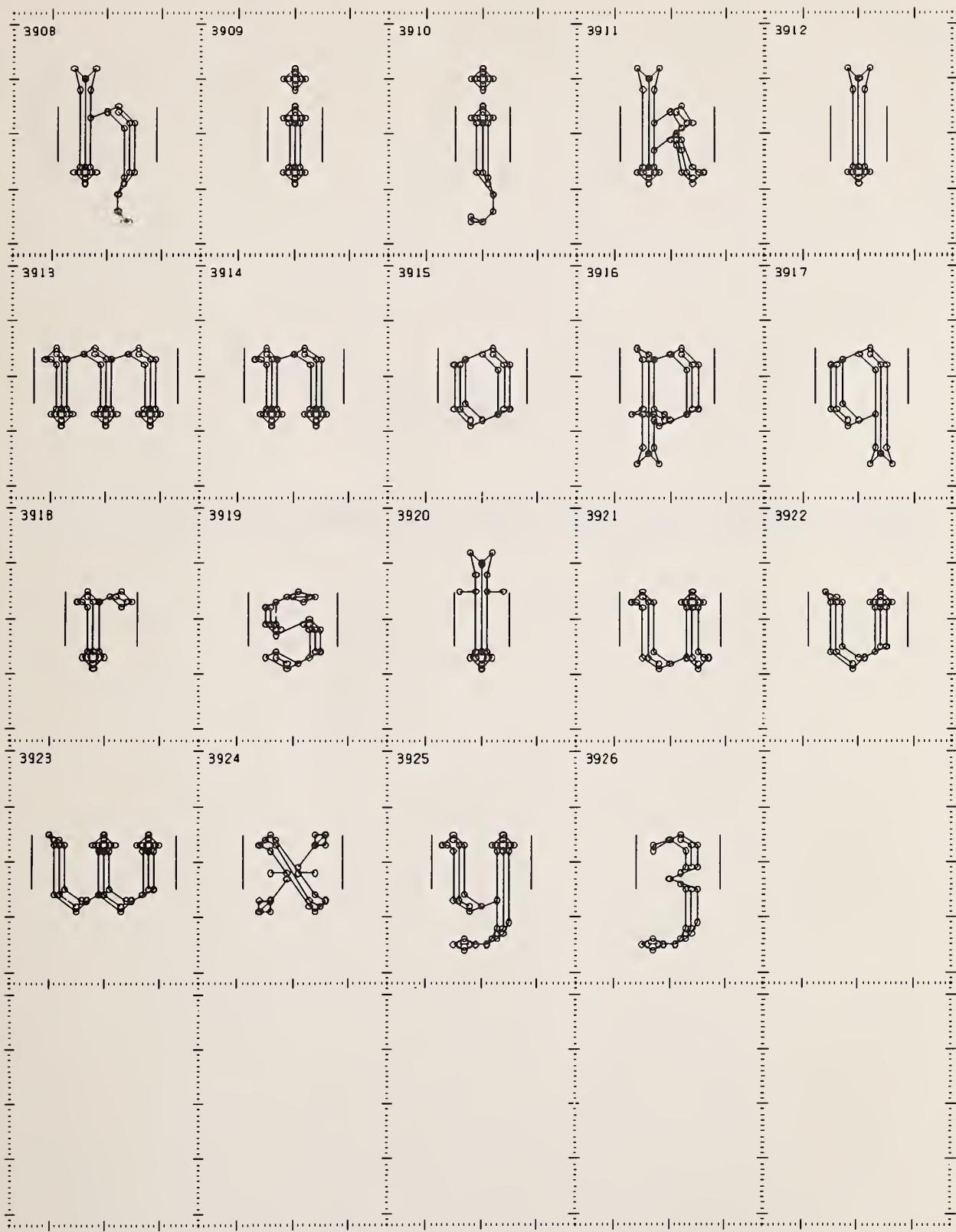


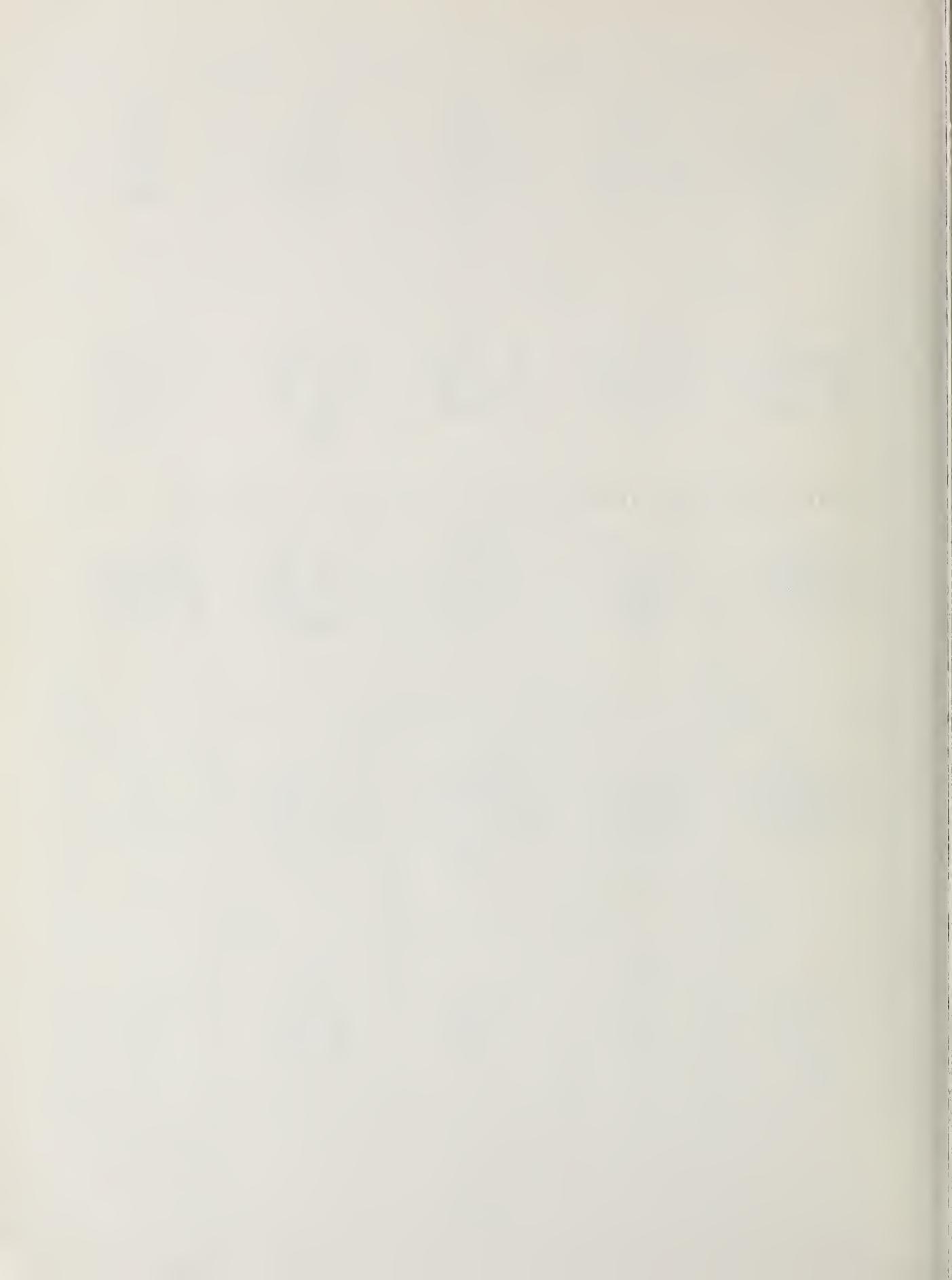












APPENDIX C

INDICES TO ALPHABETICS AND SPECIAL CHARACTERS

INDEX TO ALPHABETS

0001	CARTOGRAPHIC	ROMAN	
0027	CARTOGRAPHIC	GREEK	
0200	CARTOGRAPHIC	NUMERALS	
0501	UC SIMPLEX	ROMAN	PRIN SIZE
0527	UC SIMPLEX	GREEK	PRIN SIZE
0551	UC SIMPLEX	SCRIPT	PRIN SIZE
0601	LC SIMPLEX	ROMAN	PRIN SIZE
0627	LC SIMPLEX	GREEK	PRIN SIZE
0651	LC SIMPLEX	SCRIPT	PRIN SIZE
0700	NUMERALS SIMPLEX	ROMAN	PRIN SIZE
1001	UC COMPLEX	ROMAN	INDEX SIZE
1027	UC COMPLEX	GREEK	INDEX SIZE
1051	UC COMPLEX	ITALIC	INDEX SIZE
1101	LC COMPLEX	ROMAN	INDEX SIZE
1127	LC COMPLEX	GREEK	INDEX SIZE
1151	LC COMPLEX	ITALIC	INDEX SIZE
1200	NUMERALS COMPLEX	ROMAN	INDEX SIZE
2001	UC COMPLEX	ROMAN	PRIN SIZE
2027	UC COMPLEX	GREEK	PRIN SIZE
2051	UC COMPLEX	ITALIC	PRIN SIZE
2101	LC COMPLEX	ROMAN	PRIN SIZE
2127	LC COMPLEX	GREEK	PRIN SIZE
2151	LC COMPLEX	ITALIC	PRIN SIZE
2200	NUMERALS COMPLEX	ROMAN	PRIN SIZE
2501	UC DUPLEX	ROMAN	PRIN SIZE
2551	UC COMPLEX	SCRIPT	PRIN SIZE
