NASA CONTRACTOR
REPORT

NASA CR-144193

Scientific and Technical Information Facility
(25 copies)
P.O. Box 8757
Baltimore/Washington International Airport
Baltimore, MD 21240

BANNING ARTWORK PROGRAM USER'S MANUAL

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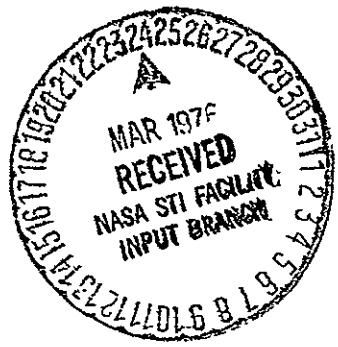
February 19, 1976



Prepared for

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

TECHNICAL REPORT STANDARD TITLE PAGE

1 REPORT NO.	2. GOVERNMENT ACCESSION NO.	3 RECIPIENT'S CATALOG NO.
CR 144193		

4 TITLE AND SUBTITLE	5 REPORT DATE
BANNING ARTWORK PROGRAM USER'S MANUAL	February 19, 1976
	6. PERFORMING ORGANIZATION CODE
7 AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT #
J. F. Taylor	70-0012
9 PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
M&S Computing, Inc. P. O. Box 5183 Huntsville, Alabama 35805	11. CONTRACT OR GRANT NO. NAS8-25621
12 SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT & PERIOD COVERED
National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	Contractor Report April 24, 1970
	14. SPONSORING AGENCY CODE EC45

15 SUPPLEMENTARY NOTES

Electronics and Control Laboratory
Electronics Development Division
Design Techniques Branch

16. ABSTRACT

This document is intended to serve as the User's Manual for the Banning Artwork Program. All program options are explained and a detail definition of the format of each input card is given. The detail description of the internal logic and flow of the Artwork Program is not included in this report, but has been incorporated into a separate document entitled "Programmer's Manual for the Artwork Program". It is recommended that every user review the Programmer's Manual in order to receive an appreciation of the functions performed by the Artwork Program; however, it will not be necessary for the designer/engineer to become intimately familiar with the internal operation of the Artwork Program in order to effectively use the extensive capabilities inherent within the program.

17 KEY WORDS	18 DISTRIBUTION STATEMENT
	Unclassified - Limited to domestic use only COR [signature] EC01 [signature] 3/1/76 for: Director, E&C Lab.

19 SECURITY CLASSIF. (of this report)	20 SECURITY CLASSIF. (of this page)	21 NO. OF PAGES	22 PRICE
Unclassified	Unclassified	90	

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REFERENCE

This document is primarily a rewrite of information contained in the original documentation for the Artwork Program produced by the Radio Corporation of America during the contract for the initial definition and implementation of the Banning System of Programs (Contract Number DA-18-119-AMC-03460(X)).

This "User's Reference Manual" and the "Programmer's Manual for the Artwork Program serve as the final documentation of the Banning Artwork Program as implemented by M&S Computing, Inc. under contract number NAS8-25621 for Marshall Space Flight Center's Astrionics Laboratory, Technology Division.

SECTION I

INTRODUCTION

The Banning Artwork Program generates commands for the Gerber Artwork Generator on magnetic tape from the following inputs:

1) Available plotter apertures,

2) Cell numbers indicating the Banning components used in designing the circuit, and the pattern library defining the artwork required to construct each level mask of each cell,

3) Placement and Interconnect Information; and

4) Program control cards.

The next four sections of this report (2 through 5) present a detail user oriented description of these four input requirements.

Figure 1.1 illustrates the scope of the Artwork Program and the three modes of operation: PRF, MANUAL and UPDATE. These modes are described in detail in the remaining sections of this report. The magnetic-tape-to-paper-tape conversion program depicted in Figure 1.1 was not an original component of the Artwork Program, but was created as an important part of the Banning implementation contract since the available Gerber Plotter could only accept paper tape input. This program is not described in this report, but documentation is available under the title "Paper Tape Utility User's Guide." The effect of the various types and sizes of apertures on plotting time and accuracy is discussed in Section 2 along with the program options and operations that influence the final Gerber Plotter output. The remaining three inputs are discussed in separate chapters under appropriate identifying titles.

In addition to creating the Gerber commands required to produce the artwork needed for fabrication of circuit masks, the Banning Artwork Program contains an extensive utility package. This utility capability enables the creation of the Banning Pattern Library, supports the development of new cells, allows the incorporation of new cells

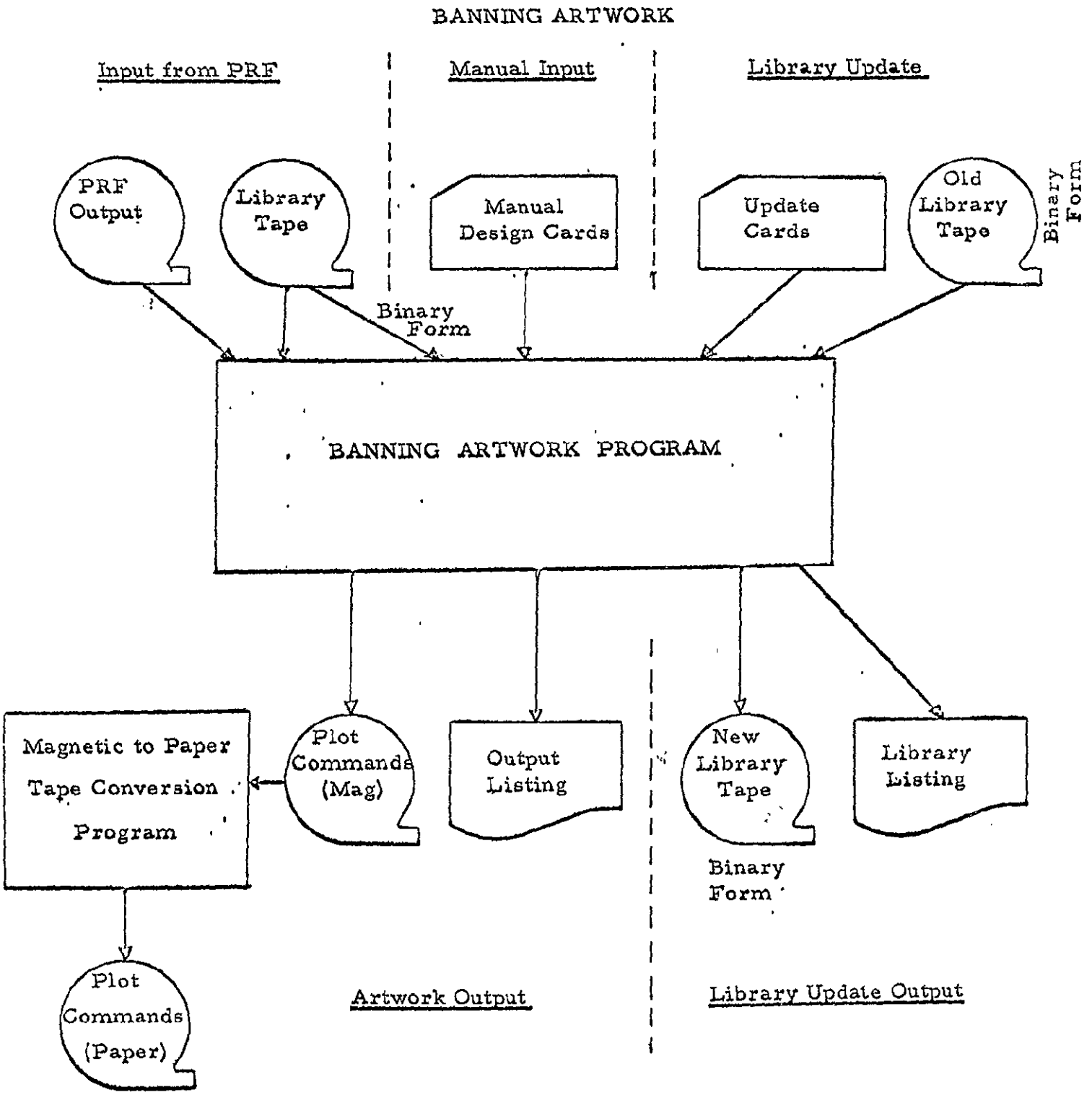


Figure 1.1

into the Banning Pattern Library, and provides the tools for performing various essential system oriented functions such as printing the pattern library, writting end-of-file on magnetic tapes, rewinding tape, and defining program operating parameters. These utility functions are described in detail under the UPDATE control card description in Section 4.

The final section of this report describes the setup operations and input requirements necessary to operate the Artwork Program with manual input data, and the modifications required to be able to drive the Artwork Program with inputs supplied by the Banning Placement-Routing-Folding program.

SECTION II

GERBER PLOTTER

Artwork is produced on the Artwork Generator by exposing photographic film with specified apertures in the photohead assembly, as the photohead is moved by the carriage. The Gerber commands that select the appropriate apertures and determine the plotter motion required to completely expose of "fill-in" the specified areas of a circuit mask are produced by the Artwork Program. This section is devoted to explaining the formats of the plotter commands produced by the Artwork Program, and describing the methods available by which the designer and program can communicate to produce Gerber commands that optimize plotting time and accuracy.

2.1 COMMAND STRUCTURE

The Artwork Program outputs binary-coded-decimal, BCD, artwork commands on magnetic tape in a command format compatible with the command structure of the 1000 and 2000 Series Gerber Artwork Generators. The general format of the Gerber Artwork Generator command is presented below followed by a description of each field within the command.

$$NN_1N_2N_3GG_1G_2X \pm X_1X_2X_3X_4X_5X_6X_7Y \pm Y_1Y_2Y_3Y_4Y_5Y_6Y_7$$

$$II_1I_2I_3I_4I_5I_6I_7JJ_1J_2J_3J_4J_5J_6J_7DD_1D_2MM_1M_2*$$

- N-FIELD: The N-field represents the N-sequence number of the Gerber command. More than three digits can be used, but more than three cannot be displayed on the control unit of the Artwork Generator. The Artwork Generator can be instructed to skip to a specific sequence number, but this capability is not used by the Banning Artwork Program. This field may be omitted from any command without effecting the plotter's operation.

- G-FIELD: The G-field, G_1G_2, represents the preparatory code for the Gerber Artwork Generator command. The following G-codes are used by the Banning Artwork Program:

  01 - Linear interpolation. Move to X, Y linearly.

02 - Circular interpolation. Move to X, Y clockwise along a circular arc whose center is I, J, incremental in X and Y dimensions from the present position of the plotter.

03 - Counter-clockwise circular interpolation.

52 - Draw the symbol specified in the D-field horizontally.

53 - Draw the symbol specified in the D-field vertically.

54 - Select the aperture specified in the D-field of the command. There are twenty-four apertures available.

55 - Flash the light to photoexpose an aperture with the plotter stopped.

- X, Y, I and J FIELDS: The X, Y, I and J fields represent locations for plotter movement, in inches. These numeric fields can be in 1-5, 2-5 or 3-5 format, which means there can be either 1, 2 or 3 digits ahead of the implied decimal point, followed by five possible digits after the decimal point. This format is set on the console of the Artwork Generator with appropriate switches. The implied decimal point is the same for the X, Y, I, and J fields. The X and Y numbers have sign positions, however, plus signs may be omitted since the Gerber Artwork Generator assumes unsigned numbers to be positive. Coordinates can be in incremental or absolute mode. The incremental mode specifies a displacement from the previous plotter position. In absolute mode the absolute position on the table is specified before any offsets are added, or scale factors are applied from the plotter console. The I and J fields are always in the incremental mode. Trailing zeros can be omitted, but leading zeros must be present. The Banning Artwork Program generates Gerber commands in the 2-5 absolute mode. The Gerber Artwork Generator available to NASA MSFC is accurate to only six digits; therefore, the final digit is truncated during the plotting operation.

- D-FIELD: The D-field, $D_1 D_2$, commands the light.

  DØ1 = Light on,

  DØ2 = Light off

for both linear and circular interpolate commands. For symbol-memory commands, the D-field contains the reference number of the alpha numeric symbol to be drawn from the commands stored in the plotter memory by reading paper tape. Such a list as shown by Table 2.1. For aperture-select commands the D-field contains the reference number of one of the 24 available apertures to be selected. For photo-expose commands, D_1D_2 set equal to 03 causes the light to flash, with the carriage at rest.

- M-FIELD: The M-field specifies the scale of the symbols for symbol-memory commands; for other commands M_1 M_2 equal to ØØ stops the plotter.

- *-FIELD: The *-field specifies the end of the Gerber command.

All presently defined cells within the Banning Standard Cell Library are defined without the use of circles are arcs. Also, the Banning Placement-Routing-Folding, PRF, program does not use the arc drawing capabilities of the plotter in defining routing and interconnect information. The most frequently used commands employed by the Banning Artwork Program are the aperture select command and the linear interpolation command. These commands are illustrated below:

- Aperture Select Command Example - N005G54D12*

  This is command number 5 and will result in the selection of aperture number 12.

- Linear Interpolation Command Example -
  N231G01X+1234567Y-0023612D01*

  This is command number 231 and will result in the movement of the carriage from the present location to X = 12.34567, Y =-00.23612 with the light on.

Once a value for a particular field within the Gerber Artwork Generator command has been specified, it will remain in effect until replaced by a new value. For example, once the linear interpolation mode of operation has been specified, the G-field may be omitted

EQUIVALENCE CODE FOR

SYMBOL-MEMORY COMMANDS

Symbol	D-Field Number	Symbol	D-Field Number
A	11	X	34
B	12	Y	35
C	13	Z	36
D	14	Ø	40
E	15	1	41
F	16	2	42
G	17	3	43
H	18	4	44
I	19	5	45
J	20	6	46
K	21	7	47
L	22	8	48
M	23	9	49
N	24	Space	10
O	25	/	39
P	26	-	51
Q	27	+	37
R	28	.	54
S	29	,	56
T	30	(	52
U	31	)	53
V	32	=	50
W	33	*	55

Table 2.1

from subsequent drawing commands until the mode changes. However, repitition of each redundant field of each command does not adversely effect the plotter efficiency or accuracy. For this reason the Banning Artwork Program creates a complete command for each generated Gerber operation. Since the X, Y, I, and J-fields are unique in that they only have meaning when in the linear or circular interpolation mode of operation, they are omitted from all other command modes. This method produces easily readible commands and ensures compatability for all 1000 and 2000 Series Gerber plotters, but produces approximately 60 percent more data than is required to produce the actual artwork output.