2601	LC DUPLEX	ROMAN	PRIN SIZE
2651	LC COMPLEX	SCRIPT	PRIN SIZE
2700	NUMERALS DUPLEX	ROMAN	PRIN SIZE
2750	NUMERALS COMPLEX	SCRIPT	PRIN SIZE
2801	UC COMPLEX	CYRILLIC	PRIN SIZE
2901	LC COMPLEX	CYRILLIC	PRIN SIZE
3001	UC TRIPLEX	ROMAN	PRIN SIZE
2051	UC TRIPLEX	ITALIC	PRIN SIZE
3151	LC TRIPLEX	ITALIC	PRIN SIZE
3200	NUMERALS TRIPLEX	ROMAN	PRIN SIZE
3250	NUMERALS TRIPLEX	ITALIC	PRIN SIZE
3301	UC GOTHIC	GERMAN	PRIN SIZE
3401	LC GOTHIC	GERMAN	PRIN SIZE
3501	UC GOTHIC	ENGLISH	PRIN SIZE
3601	LC GOTHIC	ENGLISH	PRIN SIZE
3700	NUMERALS GOTHIC		PRIN SIZE
3801	UC GOTHIC	ITALIAN	PRIN SIZE
3901	LC GOTHIC	ITALIAN	PRIN SIZE

INDEX TO SPECIAL CHARACTERS

0210	PERIOD	0733	NUMBER
0211	COMMA	0734	AMPERSAND
0212	COLON	0735	LOZENGE
0213	SEMICOLON	0737	PARALLEL
0214	EXCLAMATION	0738	PERPENDICULAR
0215	INTERROGATION	0739	ANGLE
0216	PRIME	0740	CONCLUSION
0217	SECOND	0741	SPADE
0218	DEGREE	0742	HEART
0219	DOLLAR	0743	DIAMOND
0220	SOLIDUS	0744	CLUB
0221	LEFT PARENTHESIS	0745	SHAMROCK
0222	RIGHT PARENTHESIS	0746	FLEUR DE LIS
0223	BAR	0750	DRIZZLE
0224	DIFFERENCE	0751	RAIN
0225	SUM	0752	SNOW
0226	EQUALITY	0753	SURFACE COLD FRONT
0227	CROSS	0754	SURFACE WARM FRONT
0228	ASTERISK	0755	50 KNOT FLAG
0229	DOT	0756	UPPER COLD FRONT
0230	LEFT QUOTATION	0757	UPPER WARM FRONT
0231	RIGHT QUOTATION	0758	CUMULO
0232	ARROW	0759	ALTO
0233	NUMBER	0760	ALTO
0234	AMPERSAND	0761	CIRRO
0235	LOZENGE	0762	LEFT CIRROSTRATO
0583	NABLA	0763	RIGHT CIRROSTRATO
0710	PERIOD	0764	SAND
0711	COMMA	0765	GLAZE
0712	COLON	0766	HAZE
0713	SEMICOLON	0767	THUNDERSTORM
0714	EXCLAMATION	0768	HURRICANE
0715	INTERROGATION	0796	HORIZONTAL
0716	PRIME	0797	45-OBLIQUE
0717	SECOND	0798	VERTICAL
0718	DEGREE	0799	135-OBLIQUE
0719	DOLLAR	0800	HORIZONTAL
0720	SOLIDUS	0801	30-OBLIQUE
0721	LEFT PARENTHESIS	0802	60-OBLIQUE
0722	RIGHT PARENTHESIS	0803	VERTICAL
0723	BAR	0804	120-OBLIQUE
0724	DIFFERENCE	0805	150-OBLIQUE
0725	SUM	0806	HORIZONTAL
0726	EQUALITY	0807	45-OBLIQUE
0727	CROSS	0808	VERTICAL
0728	ASTERISK	0809	135-OBLIQUE
0729	DOT	0810	UPPER LEFT QUADRANT