The excessive amount of output does not produce a problem to the NSA facility since their Gerber Artwork Generator accepts the magnetic tape produced by the Artwork Program as input and plots the commands directly from the magnetic tape. However, the data on the output command tape produced by the Artwork Program must be punched on paper tape before it can be processed by the NASA MSFC Gerber plotter. In order to reduce the amount of paper tape produced when transferring the data from magnetic tape to paper tape, logic has been included in the conversion program to eliminate the repetitious plotter command fields.

Figure 2.1 illustrates the Gerber command sequence required to outline a particular rectangle. The commands are first given in the format produced by the Artwork Program and then given in the optimized format that would be punched on paper tape.

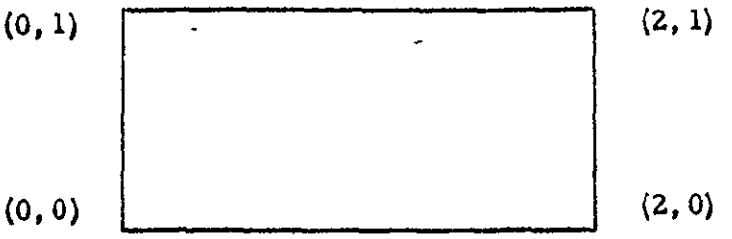
2.2 OPTIMIZATION OF GERBER CAPABILITIES

As circuit masks become more and more complex, the amount of plotting time required to produce the artwork becomes a major problem. The Banning Artwork Program has been designed to take full advantage of the various resources of the Gerber Plotter in order to optimize plotting time and accuracy. The type and size of the apertures and the fill technique used by the Artwork Program have a direct influence on both plotting time and accuracy. The following paragraphs explain how the user can control both the type of fill technique and the specific apertures employed by the Artwork Program in order to optimize the use of the Gerber Artwork Generator.

2.2.1 Apertures

The Banning Artwork Program will use any number of apertures from one to twenty-four. When more than one aperture is

GERBER COMMANDS TO OUTLINE A RECTANGLE



Format of Commands From Artwork Program

N001G01X+0000000Y+0000000D02*

N002G01X+0000000Y+0100000D01*

N003G01X+0200000Y+0100000D01*

N004G01X+0200000Y+0000000D01*

N005G01X+0000000Y+0000000D01*

Format of Commands on Paper Tape

N001G01X000000Y000000D02*

Y010000D01*

X020000*

Y000000*

X000000*

Figure 2.1

available, the program will continuously calculate the remaining area in a polygon to be filled and use the largest aperture available that does not exceed the bounds of the polygon being filled. This creates a large number of "overhead" plotter commands to continuously change the aperture; however, the commands are sorted by aperture before they are written on magnetic tape so that all the drawing is completed using a selected aperture before another aperture is selected. This gives the benefit of optimizing the use of the available apertures without sacrificing a large amount of time switching from one aperture to another.

In addition to a wide selection of judiciously sized apertures, a carefully determined arrangement of round and slit apertures is important in maximizing plotter efficiency. All Banning standard cells have been defined using masks composed entirely of rectangles, and therefore circuits designed using Banning components will produce masks composed of many small rectangular areas. Test conducted by NSA have proven that slit apertures are more efficient for filling in rectangular areas, and can result in more than a 50 percent reduction in the time required to create the artwork for a complex mask.

The user has complete control over the selection of the apertures to be used by the Artwork Program. If only one aperture is provided, care should be taken to ensure that it is small enough to provide the desired accuracy and large enough to fill polygons in a reasonable number of paint operations. In selecting the number, size, and type of apertures, the user should keep in mind that the sophisticated capabilities of the Banning Artwork Program are concerned with the following two areas:

1) Selecting the most efficient aperture available to perform each paint operation of each polygon, and

2) Breaking down complex polygons into simple rectangles so that slit apertures can be used to perform the fill-in operation.

2.2.2 Program Fill Techniques

A polygon can be outlined and filled with the plotter in many ways. Round apertures have the advantage that they can be moved in any direction and the width of the exposure will always be the same.

A narrow slit aperture is more efficient than a round one for filling in rectangular areas, if the motion is always at right angles to the slit.

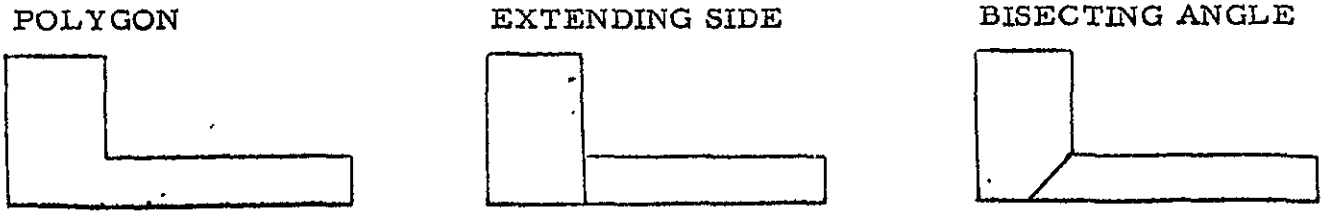
The best procedure for filling a set of complex polygons is to break up each polygon into smaller triangular and rectangular areas. The triangular areas are then outlined and filled with round apertures, and the rectangular areas are filled with slit apertures. Where extreme precision is required, each polygon is outlined accurately with a small round aperture.

Program variables are provided to allow the user to control the way in which the complex polygons are broken apart and prepared for the fill operation. The following five program variables are used to specify the combination of methods the FILL program uses to outline and fill each polygon:

- BORMAX: The BORMAX variable specifies the width of the border. This value is interpreted by the program as the depth to fill each polygon. By carefully selecting the value of BORMAX, a polygon can be filled leaving a small unfilled section in the center, or by selecting a large value for BORMAX the user can be assured that all polygons will be completely filled.

- NSQ: The NSQ variable specifies the number of slit apertures available to the Artwork Program. If the value of NSQ is greater than zero, rectangular areas will be filled with slit apertures. If the value of NSQ is zero, no slit apertures will be read in and all polygons will be filled with round apertures.

- KSMA: The variable KSMA determines the method used by the program to break up complex polygons. A positive value of KSMA results in extending one side of each re-entrant angle within the polygon. If KSMA is equal to zero, each re-entrant angle is bisected. This operation is illustrated in the figures below:



- KOUTL: If KOUTL is equal zero, the rectangles that are filled with slit apertures are not outlined. The limits of motion of the slits are increased to fill in the area that would otherwise be filled by the small round aperture if it were used to outline the rectangle. The triangular areas will be outlined and filled with round apertures in the usual way, without regard for the value of KOUTL. If KOUTL is greater than zero, all slit-filled rectangles are outlined.

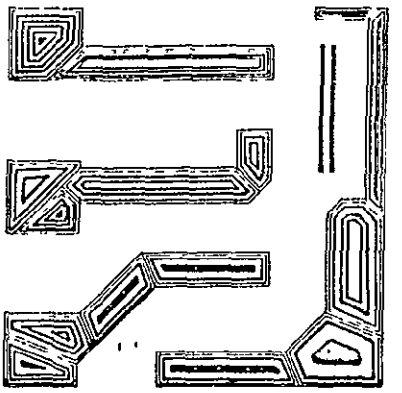
- KFSMA: If KFSMA is greater than zero, a secondary smashing operation is used during the fill. Rectangles are split off from polygons whereever possible by using a single horizontal or vertical line. Each rectangle is then filled in with slit apertures in accord with the other program options. The remaining triangles or polygons are outlined and filled with round apertures.

The five program variables can be selected to obtain eleven different types of polygon fill and outline operations, as shown by Figures 2.3 through 2.13 inclusive. Each plot was made with the proper apertures, but the scale was increased four-to-one to show the details of the aperture motion. The dark lines represent aperture paths, with the spaces between the aperture paths due to the increased plotting scale. If the scale has been used at the proper value all polygons would have been outlined and filled properly as shown in Figure 2.2.

Figure 2.2 Outline and Fill of Polygons

Figure 2.3 shows a sample of artwork produced with the options shown at the right. BORMAX = +4., means to fill to a minimum width of four inches, which is large enough to completely fill all of the polygons. NSQ = +5, KSMA = 0, means to break up the polygons by bisecting each re-entrant angle and to fill the resulting

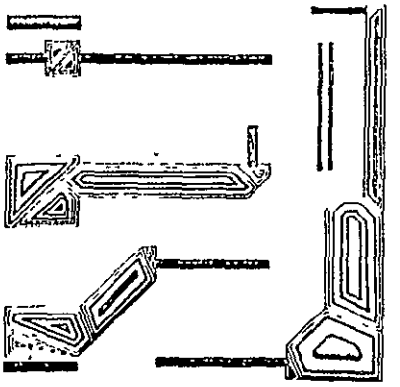
rectangles with slit apertures. KOUTL = 0, means to outline the polygons that are not rectangular with the smallest round aperture, but the rectangles are not outlined. KFSMA = 0, means that the polygons are not smashed after the re-entrant angles are bisected.



BORMAX = +4.
NSQ = +5
KSMA = 0
KOUTL = 0
KFSMA = 0

Figure 2.3 Outline and Fill of Polygons

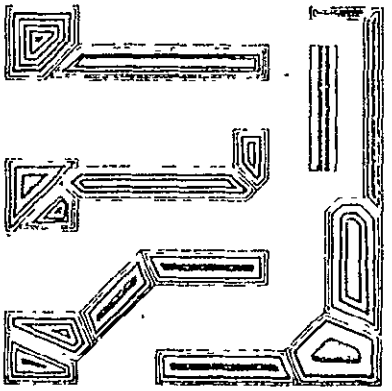
Figure 2.4 has the same option as Figure 2.3 except that KFSMA = +1 instead of 0. This means that a secondary smashing routine is applied. Rectangles are split off whenever possible, after the re-entrant angles have been bisected, and the rectangles are then filled with slit apertures, but without an outline.



BORMAX = +4
NSQ = +5
KSMA = 0
KOUTL = 0
KFSMA = +1

Figure 2.4 Outline and Fill of Polygons

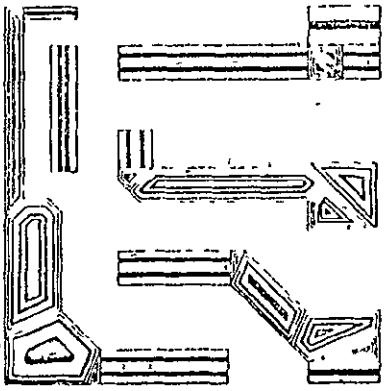
Figure 2.5 is the same as Figure 2.3 except that KOUTL = +1, instead of 0. This caused the slit-filled rectangle to be outlined.



BORMAX = +4
NSQ = +5
KSMA = 0
KOUTL = +1
KFSMA = 0

Figure 2.5 Outline and Fill of Polygons

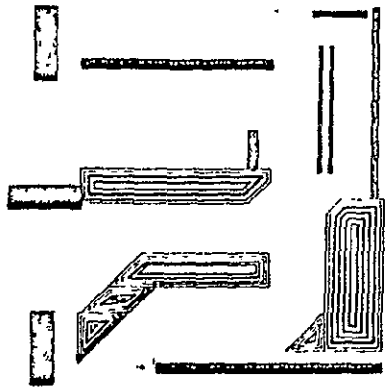
Figure 2.6 is the same as Figure 2.5 except that KFSMA = +1 instead of 0. This called for an additional smashing operation to split off as many rectangles as possible. They are outlined with a 5-mil aperture and filled with properly selected slit apertures. The image has been reversed by mistake.



BORMAX = +4.
NSQ = +5
KSMA = 0
KOUTL = +1
KFSMA = +1

Figure 2.6 Outline and Fill of Polygons

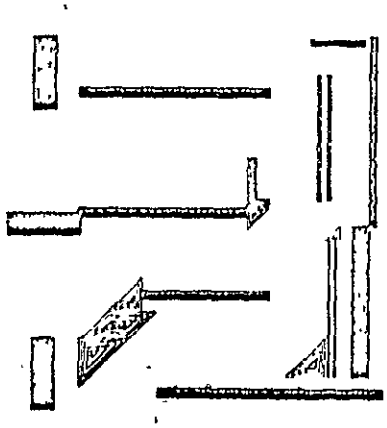
Figure 2.7 has KSMA = +1, so the polygons are smashed by extending one side of each re-entrant angle. Since KOUTL = 0 and KFSMA = 0 there are no outlines for the filled rectangles and there is no secondary smashing of the polygons.



BORMAX = +4.
NSQ = +5
KSMA = +1
KOUTL = 0
KFSMA = 0

Figure 2.7 Outline and Fill of Polygons

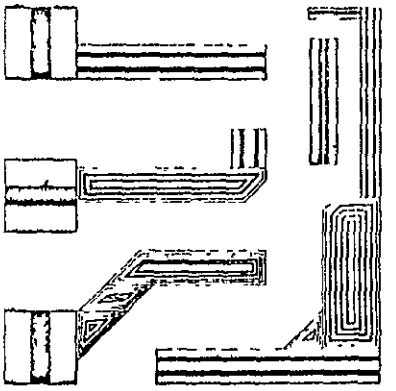
Figure 2.8 is the same as Figure 2.7 except that the secondary smashing routine is used to break up each polygon into as many rectangles as possible, using horizontal or vertical lines.



BORMAX = +4.
NSQ = +5
KSMA = +1
KOUTL = 0
KFSMA = +1

Figure 2.8 Outline and Fill of Polygons

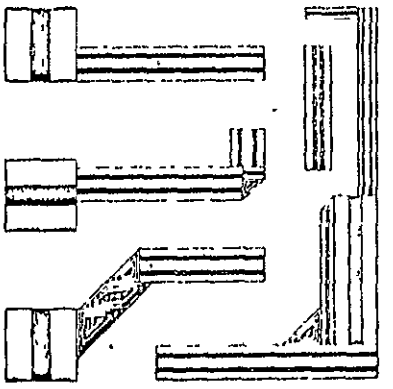
Figure 2.9 is similar to Figure 2.7 except that the rectangles are all outlined. In several cases the slits were then too wide to fit into the outlines, so two smaller slits were used instead of the wider one used in Figure 2.7.



BORMAX = +4.
NSQ = +5
KSMA = +1
KOUTL = +1
KFSMA = 0

Figure 2.9 Outline and Fill of Polygons

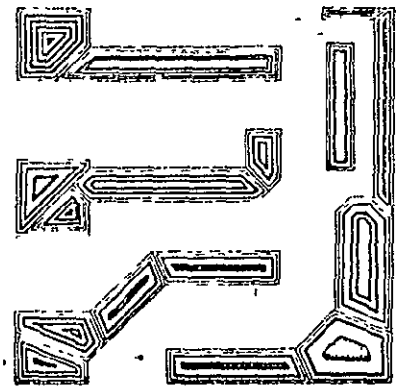
Figure 2.10 is the same as Figure 2.9 except that the secondary smashing routine has been added, KFSMA = +1.



BORMAX = +4.
NSQ = +5
KSMA = +1
KOUTL = +1
KFSMA = +1

Figure 2.10 Outline and Fill of Polygons

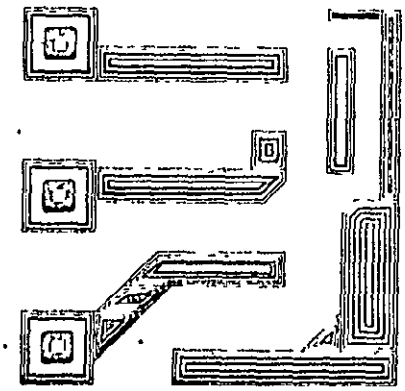
Figure 2.11 is the same as Figure 2.3 except that no slit apertures are allowed, NSQ = 0. The rectangle in the upper right part of the figure is outlined with round apertures.



BORMAX = +4.
NSQ = 0
KSMA = 0
KOUTL = 0
KFSMA = 0

Figure 2.11 Outline and Fill of Polygons

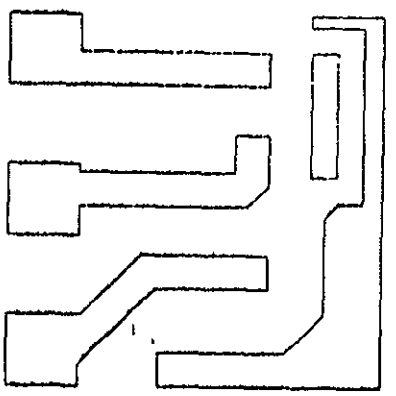
In Figure 2.12, KSMA = +1, so the re-entrant angles are eliminated by extending one side. No slit apertures are used, NSQ = 0. The secondary smashing cannot be applied when no slits are used.



BORMAX = +4.
NSQ = 0
KSMA = +1
KOUTL = 0
KFSMA = 0

Figure 2.12 Outline and Fill of Polygons

In Figure 2.13 all variables are set to zero so each polygon is outlined with a 5-mil aperture. This operation is especially useful when checking the output of the digitizer against the original drawing. This should always be done before processing the data with the outline and fill computer program.



BORMAX = 0.
NSQ = 0
KSMA = 0
KOUTL = 0
KFSMA = 0

Figure 2.13 Outline of Polygons

Table 2.2 shows a comparison of the number of commands, inches of motion, and the normalized plotter time for Figures 2.3 to 2.13. Figure 2.11 is the slowest method, where all re-entrant angles are bisected and the polygons filled with round apertures only. The plotter time has been normalized to this figure. The "inches of motion" column is for the polygons drawn to proper scale, as in Figure 2.2

Figure Number	Number of Commands	Inches of Motion	Normalized Plotter Time
2.3	420	26.2	0.98
2.4	393	20.9	0.85
2.5	425	26.6	0.99
2.6	434	23.5	0.95
2.7	201	14.9	0.51
2.8	177	10.2	0.42
2.9	252	19.6	0.67
2.10	256	17.2	0.65
2.11	431	26.8	1.00
2.12	340	25.4	0.86
2.13	48	6.4	0.15

Table 2.1 Test Results

The table shows that a reduction in plotting time was obtained whenever the smashing option (KSMA = 1) was used, the rectangle outlines were omitted (KOUTL = 0), and the fill-and-smash option was used (KFSMA = 1).

Figure 2.8 shows the greatest plotter speedup, with proper use of the options. A microscopic examination of Figure 2.8 reveals small irregularities along the sides of some of the slit-filled areas. These are attributed to double exposure due to overlap of the slits during fill-in. The size of the bulges never exceeds 1 mil, even on large areas.

Figure 2.10 uses all of the options except that rectangular outlining with a small round aperture is not suppressed. The outlining eliminates any small discontinuities that may result from the use of slits, at some sacrifice in plotting time. This type of fill-in can be used as a standard fill-in mode if the irregularities due to elimination of the outline are not acceptable.

Most of the other tests were made to compare speed and accuracy for the program options. It is unlikely that they will be used regularly for mask generation.

2.2.3 Scaling Effect on Plotting Efficiency

Choosing the scale desired for the output artwork has a direct impace on both the plotting time and accuracy. Plotting at too large a scale increases plotter time, but gives good accuracy. Plotting at too small a scale results in less accuracy and less plotter time. NSA currently uses a scale of 100X for mask plotting and a scale of 500X for cell design plotting.

In order to test the effect of changing the scale on plotter time, the conditions illustrated in Figures 2.3 through 2.13 were rerun with a five-to-one increase in final size. Table 2.3 shows the results. The slit apertures save even more time as the artwork is made larger.

2.2.4 Speedup for No Diagonal Lines

In a large number of applications, where the arrays are formed entirely from standard Banning cells, all lines are horizontal or vertical. All of the polygons can therefore be smashed into rectangles and filled using slit apertures.

Figure Number	Normalized Plotter Time	
	1 to 1 Scale	5 to 1 Scale
2.3	0.98	0.96
2.4	0.85	0.85
2.5	0.99	0.97
2.6	0.95	0.94
2.7	0.51	0.46
2.8	0.42	0.36
2.9	0.67	0.56
2.10	0.65	0.51
2.11	1.00	1.00
2.12	0.86	0.82
2.13	0.15	0.12

Table 2.3 Effect of Increasing Size of Drawing

Figure 2.14 shows an example of such a polygon, drawn full size. Figure 2.15 shows the outline and fill using the slowest method, which bisects each re-entrant angle, uses no slit apertures, does not use a supplementary smash, and fills with round apertures. The plotter time is normalized to 1.00.

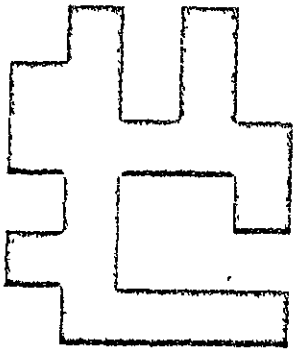
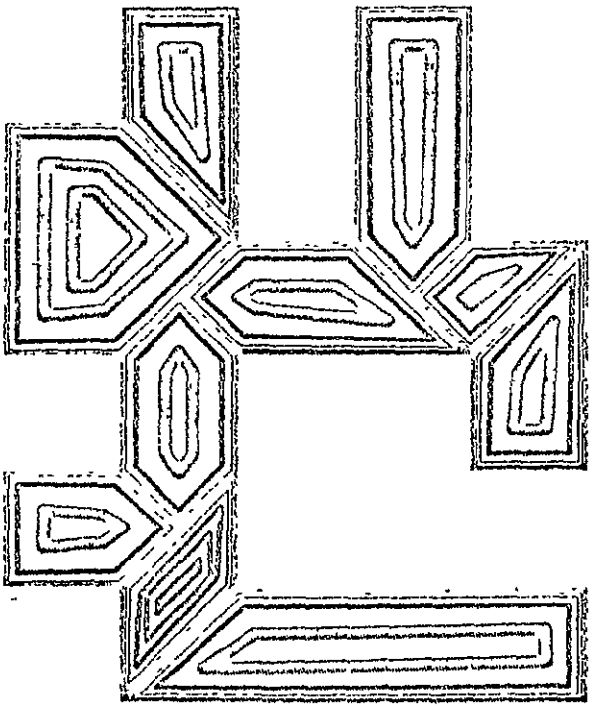


Figure 2.14 Outline and Fill of Polygon



BORMAX = +4.
NSQ = 0
KSMA = 0
KOUTL = 0
KFSMA = 0

Figure 2.15 Outline and Fill of Polygon, shown 2X actual size (Normalized Plot Time = 1.00)

Figure 2.16 shows a method of smashing, KSMA = +1, outlining, KOUTL = +1, and filling with slit apertures, NSA = +5. The normalized running time was 0.27.

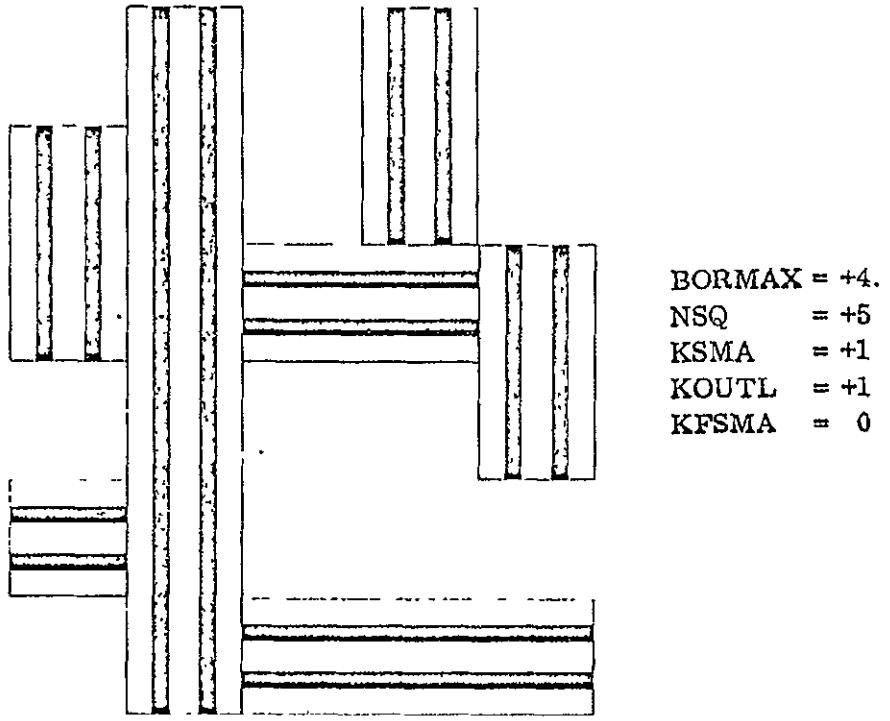


Figure 2.16 Outline and Fill of Polygon, shown 2X actual size (Normalized Plot Time = 0.27)

If the outline is omitted, KOUTL = 0, as shown by Figure 2.17, the running time is reduced to 0.12. This shows the greatest saving of plotter time that can be achieved by using the proper program options.

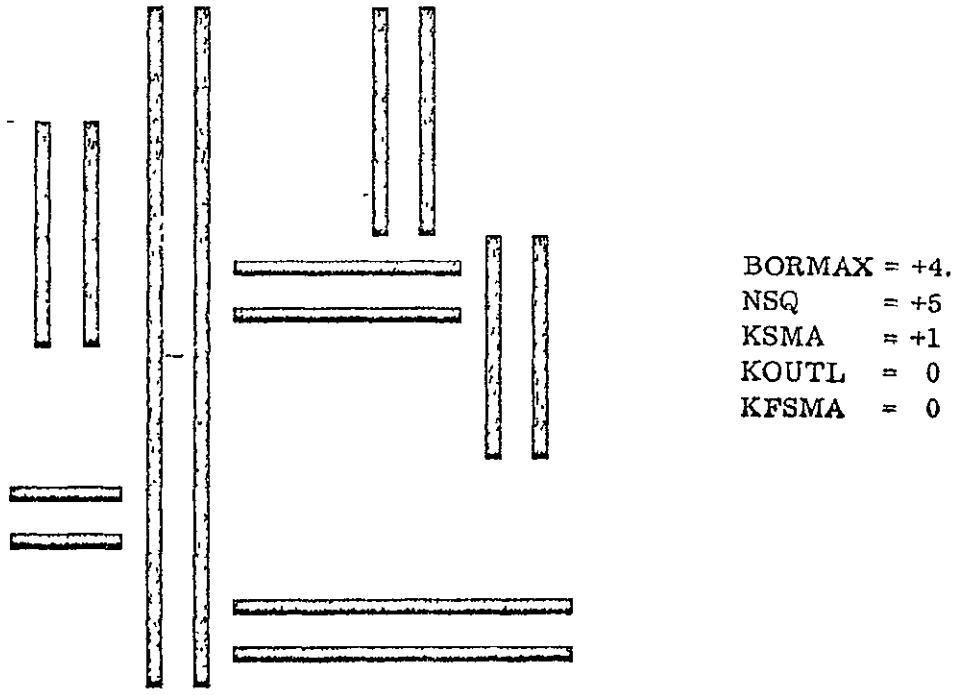


Figure 2.17 Fill of Polygon, shown 2X actual size (Normalized Plot Time = 0.12)

2.3 SUGGESTED PLOTTER COMMUNICATION FORM

The Gerber tape should be sent to the plotter activity with an instruction sheet similar to the examples shown in Figures 2.18, 2.19. The limits of the plot shown on the computer printout will aid in determining the size film required and the X- and Y-offsets. Computer plotter time for each level will also prove helpful to the plotter operator. This information will be provided by the Artwork Program as printed information at the completion of each run.