0730	LEFT QUOTATION	0811	LOWER LEFT QUADRANT
0731	RIGHT QUOTATION	0812	LOWER RIGHT QUADRANT
0732	ARROW	0813	UPPER RIGHT QUADRANT

INDEX TO SPECIAL CHARACTERS

0814	LOWER QUADRANT	0873	WILLOW
0815	LEFT QUADRANT	0874	GRASS
0816	RIGHT QUADRANT	0899	DOT
0817	UPPER QUADRANT	0900	2-CIRCLE
0818	VERTICAL ZIGZAG	0901	4-CIRCLE
0819	HORIZONTAL ZIGZAG	0902	5-CIRCLE
0820	30-ZIGZAG	0903	7-CIRCLE
0821	45-ZIGZAG	0904	11-CIRCLE
0822	UPPER LOOP	0905	17-CIRCLE
0823	LEFT LOOP	0906	22-CIRCLE
0824	LOWER LOOP	0907	41-CIRCLE
0825	RIGHT LOOP	0908	US HIGHWAY
0826	30-LOOP	0909	IS HIGHWAY
0827	45-LOOP	1210	PERIOD
0828	JUNCTION	1211	COMMA
0829	JUMPER	1212	COLON
0830	GRID	1213	SEMICOLON
0831	SHIELD	1214	EXCLAMATION
0832	FILAMENT	1215	INTERROGATION
0833	GROUND	1216	PRIME
0834	ANTENNA	1217	SECOND
0840	CIRCLE	1218	DEGREE
0841	SQUARE	1219	ASTERISK
0842	TRIANGLE	1220	SOLIDUS
0843	DIAMOND	1221	LEFT PARENTHESIS
0844	STAR	1222	RIGHT PARENTHESIS
0845	MARK	1223	LEFT BRACKET
0846	CROSS	1224	RIGHT BRACKET
0847	ASTERISK	1225	LEFT BRACE
0850	CIRCLE	1226	RIGHT BRACE