The artwork obtained from the plotter should be inspected visually, using high-power optical inspection equipment. One should look for pin holes, unfilled areas, and undesirable bulges and indentations. Most of these defects can be corrected by manual touchup.

PLOTTER INPUT NAME - - - WORK NUMBER

JOB BANNING Sample DATE June 1, 1970

NUMBER OF PAPER TAPES 1

MODE: 1.5 (2.5) 3.5 (ABSOLUTE) INCREMENTAL

SCALE 1.0 SPEED 60 in/min

STANDARD SYMBOL TAPE IN MEMORY? (Yes) No

SYMBOL SCALE SWITCH: (Auto.) Size 1, 2, 4, 8, 16

ESTIMATED PLOTTING TIME: Level 1 20 min.; Level 2 40 min.;
Level 3 11 min.; Level 4 50 min.

OPERATOR: Fill in the Actual Plotter Time Here _____.

STANDARD ROUND APERTURE LIST: (Yes) No

Position	D	Diameter
1	10	0.005
2	11	0.010
3	12	0.012
4	13	0.048
5	14	0.014
6	15	0.015
7	16	0.020
8	17	0.096
9	18	0.040
10	19	0.080
11	70	0.085
12	71	0.150
13	20	0.056
14	21	0.112

X Offset 7.0 Y Offset 7.0

SPECIAL INSTRUCTIONS:
Put down new film for each of the levels

STANDARD SLIT APERTURE LIST: (Yes) No

Position	D	Length	Orient.
15	22	0.015	H
16	23	0.026	H
17	24	0.048	H
18	25	0.091	H
19	26	0.175	H
20	27	0.015	V
21	28	0.026	V
22	29	0.048	V
23	72	0.091	V
24	73	0.175	V

H = Horizontal Slit
V = Vertical Slit

MATERIAL SIZE: X 24 Y 20

LOWER LEFT HAND CORNER AT
X = 0, Y = 0.

Figure 2.18 Sample Plotter Instruction Sheet

PLOTTER INPUT _____

JOB _____ DATE _____

NUMBER OF PAPER TAPES ___

MODE: 1.5 2.5 3.5 ABSOLUTE INCREMENTAL

SCALE _____ SPEED _____ in/min

STANDARD SYMBOL TAPE IN MEMORY? Yes No

SYMBOL SCALE SWITCH: Auto. Size 1, 2, 4, 8, 16

ESTIMATED PLOTTING TIME: Level 1 _____ min.; Level 2 _____ min.;
Level 3 _____ min.; Level 4 _____ min.

OPERATOR: Fill in the Actual Plotter Time Here _____.

STANDARD ROUND APERTURE LIST: Yes No

Position	D	Diameter

X Offset ____ Y Offset ____

SPECIAL INSTRUCTIONS:
Put down new film for each of the levels

STANDARD SLIT APERTURE LIST: Yes No

Position	D	Length	Orient.

H = Horizontal Slit
V = Vertical Slit

MATERIAL SIZE: X Y

LOWER LEFT HAND CORNER AT
X = 0, Y = 0.

Figure 2.19 Sample Plotter Instruction Sheet

SECTION III

BANNING PATTERN LIBRARY

Within the Banning System, the term pattern is used to identify the polygon or set of polygons defining the artwork required to construct a given mask. Therefore the Banning Pattern Library may be defined as the collection of polygons defining the artwork required to construct each mask of every standard Banning cell. Figure 3.1 is a drawing of the pattern defining the metalization mask of the Banning 2 Input Nor Cell. Within the Pattern Library, this pattern consists of the coordinates required to construct the six polygons that make up the pattern.

In order to describe the method in which the Artwork Program processes the pattern definitions, it is important to understand the arrangement of patterns within the Pattern Library. The following paragraphs describe the format of the Pattern Library and the facilities provided within the Artwork Program to support the update and maintenance of the Pattern Library.

3.1 PATTERN LIBRARY FORMAT

Since the Artwork Program produces the output artwork commands for one mask level at a time, the pattern library has been formatted into levels where each level contains all of the patterns defining the particular mask level of each standard Banning cell. The Artwork Program is capable of supporting up to nine levels of circuit masks, and therefore the pattern library can theoretically be divided into nine major sections. However, there are presently only six levels defined within the Banning system, resulting in the following divisions in the pattern library:

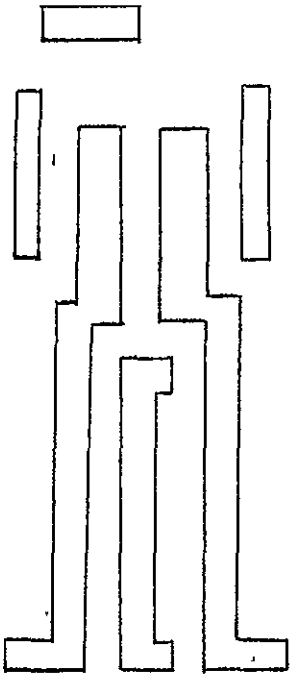
LEVEL 1 - P-REGION
LEVEL 2 - CONTACT & GATE
LEVEL 3 - CONTACT
LEVEL 4 - METAL
LEVEL 5 - SAME AS LEVEL 2 (DEEP DIFFUSION)
LEVEL 6 - PROTECTIVE COVERING

This multi-level division of the pattern library assumes that each standard Banning Cell has a particular design for each mask

EXAMPLE OF A BANNING PATTERN

METALIZATION PATTERN

FOR THE 2 INPUT NOR CELL



DESCRIPTION:

1) In the Banning system this figure is considered to be one pattern made up of six polygons.

2) In the Banning system this figure would be named "pattern number 2074 of family-pattern 2070."

Figure 3.1

level. However, there are Banning cells that appear on only one level mask or appear on every level, but use the same shape on each level. In order to facilitate the definition of cells of this type, the following numbering scheme was developed:

- 0000-9999: All Banning cells must be assigned a number within this range.

- 0000-8999: Banning cells with numbers within this range will be considered Family Patterns. That is each cell will be assigned a number with the units digit equal to zero and be broken down into mask levels with the value of the units digit specifying the level. For example, the Banning 2 Input Nor cell is defined as a family pattern and referred to as cell number 2070. The cell contains a unique pattern for each level mask with each level indicated by the unit digit of the number: 2071 for level one, 2072 for the level 2, etc.

- 9000-9599: Banning cells with numbers within this range are considered One-Level Patterns. Each cell will consist of only one pattern definition which is included in the pattern library at the level indicated by the units digit of the number assigned to the cell. For example, cell number 9034 refers to a Banning Pad that consist of one pattern on the fourth level of the pattern library.

- 9599-9999: Banning cells with numbers within this range are considered All-Level-Patterns. Each cell will consist of only one pattern definition, but it will be included on each level of the pattern library. The units digit has no significance for All-Level-Patterns. An off-chip alignment mark is a good example of an all-level-pattern.

Figure 3.2 illustrates the format of the pattern library. With this arrangement of patterns, the artwork program can position the library tape at the level being processed and have immediate access to all predefined patterns. The family-pattern concept is the most important and includes the majority of the patterns encountered. Family-patterns are specified to the Artwork Program by number, for example 2070, to be drawn at a desired location with a specified orientation. The Artwork Program then places pattern 2071 at this location for level 1 of the artwork, pattern 2072 for level 2 of the artwork, etc., continuing to the last level.

BANNING PATTERN LIBRARY

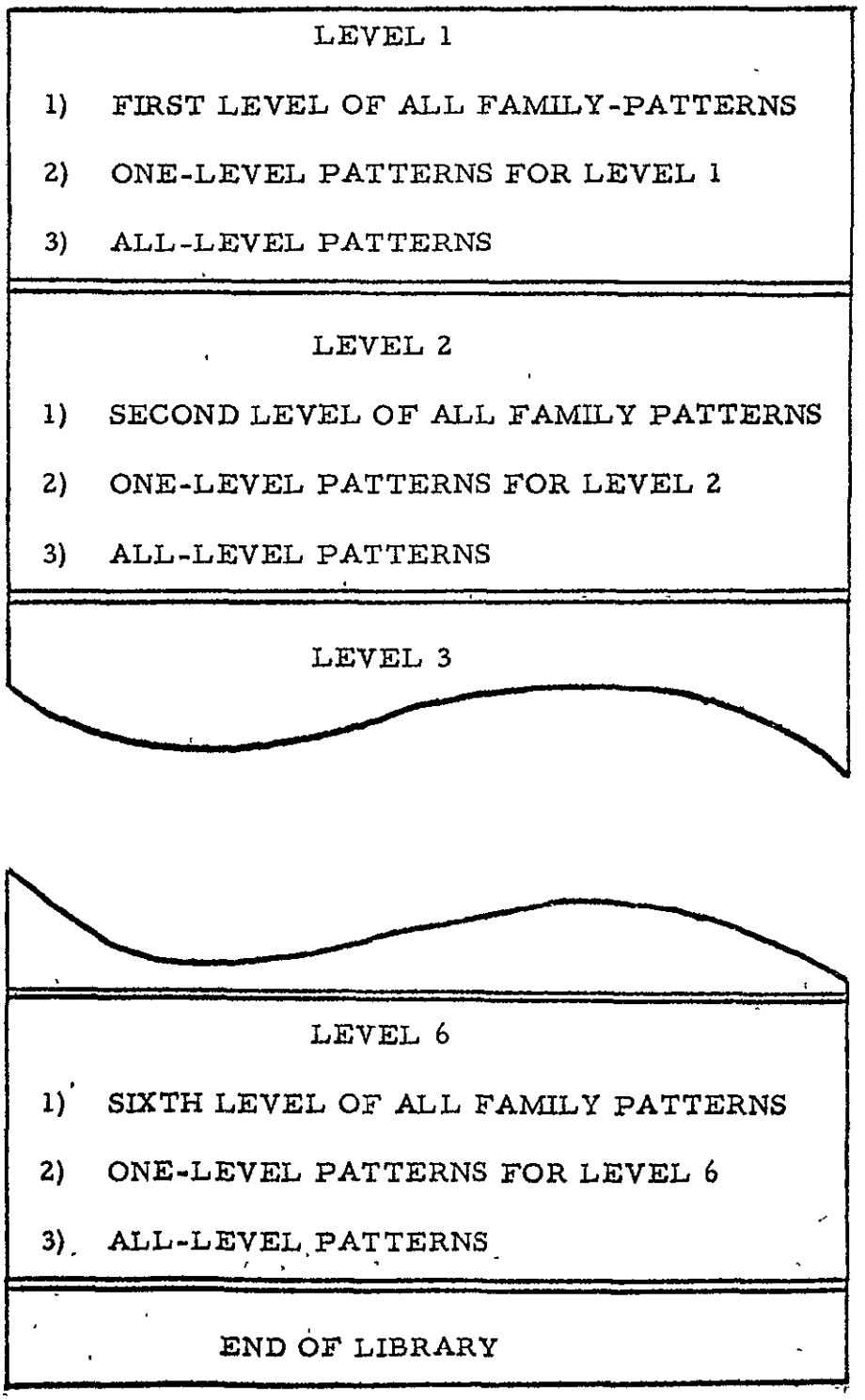


Figure 3.2

An orientation for a cell can be specified relative to the reference point. This results in every pattern defining the cell being rotated by a multiple of 90 degrees or a mirror image being taken about either the X or Y axis. Figure 3.3 presents the various orientations that may be specified.

3.2 PATTERN LIBRARY UPDATE FEATURES

Through the utility functions provided by the Artwork Program, the following capabilities exist for working with the Banning Pattern Library:

- Create the Library
- Delete Patterns from the Library
- Add Patterns to the Library
- Print the Library

Each of these capabilities is described in the following paragraphs.

3.2.1 Create the Library

The actual patterns that form the pattern library are defined by approximately 50,000 cards, each card containing the X and Y coordinate of one vertice of a polygon. A pattern may contain none, one, or more polygons. The no-polygon case defines a dummy pattern having no artwork on a particular level for family-type patterns. The cards defining the patterns on the library follow the following format:

- The first card with a new pattern number identifies the reference point of a pattern. If it is the only card of a pattern, it represents a dummy pattern. This is illustrated by the sample patterns of Figures 3.4 and 3.5.
- Following cards with the same pattern number give the vertices of each polygon in clockwise or counter-clockwise order. The beginning and ending points are repeated exactly, closing the polygon. An N-sided polygon requires N+1 cards plus a reference card. See Figure 3.5.

POSSIBLE PATTERN ORIENTATIONS

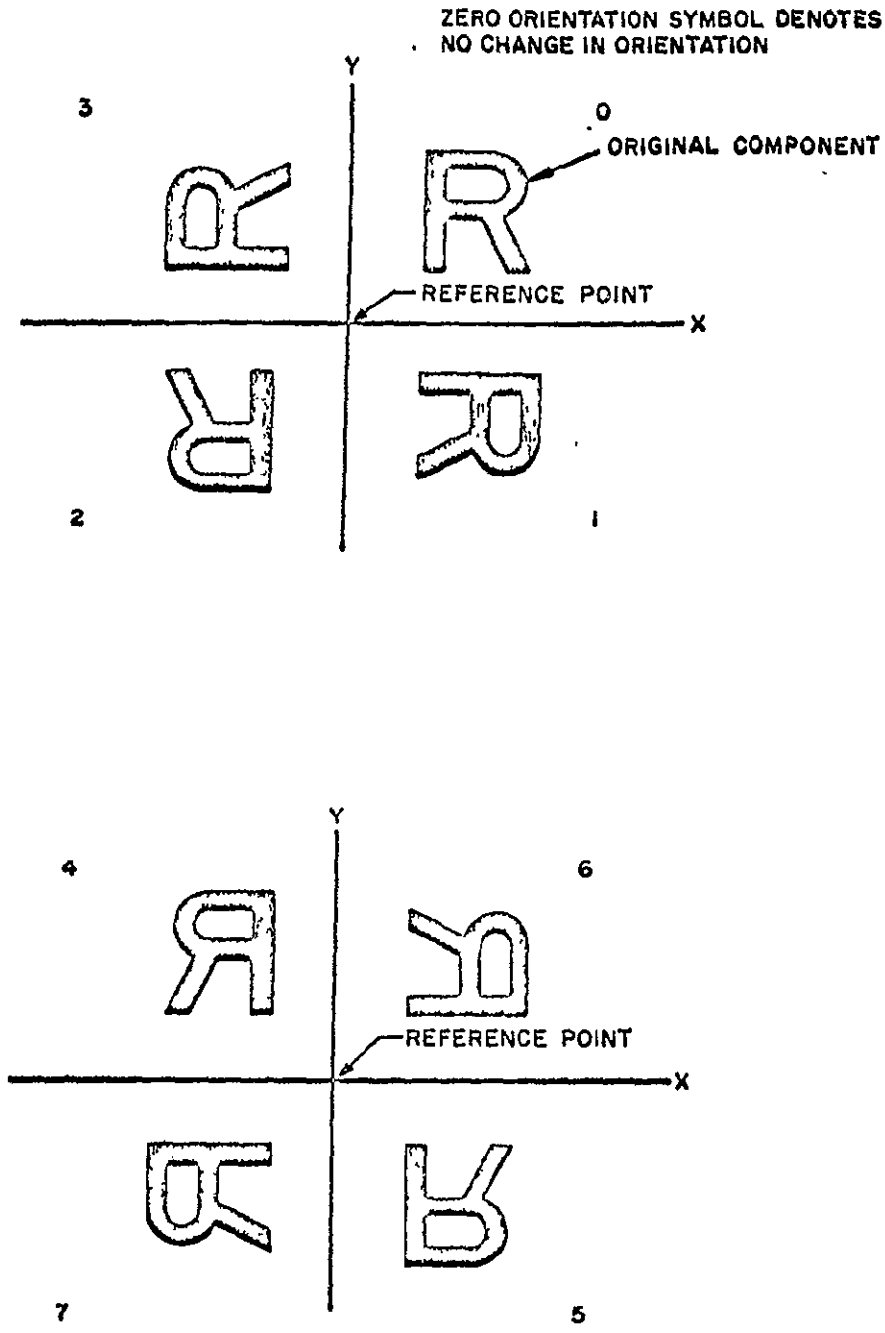


Figure 3.3

PATTERN EXAMPLES

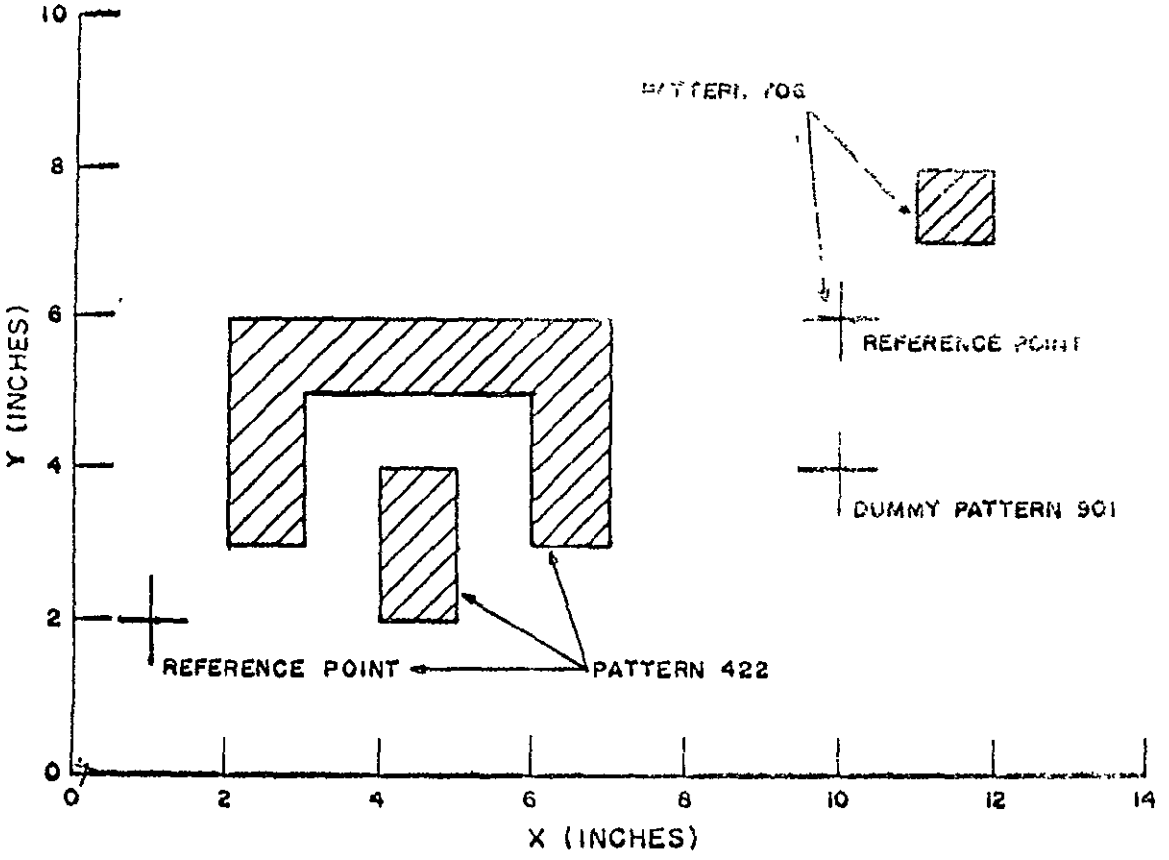


Figure 3.4

SAMPLE CARDS DEFINING PATTERNS FOR PATTERN LIBRARY

```
N422X+01000Y+02000D02*
N422X+02000Y+03000D02*
N422X+02000Y+06000D01*
N422X+07000Y+06000D01*
N422X+07000Y+03000D01*
N422X+06000Y+03000D01*
N422X+06000Y+05000D01*
N422X+03000Y+05000D01*
N422X+03000Y+03000D01*
N422X+02000Y+03000D01*
N422X+04000Y+04000D02*
N422X+04000Y+02000D01*
N422X+05000Y+02000D01*
N422X+05000Y+04000D01*
N422X+04000Y+04000D01*
```

Pattern 422

```
N901X+10000Y+04000D02*
```

Pattern 901

```
N706X+10000Y+06000D02*
N706X+11000Y+07000D02*
N706X+11000Y+08000D01*
N706X+12000Y+08000D01*
N706X+12000Y+07000D01*
N706X+11000Y+07000D01*
```

Pattern 706

NOTE 1: DØ2* = Light off, DØ1* = Light on.

NOTE 2: The N-field gives the pattern number and the X and Y-fields give the location of the vertices.

Figure 3.5

- Polygons that cross, when outlined in a clockwise or counter-clockwise manner, must be broken up into separate polygons.

- Polygons with more than 200 sides must be broken up into smaller polygons.

- Polygons with open (unfilled) areas in the center must be broken up into two or more simple filled polygons with sufficient overlap to avoid notches along the edge, or an open space where they join.

- The limit on the number of vertices in a pattern is 1/2 (2000 - Number of Polygons).

- An error printout is made if a polygon does not close during pattern loading.

- Duplicate vertex cards are eliminated and a warning printed during pattern loading.

Patterns are loaded onto the pattern library magnetic tape, within any one level, in the order in which they are defined by the input cards. However, patterns will be separated by levels in order to create the library in the format illustrated by Figure 3.2.

3.2.2 Delete Pattern from the Library

The capability exist to delete any pattern from the pattern library by specifying its number. When a pattern is deleted, all polygons making up the pattern are purged from the tape. To delete a family-pattern, all levels of the family-pattern must be deleted separately.

3.2.3 Add Patterns to the Library

Adding a pattern to the library is merely a subset of the capability to create the entire library. The patterns added are inserted at the end of their respective levels. All cards defining the polygons of the patterns to be added to the library must follow the general format described under Section 3.2.1.

3.2.4 Print the Library

The capability exists to print the contents of the pattern library. The print option begins with the first level on the tape and continues until the entire library has been printed. Printing the pattern library currently produces approximately 1000 pages of output.

SECTION IV

PROGRAM CONTROL CARDS

The Banning Artwork Program has a variety of modes of operation with each mode controlled by user supplied control cards. The flexibility incorporated within the program was essential to the type of study efforts being conducted by NSA at the time the program was developed. The program proved to be an effective tool for evaluating the various types of apertures and fill techniques discussed in Section 2 of this report. However, formats for input cards were soon standardized, an optimized selection of apertures became standard, and the most efficient plotting scale and techniques were adopted.

The user control options that were initially incorporated within the Artwork Program have remained in the program even though they are rarely used. The generalized capabilities of the Artwork Program have facilitated the implementation of the program on different computers in different facilities. During the implementation of the Artwork Program on the XDS Sigma 5 computer facility available to the Technology Division of the Astrionics Laboratory, several program-oriented options were incorporated directly into the program to eliminate specifying the options through input control cards. As the NASA-MSFC design processes and operating procedures become more standardized, additional program control options may be incorporated within the program, simplifying the designer/engineer's input control requirements even further.

The remainder of this section discusses each input card used by the Artwork Program. As each input card is discussed the value currently used by NSA will be given, where applicable, to serve as an example and as a suggested standard for adoption by the NASA facility.

4.1 RUN TITLE CARD

The title card should be the first card in the user's input control deck. The information on the card is not used by the program, but is printed as the first line of the output information. The card can contain any information that the user specifies in columns 1 through 72. The card is generally used to specify such information as the user's name, date, etc.

4.2 NUMBER OF ROUND APERTURES

The second control card specifies the number of round apertures available to the Artwork Program. The number must be a two-digit number right justified in the first two columns of the card. There must be at least one and no more than 18 round apertures specified. Cards specifying the D-number and diameter of each round aperture should follow this card. There should be one card for each aperture with the two-digit D-number specified in the first two columns of the card, and the diameter in inches specified in the next four columns. For example a card containing the following information '10.075' would specify the aperture occupying position D10 on the plotter's aperture wheele, and define the aperture as having a diameter of .075 inches. Table 4.1 lists the assortment of apertures currently used by NSA.

4.3 NUMBER OF SLIT APERTURES

The next card after the cards defining the round apertures should contain a one-digit number in column two that defines the number of slit apertures available to the Artwork Program. The number specifies the number of horizontal and vertical aperture pairs available. The total number of slit apertures can be zero or any multiple of two up to eighteen provided that the total number of round and slit apertures do not exceed the aperture wheele capacity of 24. Cards defining the D-number and length of each horizontal aperture and then each vertical aperture immediately follow this card. Table 4.1 lists the assortment of apertures currently used by NSA.

4.4 FILL OPTIONS CARD

The inputs specified on the fill options card effect the plotting scale and fill technique employed by the program. These input parameters effect both the accuracy and time used in creating the Gerber artwork. Since a detail explanation of these input variables is presented in Section 2.2 of this report, they will only be listed here in order to document their input format and their sequence within the input deck.

- KSMA: Smashing option. For best results use a one in the first column to extend sides of re-entrant polygons instead of bisecting. This will cause more rectangles to be formed and allow the use of slit apertures for reduced plotter time.

APERTURES USED BY NSA

ROUND APERTURES		SLIT APERTURES		
D-Number	Diameter (Mils)	D-Number	Length (Mils)	Orientation
D-10	5	D-18	10	Horizontal
D-11	10	D-19	15	Horizontal
D-12	20	D-20	20	Horizontal
D-13	30	D-21	25	Horizontal
D-14	40	D-22	30	Horizontal
D-15	60	D-23	45	Horizontal
D-16	80	D-24	60	Horizontal
D-17	100	D-25	100	Horizontal
		D-26	10	Vertical
		D-27	15	Vertical
		D-28	20	Vertical
		D-29	25	Vertical
		D-70	30	Vertical
		D-71	45	Vertical
		D-72	60	Vertical
		D-73	100	Vertical

Table 4.1

- KOUTL: Outline option. A one in column two will allow polygons to be outlined using the smallest round aperture.

- KFSMA: Secondary smashing option. A one is column three allows secondary smashing of nonre-entrant angle polygons into rectangle.

- SCALL: This field describes the scale of the input component placement information. This field should be set to 10.0 when using placement information from the Banning Placement-Routing-Folding program. The scale value must be specified between columns 5 through 25.

- SF: This field describes the scale of the output artwork. NSA currently uses a scale of 100X for circuit artwork and 500X for cell design artwork. The value for SF must be specified between columns 26 through 45 of the card.

- BORMAX: The BORMAX variable specifies the depth to fill polygons. If BORMAX is set to zero, patterns are outlined only. The value is normally set to a relatively large number to insure that all polygons are completely filled. The value for BORMAX must be between columns 46 through 65.

- NINL: This variable must be a two-digit number in columns 66 and 67 indicating the logical input unit for component input data. When using the artwork program in the manual mode, the logical input unit should specify the card reader. If PRF supplied input is driving the artwork program, the input unit should identify the magnetic tape unit used for the PRF output.

4.5 UTILITY CARDS

At this point within the control card input deck control is passed to the utility subroutine within the artwork program. The utility subroutine will continue to read and process control cards until it encounters a RETURN or EXIT control card. Each control card must contain one of the eight following three character control commands in the first three columns of the card:

RET - RETURN CONTROL TO THE MAIN PROGRAM
EXI - EXIT TO THE SYSTEM MONITOR
PRL - PRINT THE LIBRARY TAPE
REW - REWIND A SPECIFIED MAGNETIC TAPE

PAU - PAUSE AND PRINT MESSAGE TO OPERATOR
ENF - WRITE END-OF-FILE ON A SPECIFIED MAGNETIC TAPE
RED - REDEFINE THE FILL OPTIONS
UPL - UPDATE THE PATTERN LIBRARY

The specific use of each command is described in the following paragraphs.