0851	SQUARE	1227	LEFT ELBOW
0852	UP VERTEX	1228	RIGHT ELBOW
0853	LEFT VERTEX	1229	BAR
0854	DOWN VERTEX	1230	DOUBLE BAR
0855	RIGHT VERTEX	1231	MINUS
0856	STAR	1232	PLUS
0857	FLAG	1233	PLUS OR MINUS
0860	ANCHORAGE	1234	MINUS OR PLUS
0861	AERODROME	1235	CROSS PRODUCT
0862	MINE	1236	DOT PRODUCT
0863	DERRICK	1237	QUOTIENT
0864	LIGHTSHIP	1238	EQUALITY
0865	WRECK	1239	INEQUALITY
0866	CROSS	1240	IDENTITY
0867	CRESCENT	1241	LESS
0868	STAR	1242	MORE
0869	BELL	1243	EQUAL OR LESS
0870	PALM	1244	EQUAL OR MORE
0871	PINE	1245	VARIATION
0872	OAK	1246	APPROXIMATION

INDEX TO SPECIAL CHARACTERS

1247	CARET	1404	RIGHT PARENTHESIS
1248	ACUTE ACCENT	1405	LEFT BRACKET
1249	GRAVE ACCENT	1406	RIGHT BRACKET
1250	BREVE	1407	LEFT BRACE
1251	RIGHT QUOTATION	1408	RIGHT BRACE
1252	LEFT QUOTATION	1409	UPPER HALF BRACE
1253	NORMAL ASPIRATE	1410	LOWER HALF BRACE
1254	INVERTED ASPIRATE	1411	RADICAL
1256	RIGHT HOOK	1412	INTEGRAL
1257	UP HOOK	2077	ALEPH
1258	LEFT HOOK	2210	PERIOD
1259	DOWN HOOK	2211	COMMA
1260	ELEMENT	2212	COLON