4.5.1 Return Card

This card is used to direct the utility subroutine to return control to the main program. The card allows the artwork program to exit the update mode of operation and begin creating the output artwork for circuit masks. Since all cells that make up a circuit must be defined on the Banning Pattern Library, it may be necessary to add a new cell to the library using the utility update capabilities and then return to the main program which will use the new cell definition in producing the Gerber artwork commands for the generation of circuit masks.

4.5.2 Exit Card

When the utility subroutine encounters this card, control is given to the operating control system and the artwork program is terminated. If the exit card is used after the update card, the program will terminate after the update process has completed rather than returning to the main program for further processing.

4.5.3 Print Library Tape Card

This control command must be accompanied by one parameter in column eight of the card specifying the logical tape unit assigned to the pattern library. The utility program prints the contents of the pattern library, rewinds the magnetic tape, and then reads the next control card.

4.5.4 Rewind Tape Card

The magnetic tape mounted on the logical tape unit specified in column eight of the card will be rewound.

4.5.5 Pause Card

The pause card is used to stop program execution and print a message for the operator. When the pause card is read the utility

subroutine will read the next card from the input control deck and print the contents on the line printer. This capability is particularly useful when the program uses a large number of magnetic tapes, requiring that certain tapes be dismounted and fresh tapes mounted in order to complete the job.

4.5.6 Write End-of-File Card

This control card causes an end-of-file to be written on the magnetic tape mounted on the logical tape unit specified in column eight of the card.

4.5.7 Redefine Fill Options

This card allows the fill options defined in Section 4.4 to be redefined. A fill options card in the same format as described in Section 4.4 must follow this control card. This capability allows the fill options to be defined one way during the update mode of the artwork program and then be redefined for the artwork creation phase of the program.

4.5.8 Update Card

The pattern library update capabilities are explained in detail in Section 3.2 of this manual. The following section describes the control variables that must be specified to the update subroutine in order to perform the various update functions. Eleven parameters may be specified on the update control card. Each input parameter must be right justified in a five column field beginning with parameter one (P1) in columns four through eight, parameter two (P2) in columns 9 through 13, etc. Each of the eleven inputs is described below:

- P1: Parameter 1 identifies the logical tape unit of the old library tape. If the field is zero or blank, it is assumed that no old library tape exist.

- P2: Parameter 2 identifies the logical tape unit of the new library tape. If the field is zero or blank, a new library tape will not be created.

- P3: Parameter 3 specifies the logical tape unit of a work tape available to the utility program. A tape unit must be specified.

- P4 and P5: Parameters 4 and 5 define the break points used to divide the pattern library into the three divisions: Family-Pattern, One-Level Patterns, and All-Level Patterns. The format of the pattern library is presented in detail in Section 2.1, however, a warning should be made at this time concerning any redefinition of these break points. Any deviation from the library demarcation points as defined in Section 2.1 may require the redefinition of existing cells in the library.

- P6: Parameter 6 will cause the utility program to generate Gerber commands for the new patterns as they are loaded if it is set equal to a logical tape unit available to the output commands. A minus tape unit will permit the use of the special plot options (dotted line, cross hatch, etc.) by causing a special plot options card to be read as the next card. The special plot options card will be discussed later in this section. A plotter stop command is placed after each pattern to permit check plots to be made of individual patterns. If parameter 6 is zero, patterns are loaded directly without making a check-plot tape, and no checks will be made for self-intersecting polygons.

- P7: Parameter 7 specifies the number of purge cards (see Section 4.5.8.2) that follow the update card. The purge cards designate patterns to be deleted from the old library tape when the new tape is generated.

- P8: Parameter 8 specifies the first mask level to place on the new library tape.

- P9: Parameter 9 specifies the last mask level to place on the new library tape.

- P10: Parameter 10 specifies the input device unit number from which the pattern definitions should be read. This unit may be the card reader or a magnetic tape.

- P11: Parameter 11 is used to suppress printing each pattern as it is read. If the field is zero or blank the patterns will be printed; otherwise, the printing will be surpressed.

4.5.8.1 Special Plot Options Card

The special plot options card comes immediately after the update card if a negative logical tape unit has been specified for Gerber output commands. There are five special plots that can be specified:

1) Dashed outline,

2) Cross hatch,

3) Normal fill,

4) Outline only, and

5) Cross hatch.

Options 2 and 5 are identical, but the angle of inclination of the cross hatch lines may be positive for one and negative for the other, resulting in a criss-cross pattern. The first nine columns on the option card correspond to the possible nine levels of a pattern; however, only the levels used need to be specified. For example, a 1 in the first column specifies a dashed outline for level one, a blank or zero in column two bypasses level two, a five in column three specifies cross hatch lines for level three, etc.

The format of the complete option card is:

- Columns 1-9: The special plot option (1-5) associated with each mask level (1-9).
- Columns 10-12: Right justified three-digit number specifying the aperture that will draw the dashed outline.
- Columns 13-18: Approximate dash length in inches.
- Columns 19-24: Approximate gap between dashes in inches.
- Columns 25-30: Spacing between cross-hatch lines in inches.
- Columns 31-36: Angle of inclination of the cross hatch lines in degrees. A negative angle is permissible.
- Columns 37-39: Right justified three-digit number specifying the aperture that will do the cross hatching.

- Columns 40-24: Right-justified three-digit number specifying the aperture that will outline the cross hatched areas.
- Columns 43-45: Right-justified three-digit number specifying the aperture that will draw the outline when Option 4 is specified.
- Columns 46-51: Spacing between cross hatch lines is a second cross hatch option is specified.
- Columns 52-57: Angle of inclination for the second cross hatch option.
- Columns 58-60: Aperture to do the cross hatching for the second cross hatch option.
- Columns 61-63: Aperture to outline the second cross hatch area.

Figure 4.1 is an example of a special plot resulting from using a card punched as shown by Figure 4.2. Care should be taken in selecting the cross hatch line spacing value. Small values can cause a large number of lines to be generated which can result in long plotting times. It may be advantageous at times to make special option plots at a small scale.

4.5.8.2 Purge Cards

The purge cards list the pattern numbers of patterns to be deleted from the old library tape. Each pattern to be deleted must be listed separately; a delete family-pattern capability does not exist. Each pattern number to delete must be right justified in a 5-column field with the first pattern number appearing in columns 1 thru 5. The entire 80 columns of the card may be used and as many cards as needed may be used.

4.5.8.3 Pattern Cards

At this point, pattern cards are read. There are two types of patterns: polygon types defined by polygon vertices or annular ring type circle patterns defined by inner and outer radii. Patterns of similar type and scale can be loaded together. The last card of a type group is E (for end) in column one. A card with E in column one also specifies the end-of-pattern card input for the update utility when attempting to read a new type card; therefore, two E cards will be adjacent at the end of card input. Each type of pattern input is described below:

4.5.8.3.1 Circle Type Patterns

Circle patterns are defined relative to location zero. The format of the first card of each pattern is:

- Columns 1-6: CIRCLE

COMPOSIT LAYOUT OF NAND GATE

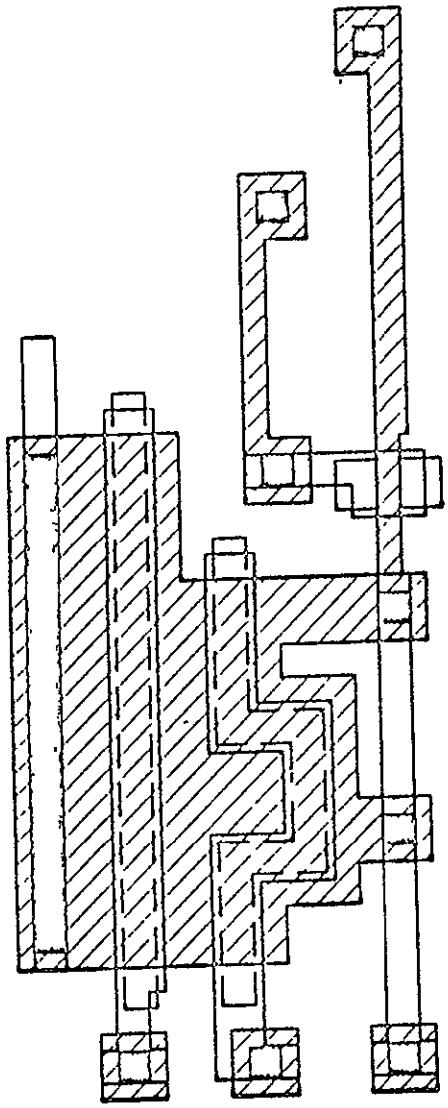


Figure 4.1

EXAMPLE OF SPECIAL PLOT OPTION CARD

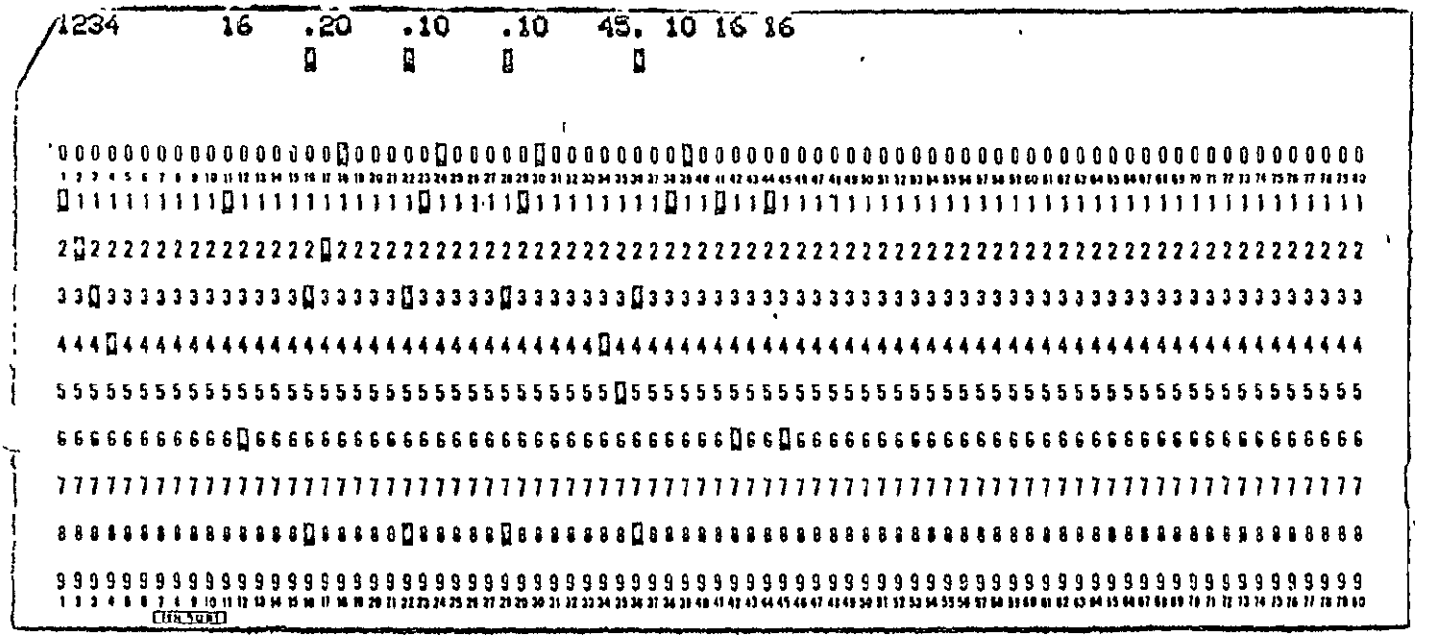


Figure 4.2

- Columns 7-11: A five-digit right-justified number indicating the number of rings in the pattern.

The remaining cards in a circle pattern are called "ring" cards with each card containing the inner and outer radius of a ring in the following format:

- Columns 1-20: Inner radius in inches. The inner radius can be zero.

- Columns 21-40: Outer radius of the ring in inches.

4.5.8.3.2 Polygon Type Patterns

A polygon-type pattern may contain none, one, or more polygons. The no-polygon case is the dummy pattern having no artwork on a particular level for family-type patterns. The format of the first card of each pattern is:

- Columns 1-6: POLY left justified

- Columns 7-11: A five-digit right-justified number indicating the scale of the following polygon cards.

The remaining cards in a polygon pattern define the vertices of the polygon and are in the following format:

EXAMPLE: $NN_1N_2N_3N_4X\pm X_1X_2X_3X_4X_5Y\pm Y_1Y_2Y_3Y_4Y_5$

The N-field begins in column one and gives the pattern number, and the X and Y fields give the location of the vertices. The general rules for defining patterns are given in Section 3.2 of this manual.

4.6 LEVEL CARD

The level card is the first control card read by the main artwork program after returning from the utility routine. The card specifies the first level to draw and the number of levels to draw including the first. This card is also used to specify the pattern library break points for the CMOS or PMOS pattern library. For PMOS the break points 8999 and 9599 must be specified. For CMOS the break points 9998 and 9999 are automatically provided and need not be specified. The format of the LEVEL card is as follows:

- Column 2: A one-digit number specifying the first level to draw.

- Column 4: A one-digit number specifying the number of levels to draw.

- Columns 5-9: First pattern library break point. If the field is left blank, the CMOS break point is assumed.

- Columns 10-14: Second pattern library break point. If the field is left blank, the CMOS break point is assumed.

4.7 TAPE CARD

The tape card specifies the pattern library tape unit and a tape unit for the Gerber output commands. The format of the tape card is as follows:

- Columns 1-3: A right-justified number specifying the pattern library tape unit.
- Columns 4-6: A right-justified number specifying the tape unit for Gerber output commands.

4.8 PATTERN SET DEFINITION

A pattern set is composed of one or more patterns and is used merely to facilitate the manual input requirements of the artwork program. PRF does not use the pattern set capabilities of the artwork program. The format of the first card of a pattern set is defined as follows:

- Columns 11-15: A right-justified pattern set number.
- Columns 16-26: The scale of the pattern set.

Pattern cards in the set are formatted according to the following example:

$$NTP_1P_2P_3P_4G01X\pm X_1X_2X_3X_4X_5Y\pm Y_1Y_2Y_3Y_4Y_5$$

The symbol T is the orientation symbol (Figure 3.3). The next four digits, $P_1P_2P_3P_4$, specify the pattern number to be placed. The X and Y-fields specify the location at which the pattern is to be placed.

The limits of the artwork program allow 50 pattern sets or a maximum of 500 patterns in all pattern sets. The last card of a pattern set must have END PATTERN SET in columns 50 through 64. The last card of the pattern sets input is a card containing END SETS in columns 50 through 58. This card is necessary even if there are no pattern sets.

4.9 COMPONENT PLACEMENT DATA

A component is either a pattern on the library tape or a pattern set. The component placement data has the same format as the pattern

set cards described above:

$$NTP_1P_2P_3P_4G01X\pm X_1X_2X_3X_4X_5Y\pm Y_1Y_2Y_3Y_4Y_5$$

The mandatory last record for component placement data is a card containing END COMPONENTS in columns 50 through 64. The limit on the number of component input records if 500. The end of each level is defined by the end level record of the form:

- Columns 50-58: END LEVEL

An end-level record is included for each level to be drawn. While searching for the end level record for a particular level, LINE set, SHAPE set, and SYMBOL records will be accepted.

4.10 LINE SET CARD

A line set is used to draw interconnect lines one aperture in width. The lines are broken into strokes with each stroke having a beginning and ending point as defined by the following format:

$$NN_1N_2N_3N_4X\pm X_1X_2X_3X_4X_5Y\pm Y_1Y_2Y_3Y_4Y_5$$

The X and Y-fields specify the starting location of a line stroke, and the X and Y-fields on the next record denote the ending location of the line stroke.

The first record of line set data must contain the words LINE SET in columns 50 through 57.

The second card of the line set data specifies the aperture for drawing the lines and the scale of the input locations in the following format:

- Columns 1-2: The aperture to draw the lines.
- Columns 3-22: The scale of the input coordinates.

The line set data must be terminated by a card containing END LINE SET in columns 50 through 61.

4.11 SYMBOL DATA

Symbol data provides a method of labeling output artwork. The first card identifying the symbol data must contain the word SYMBOL beginning in column 50 of the card.

The second card is formatted as follows:

- Columns 1-6: The X location to start the output label.
- Columns 7-12: The Y location to start the output label.
- Columns 13-14: The aperture to use in drawing the symbols.
- Column 15: An H for horizontal or a V for vertical draw.
- Columns 16-17: The symbol scale to use:

M	Size Symbol
50	0.0896 inches
51	0.1792 inches
52	0.3584 inches
53	0.7168 inches
54	1.4336 inches

- Columns 18-80: From 1 to 63 characters to be drawn

4.12 SHAPE SET DATA

A SHAPE set is used to draw one polygon of N sides. The SHAPE set records are generated by the PRF Program to describe the datum or scribe-line border around the array. Since the dimensions of this border vary with each array, it cannot be a standard pattern on the library tape.

The first card identifying the start of shape set data must contain the words SHAPE SET in columns 50 through 58. The second card of shape set data specifies the number of sides on the polygon and the scale of the input points. The format of the second card is as follows:

- Columns 1-3: Number of sides of the polygon
- Columns 4-23: Scale of the input points

The remaining cards of the shape set data specify the vertices of the polygon in the same format used to define line set interconnect data.

SECTION V

EXAMPLES OF CONTROL CARD SETUP

This section describes the control card variations necessary to use the Artwork Program with manually supplied input data or with input data supplied by the Placement-Routing-Folding program. The Banning Test Chip supplied by NSA is used to illustrate the use of the program from manual layout data. The control card modifications required to create the same test chip using the automatic placing and routing capabilities of the PRF program are then discussed.

5.1 MANUAL MODE ARTWORK

The Artwork Program can accept input from layouts made by hand rather than by the PRF program. When used in this mode, layouts are made on grid sheets and digitized to produce cards for program input. If a digitizer is not available, cards can be punched by hand to build up the pattern files.

In order to minimize preparation of computer input, the PATTERN SETS feature should be investigated. This feature allows a number of patterns from the library to be combined to form a larger, more complicated, pattern. An example of this would be in grouping a number of transistors tunnels and resistors to make a gate. Calling for this pattern-set component to be placed would place all of the basic patterns composing the pattern set. The following paragraphs explaining the creation of the Banning Test Chip from manual layout data illustrate how pattern sets can be effectively used to reduce manual input requirements.

Each of the six 1000X parts of the Banning Test Chip composite layout was assigned an identification letter and a family pattern number, as shown by Figure 5.1. Each level of each section was digitized to produce a deck of cards containing all of the details except the locations and orientations of the standard cells. Each section was referenced to location (0, 0).

The standard-cell patterns of Table 5.1 were used in the test chip. The two special patterns -

6600 = Border for scribing
9001 = Alignment keys

were added and a special library pattern tape was produced.

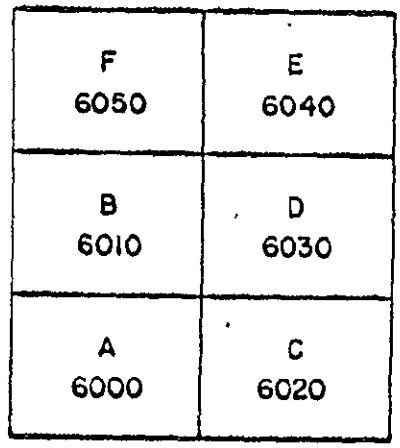


Figure 5.1 Pattern Numbers and Identification Symbol

Pattern Number	Name
0020	Inverter with ϕ_2 clock connection
0140	Two-input NAND with ϕ_2 clock connection
0170	Internal buffer
0190	DC output buffer to drive 15 pF
0210	Precharged buffer
0350	Shift register, C_L = 4
0390	Shift register, C_L = 4, ϕ_1 available

Table 5.1 Patterns Used on Test Chip

The locations and orientations of the standard patterns were also digitized to produce component location and orientation commands. The artwork generator program was then used to combine the two sets of digitized outputs to produce the complete pattern sets, in accord with Table 5.2.

Section	Pattern Set
A	6000
B	6010
C	6020
D	6030
E	6040
F	6050

Table 5.2 Location of Pattern Sets

Component placement cards were prepared to place each of the pattern sets at the correct location for each section, plus the border for scribing (pattern 6600) at (0, 0). The alignment keys (pattern 9001) were also placed on the mask. Since it was desired to have 18 inches between the alignment keys on both the 60X and 100X final plots, adjustment was necessary both in the scale of the alignment keys and in the 1000X location at which they were placed, if the keys were to center on the plot. Table 5.3 shows the values used.

Final Plot Scale	Scale of Pattern 9001	Placement
60X	50X	X = -4.0, Y = -9.0
100X	83.3333X	X = 13.2, Y = 10.0

Table 5.3 Placement and Scale of Alignment Keys

When the pattern sets had been assembled, it was necessary to move them to the proper locations, as shown by Table 5.4.

Pattern	X-Coordinate	Y-Coordinate
5000	0.0	0.0
5010	0.0	28.4
5020	41.9	0.0
5030	34.6	28.4
5040	34.4	50.2
5050	0.0	50.2

Table 5.4 Placement of Pattern Sets

The listing in Figure 5.2 represents the control cards that were used to make the 100X plot of the test chip. Figure 5.3 presents the definition of the pattern sets used in the test chip and lists the components used to construct the chip. Figures 5.4 to 5.7 inclusive show the 60X artwork that was produced on the Gerber Artwork Generator.

CONTROL CARDS USED TO CREATE THE BANNING TEST CHIP FROM MANUAL LAYOUT DATA

1) Title Card

2) Number of Round Apertures

*** Round Aperture Definition Cards

3) Number of Slit Apertures

*** Horizontal Aperture Definition Cards

*** Vertical Aperture Definition Cards

4) Fill Options Card

5) Library Update Card

*** Digitizer or User Created Pattern Definition Cards

6) Return Card

7) Level Card

8) Tape Card

9) Pattern Set Definitions

10) Component Placement Data

11) Symbol Data

12) End Level Card

13) Symbol Data

14) End Level Card

15) Symbol Data

16) End Level Card

17) Symbol Data

18) End Level Card

Figure 5.2

PATTERN SETS AND COMPONENTS

```
            5CCC1CCC.                                  Pattern Set 5000
^CC35CGC1* 1C6CCY 11CCCC02*C55D03*                     Scale = 1000
^CCC2CCC1* 17CCCY 11CCCC02*G55D03*
^CCC2CGC1* 243CCY 11CCCC02*G55D03*
^CCC2CGC1* 313CCY 11CCCC02*G55C03*
^CCC2CGC1* 3E3CCY 11CCCC02*G55D03*
^C6CCC
                                                          END PATTERN SET
            5C1C1CCC.                                  Pattern Set 5010
^C6C1C                                                 Scale = 1000
^2C17CGC1* 146CCY 1C4CCC02*G55C03*
^2CC2CGC1* 2C9CCY 1C4CCC02*G55C03*
^2C17CGC1* 26ECCY 1C4CCC02*G55C03*
^2CC2CGC1* 347CCY 1C4CCC02*G55D03*
                                                          END PATTERN SET
            5C2C1CCC.                                  Pattern Set 5020
^C6C2C                                                 Scale = 1000
^CCC2CGC1* C34CCY 11CCCC02*G55C03*
^CCC2CGC1* 1C7CCY 11CCCC02*G55C03*
^CCC2CGC1* 145CCY 11CCCC02*G55C03*
^CCC2CGC1* 1E3CCY 11CCCC02*G55D03*
^CCC2CGC1* 221CCY 11CCCC02*G55C03*
                                                          END PATTERN SET
            5C3C1CCC.                                  Pattern Set 5030
^C6C3C                                                 Scale = 1000
^2C15CGC1* 11CCCY 1C4CCC02*G55C03*
^2C21CGC1* 1F6CCY 1C4CCC02*G55C03*
^2C14CGC1* 246CCY 1C4CCC02*G55D03*
                                                          END PATTERN SET
            5C4C1CCC.                                  Pattern Set 5040
^C6C4C                                                 Scale = 1000
^CCC2CGC1* CC6CCY CC2CCC02*G55C03*
^CCC2CGC1* 226CCY CC2CCC02*G55C03*
^CCC2CGC1* 292CCY CC2CCC02*G55C03*
^CC35CCC1* 126CCY CC2CCC02*G55C03*
^CC17CGC1* C73CCY CC2CCC02*G55C03*
                                                          END PATTERN SET
            5C5C1CCC.                                  Pattern Set 5050
^C6C5C                                                 Scale = 1000
^CCC2CGC1* 216CCY CC2CCC02*G55C03*
^4CC2CGC1* 216CCY CC2CCC02*G55C03*
^CC17CGC1* 252CCY CC2CCC02*G55C03*
                                                          END PATTERN SET
                                                          END SETS

^C5CCCCC1*      Y
^C5C1CGC1*      Y 284CC
^C5C2CGC1* 415CCY CCCCC
^C5C3CGC1* 246CCY 284CC
^C5C4CCC1* 344CCY 5C2CC
^C5C5CGC1* CCCCCY 5C2CC
^C6CCC
^C5CG1     128CC  1CCCC                                 END COMPONENTS
```

Figure B.1

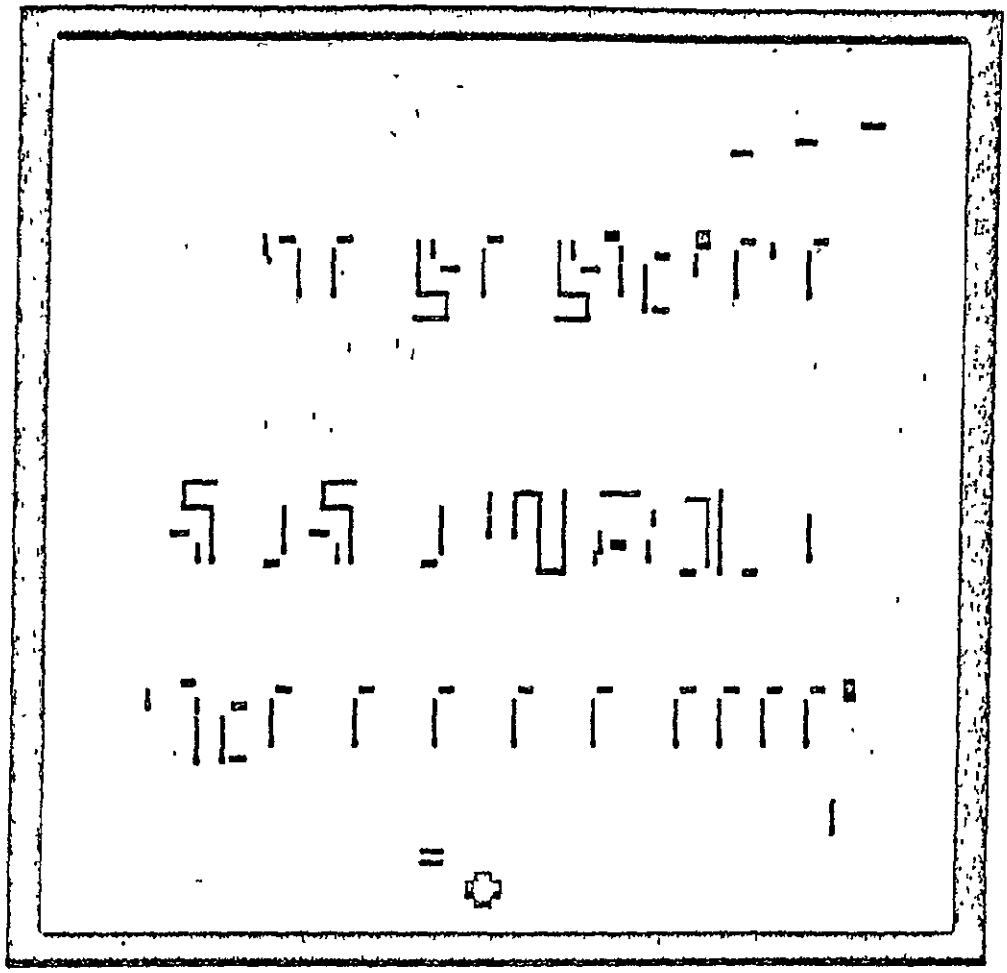


Figure 5.4 BANNING Test Chip, Level 1
(Alignment marks and symbol label are not shown.)