1261	RIGHT ARROW	2213	SEMICOLON
1262	UP ARROW	2214	EXCLAMATION
1263	LEFT ARROW	2215	INTERROGATION
1264	DOWN ARROW	2216	PRIME
1265	DELTA	2217	SECOND
1266	NABLA	2218	DEGREE
1267	RADICAL	2219	ASTERISK
1268	INTEGRAL	2220	SOLIDUS
1269	CIRCUIT INTEGRAL	2221	LEFT PARENTHESIS
1270	INFINITY	2222	RIGHT PARENTHESIS
1271	PERCENT	2223	LEFT BRACKET
1272	AMPERSAND	2224	RIGHT BRACKET
1273	AT	2225	LEFT BRACE
1274	DOLLAR	2226	RIGHT BRACE
1275	NUMBER	2227	LEFT ELBOW
1276	PARAGRAPH	2228	RIGHT ELBOW
1277	DAGGER	2229	BAR
1278	DOUBLE DAGGER	2230	DOUBLE BAR
1279	EXISTENCE	2231	MINUS
1281	SUN	2232	PLUS
1282	MERCURY	2233	PLUS OR MINUS
1283	VENUS	2234	MINUS OR PLUS
1284	EARTH	2235	CROSS PRODUCT
1285	MARS	2236	DOT PRODUCT
1286	JUPITER	2237	QUOTIENT
1287	SATURN	2238	EQUALITY
1288	URANUS	2239	INEQUALITY
1289	NEPTUNE	2240	IDENTITY
1290	PLUTO	2241	LESS
1291	MOON	2242	MORE
1292	COMET	2243	EQUAL OR LESS
1293	STAR	2244	EQUAL OR MORE
1294	ASCENDING NODE	2245	VARIATION
1295	DESCENDING NODE	2246	APPROXIMATION
1401	PI	2247	CARET
1402	SIGMA	2248	ACUTE ACCENT
1403	LEFT PARENTHESIS	2249	GRAVE ACCENT

INDEX TO SPECIAL CHARACTERS

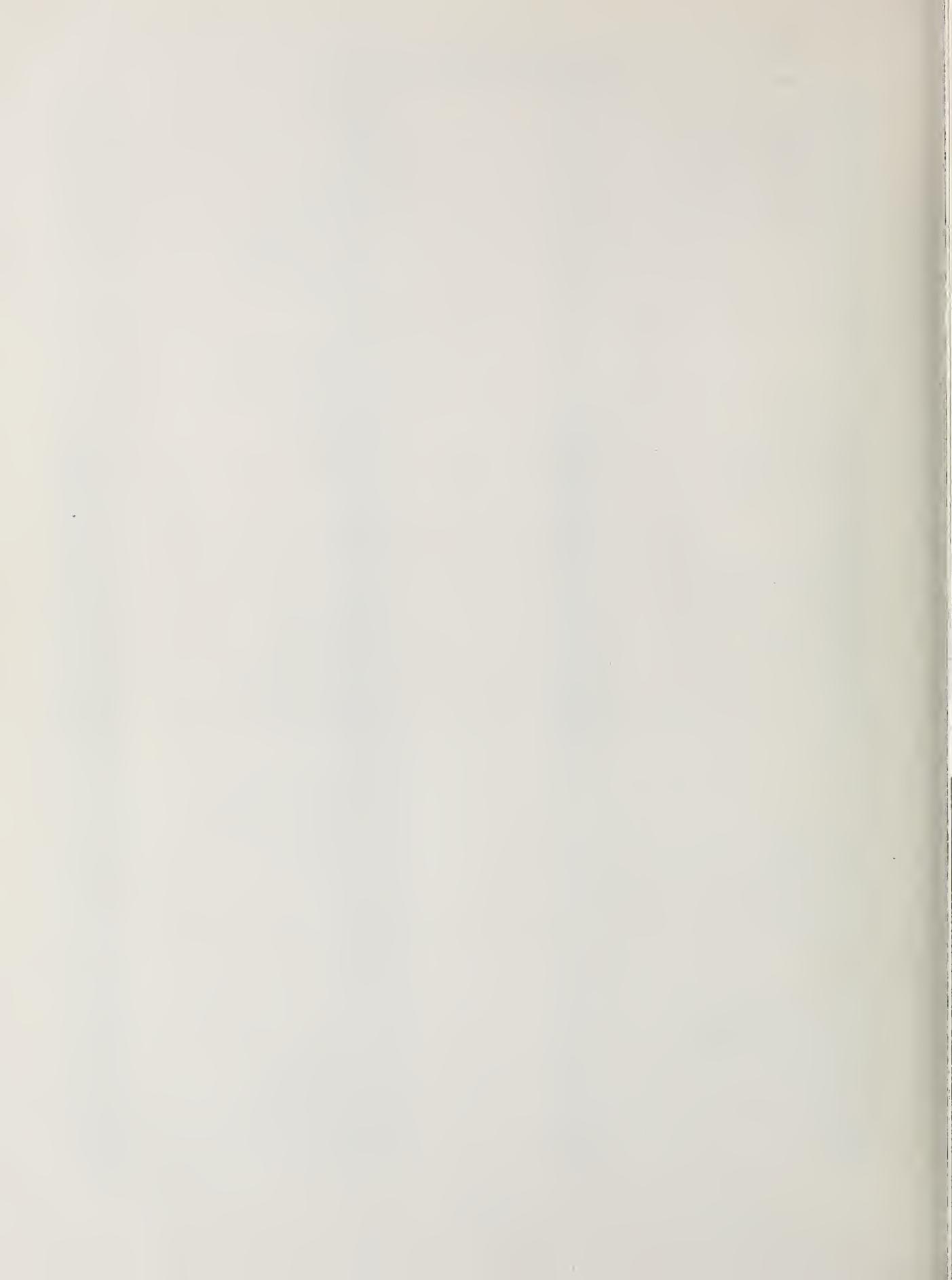
2250	BREVE	2306	VIRGO
2251	RIGHT QUOTATION	2307	LIBRA
2252	LEFT QUOTATION	2308	SCORPIO
2253	NORMAL ASPIRATE	2309	SAGITTARIUS
2254	INVERTED ASPIRATE	2310	CAPRICORNUS
2255	RADICAL	2311	AQUARIUS
2256	RIGHT HOOK	2312	PISCES
2257	UP HOOK	2317	DOT
2258	LEFT HOOK	2318	UPPER FLAG
2259	DOWN HOOK	2319	LOWER FLAG
2260	ELEMENT	2320	WHOLE NOTE
2261	RIGHT ARROW	2321	HALF NOTE
2262	UP ARROW	2322	QUARTER NOTE
2263	LEFT ARROW	2323	SHARP
2264	DOWN ARROW	2324	NATURAL
2265	DELTA	2325	FLAT
2266	NABLA	2326	WHOLE REST
2267	RADICAL	2327	HALF REST
2268	INTEGRAL	2328	QUARTER REST
2269	CIRCUIT INTEGRAL	2329	EIGHTH REST
2270	INFINITY	2330	G CLEF
2271	PERCENT	2331	F CLEF
2272	AMPERSAND	2332	C CLEF
2273	AT	2367	DOT
2274	DOLLAR	2368	UPPER FLAG
2275	NUMBER	2369	LOWER FLAG
2276	PARAGRAPH	2370	WHOLE NOTE
2277	DAGGER	2371	HALF NOTE
2278	DOUBLE DAGGER	2372	QUARTER NOTE
2279	EXISTENCE	2373	SHARP
2281	SUN	2374	NATURAL
2282	MERCURY	2375	FLAT
2283	VENUS	2376	WHOLE REST
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2285	MARS	2378	QUARTER REST
2286	JUPITER	2379	EIGHTH REST
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2288	URANUS	2381	F CLEF
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2290	PLUTO	2401	PI
2291	MOON	2402	SIGMA
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2301	ARIES	2407	LEFT BRACE
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2303	GEMINI	2409	UPPER HALF BRACE
2304,	CANCER	2410	LOWER HALF BRACE
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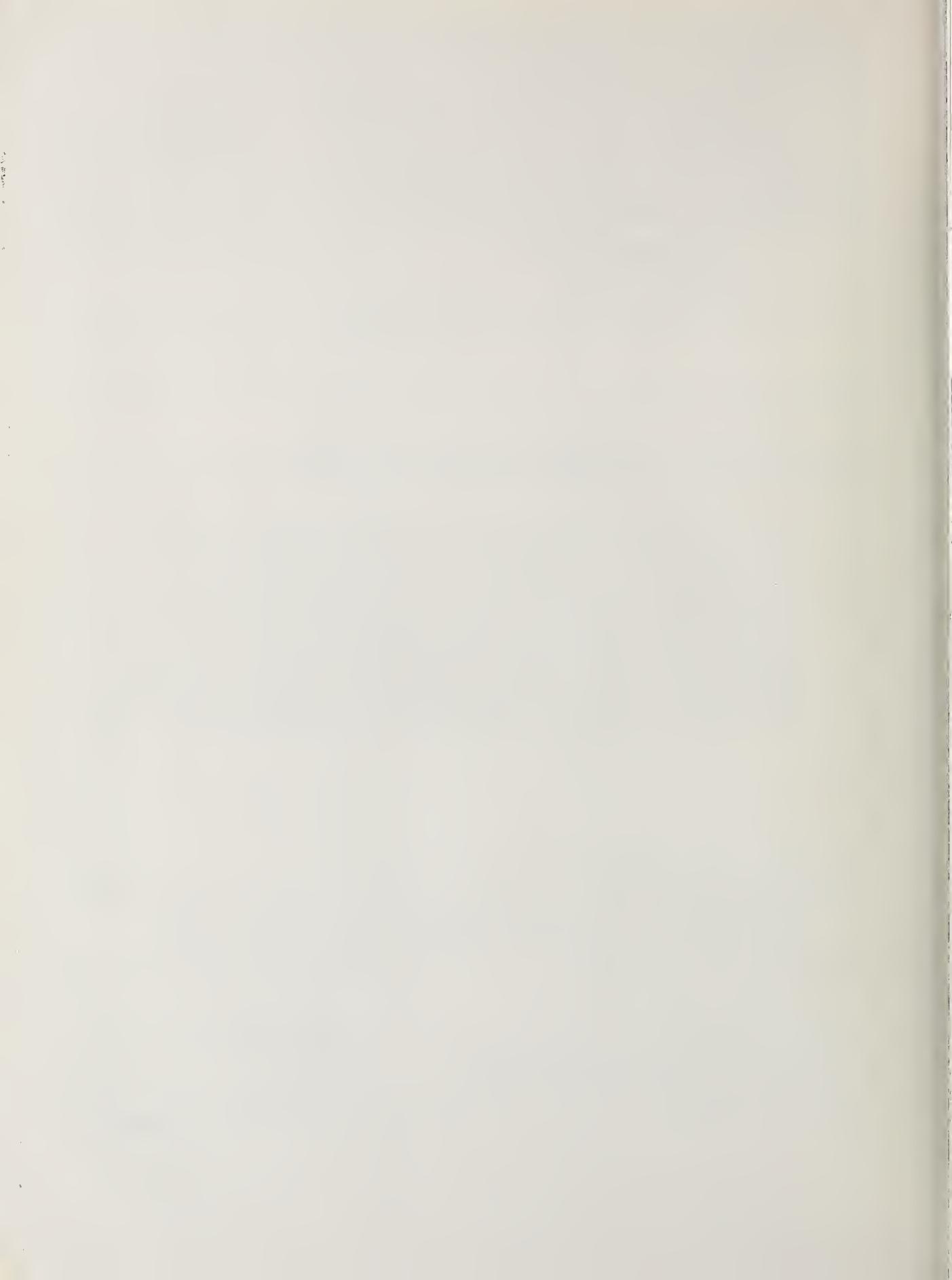
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2710	PERIOD	3220	SOLIDUS
2711	COMMA	3221	LEFT PARENTHESIS
2712	COLON	3222	RIGHT PARENTHESIS
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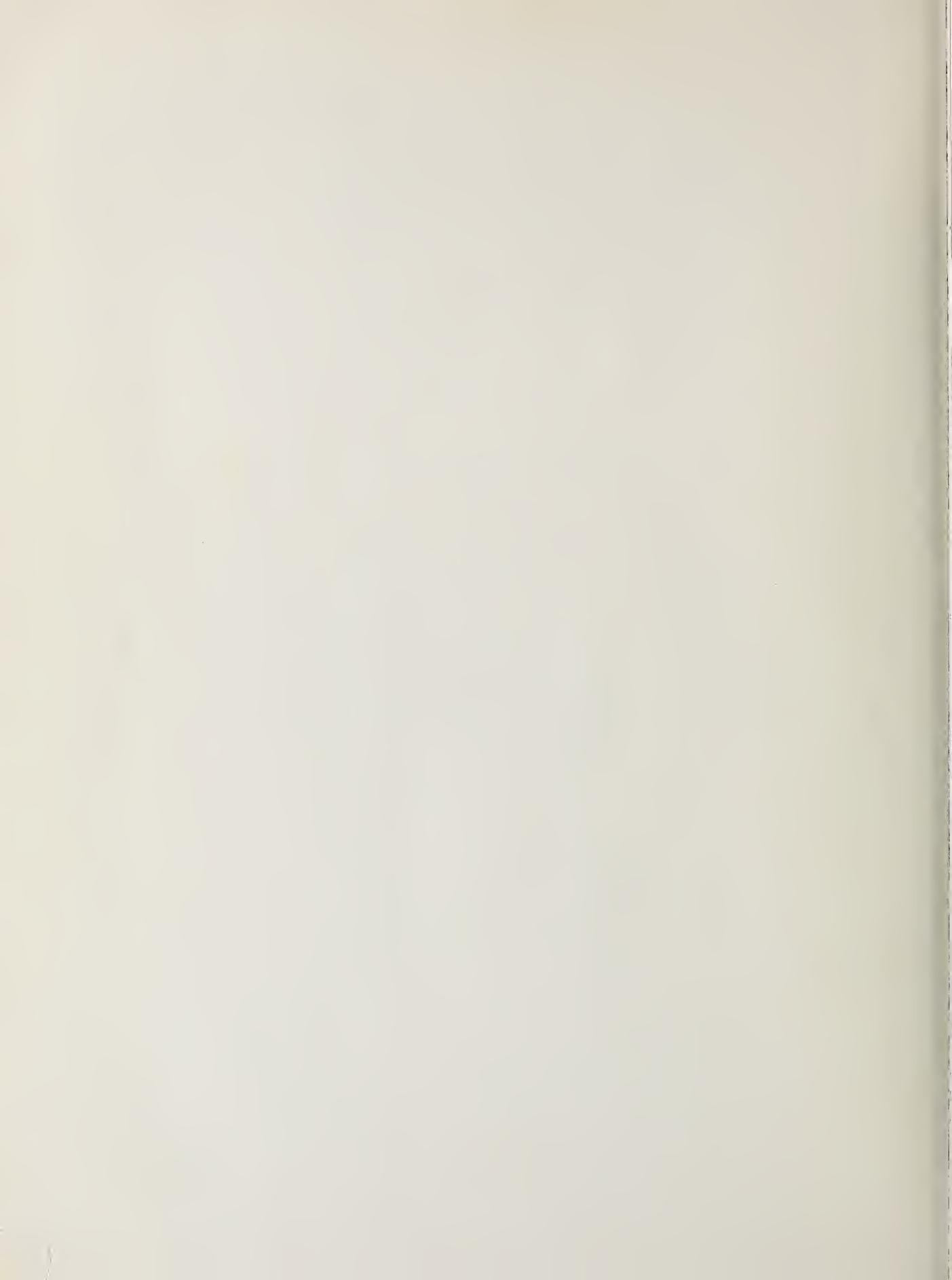
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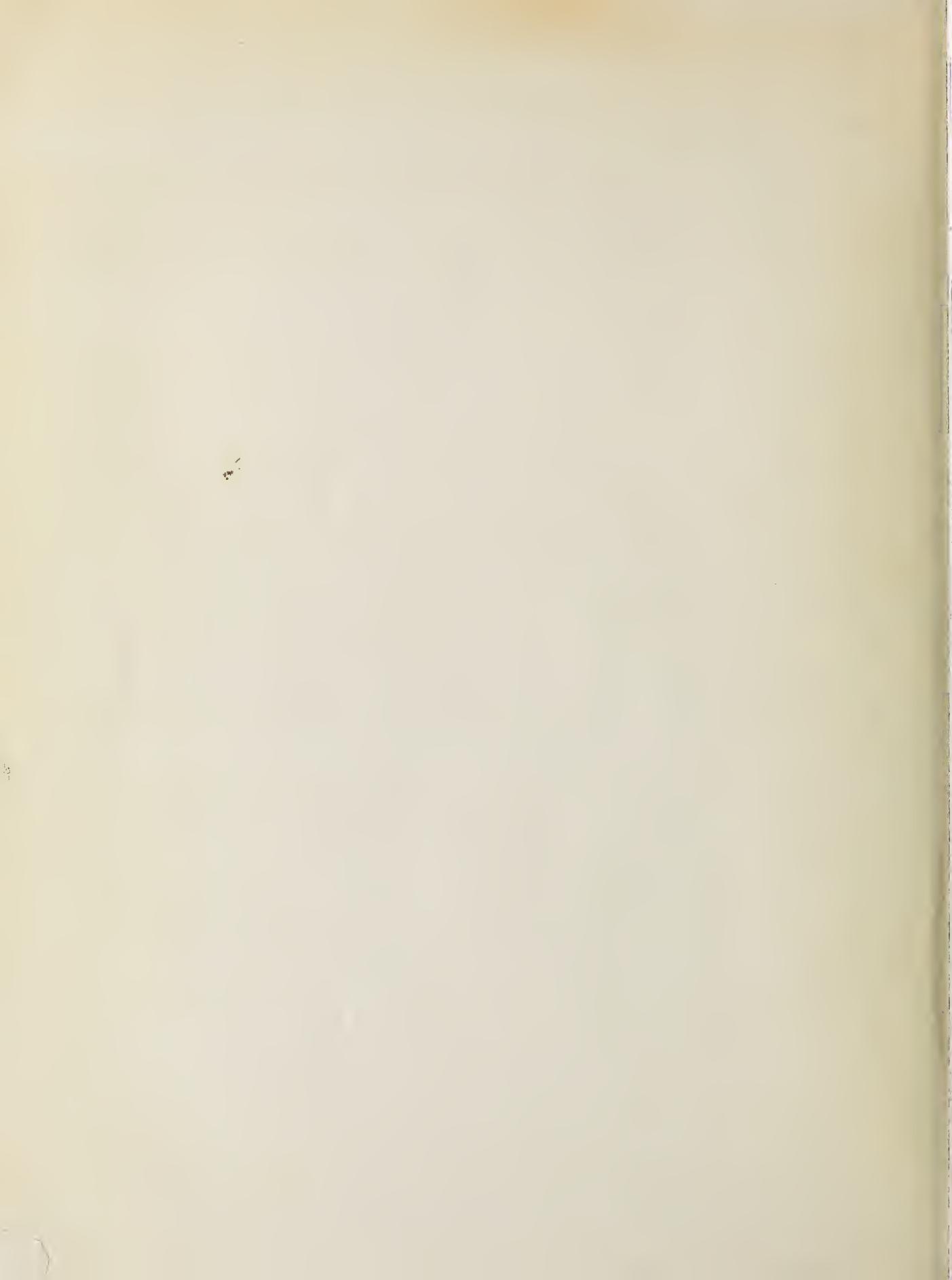


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