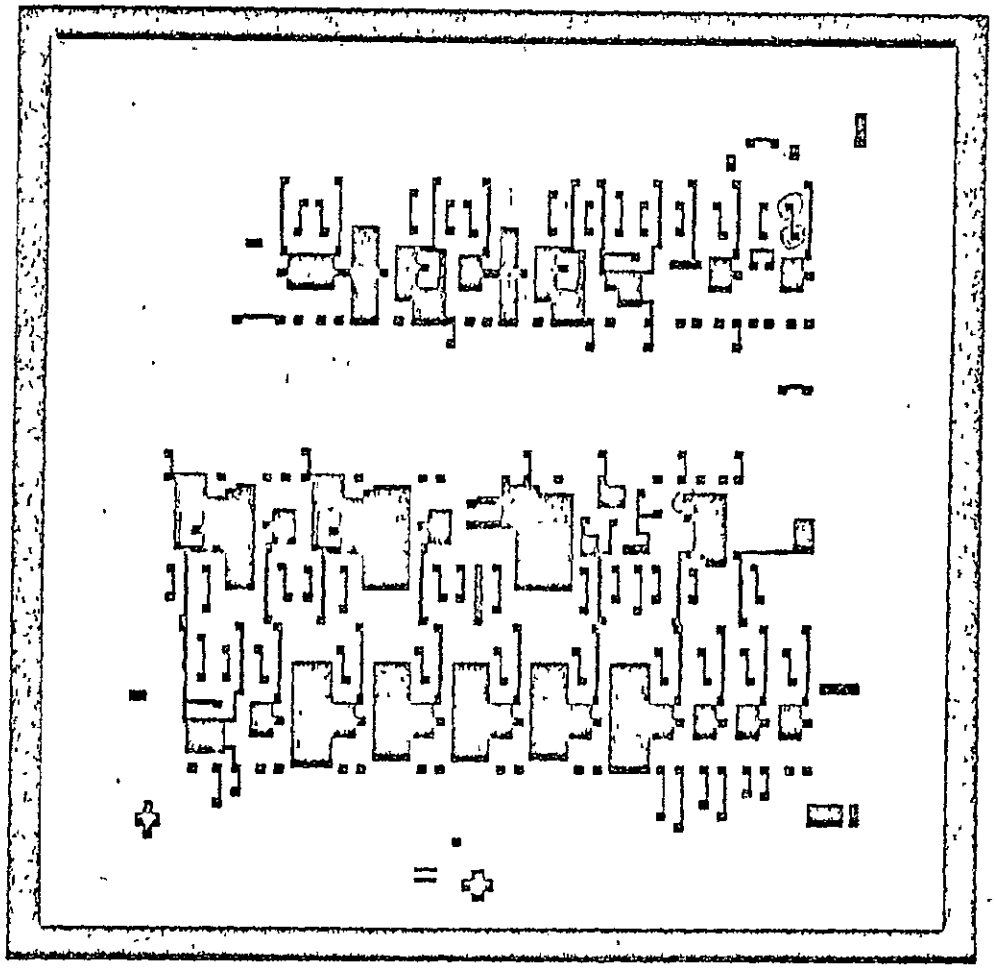


Figure 5.5 BANNING Test Chip, Level 2
(Alignment marks and symbol
label are not shown.)

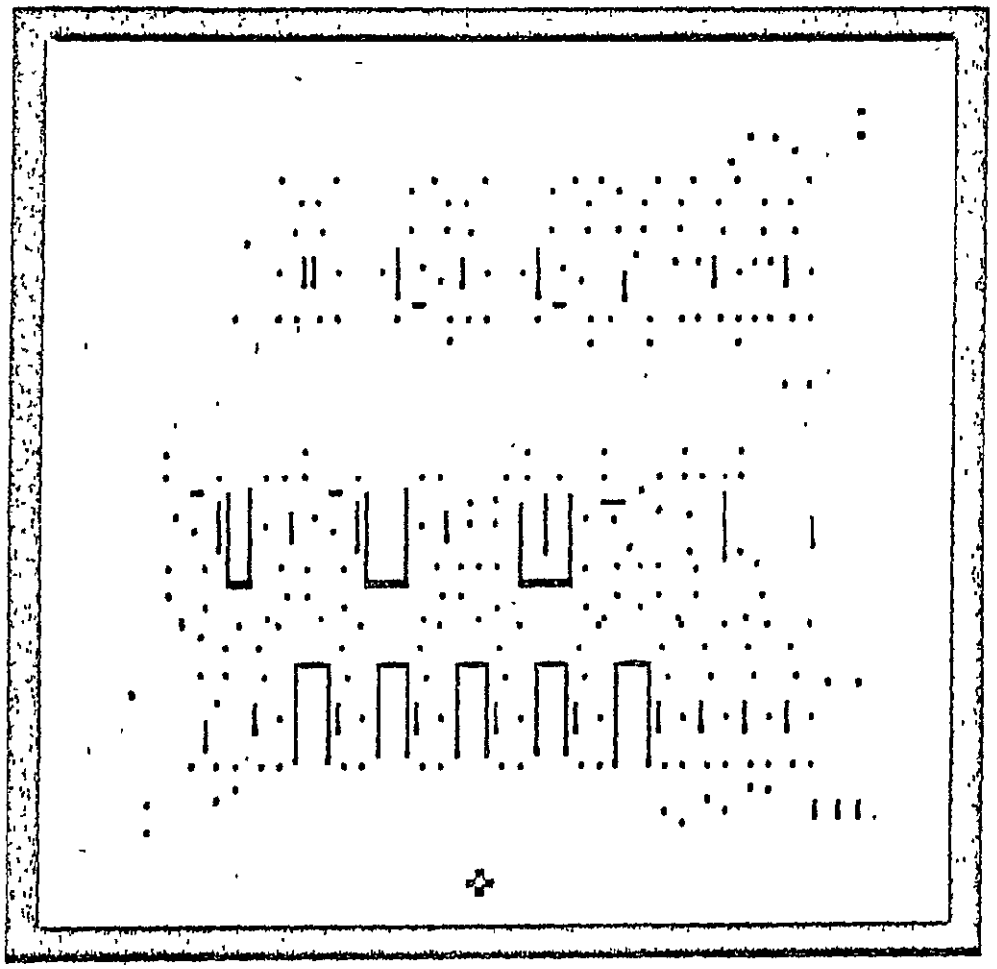


Figure 5.6 BANNING Test Chip, Level 3
(Alignment marks and symbol
label are not shown.)

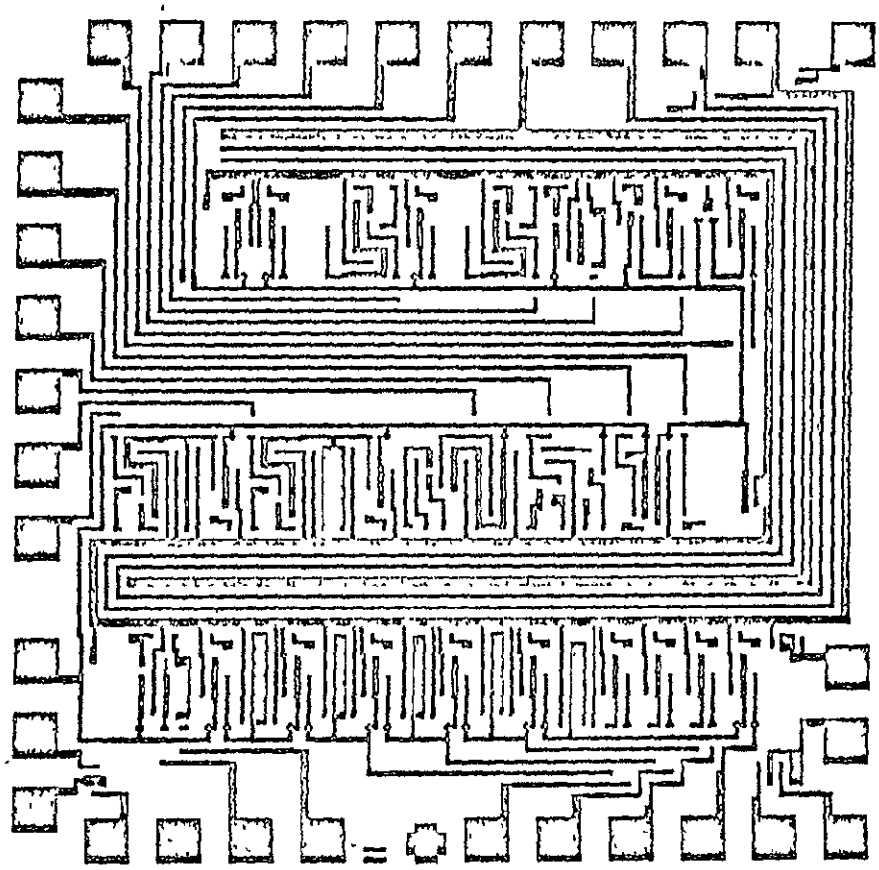


Figure 5.7 BANNING Test Chip, Level 4
(Alignment marks and symbol
label are not shown.)

5.2 PRF MODE ARTWORK

The output from the Placement-Routing-Folding, PRF, Program contains the placement and orientation information for the components which, in this case, are the patterns used from the library tape. It also contains the line-set information to draw the interconnections, the shape-set information to draw the datum or scribe line around the chip, the symbol records to label each level of the plot and a record to place a pattern containing the alignment keys for the step-and-repeat photo-reduction operation.

Assuming that each cell used in building the Banning Test Chip is a standard cell that is defined in the Banning Pattern Library, the following operations may be omitted from an artwork run using PRF supplied input:

- The two special patterns, 6600 and 9001, that define the border for scribing and the alignment keys will be supplied automatically by PRF so they need not be defined manually.

- The division of the test chip into six parts was made in order to create cells 6000, 6010, 6020, 6030, 6040, and 6050 defining the interconnect information. Since the interconnect information is supplied automatically by the PRF program in the form of LINE SET data, the definition of these six cells can be omitted.

- The component placement information is supplied by the PRF program. Therefore the pattern set definitions and component placement information need not be supplied by the user.

- The SYMBOL data and END LEVEL cards for each level will automatically be supplied by the PRF program.

The listing in Figure 5.8 represents the control cards that should be used to create the Banning Test Chip from inputs supplied by the PRF program.

CONTROL CARDS USED TO CREATE THE BANNING TEST CHIP FROM PRF INPUT

1) Title Card

2) Number of Round Apertures

    *** Round Aperture Definition Cards

3) Number of Slit Apertures

    *** Horizontal Aperture Cards

    *** Vertical Aperture Cards

4) Fill Options Card

5) Return Card (No Library Update is Required)

6) Level Card

7) Tape Card

    *** PRF Supplied Input

Figure 5.8

SECTION VI

EXAMPLE OF ARTWORK PROGRAM OUTPUT

Figure 6.1 illustrates the type of output supplied by the Artwork Program. The printed output supplies important information concerning the output produced for the Gerber plotter. This printed output can serve as a record of the type of run and the program options used in creating the output artwork. Figure 6.1 only supplies information for the first level of artwork generated, however, a complete printed output would provide similar information for every level of output produced.

The first page of the printed output prints the job title, the apertures specified for this run, and the program options selected by the fill options card.

The second page of output list the operations performed by the utility subroutine, the contents of the level control card, and the contents of the tape control card. If pattern sets had been used their definitions would have appeared on this page in the same format as illustrated in Figure 5.3. However, in this example the END SETS statement signifies that pattern sets were not used.

The third and fourth pages of the printed output list the component input information supplied to the Artwork Program.

Pages 5 and 6 list the first level mask of each component. The masks or patterns are listed first in order of their specification to the Artwork Program and then in the order in which they are processed by the program.

The last page of each level of output will supply plotting statistical data. This data should be given to the plotter operator so that he can estimate the size film required for the artwork output. The plot time statistics will provide the operator with sufficient information for scheduling the plotter activities.

BANNING TEST RUN

```
ROUND APERTURES
D10       DIA.        0.50001000E-02
D11       DIA.        0.10000000E-01
D12       DIA.        0.12000000E-01
D14       DIA.        0.14000000E-01
D15       DIA.        0.17000000E-01
D16       DIA.        0.24000000E-01
D18       DIA.        0.40000000E-01
D13       DIA.        0.48000000E-01
D20       DIA.        0.50000000E-01
D19       DIA.        0.40001000E-01
D70       DIA.        0.15000000E-01
D17       DIA.        0.96000000E-01
D21       DIA.        0.11200000E 00
D71       DIA.        0.15000000E 00

 5X2 RECTANGULAR APERTURES
HORIZONTAL
D22       LENGTH      0.15000000E-01
D23       LENGTH      0.20000000E-01
D24       LENGTH      0.46000000E-01
D25       LENGTH      0.91000000E-01
D26       LENGTH      0.17500000E 00

VERTICAL
D27       LENGTH      0.15700000E-01
D28       LENGTH      0.20000000E-01
D29       LENGTH      0.46000000E-01
D72       LENGTH      0.91000000E-01
D73       LENGTH      0.17500000E 00

OPTIONS
SMASH 1
OUTLINE 1
RECTANGLE SMASH 1

LOC. SCALE      0.10000000 02          SCALE    0.50000000E 02          NORMAX    0.                    DATA TRUNK  5
```

Figure 6.1

(Page 1 of 7)

```
                                                    RANNING UTILITY ROUTINE
OPERATION RET    =0    =0    =0    =0    =0    =0    =0    =0    =0
RETURN TO MAIN PROGRAM.



FIRST LEVEL 1.LEVELS TO DRAW 4.PATTERN NUMBER BREAK POINTS  8999 9599
LIBRARY TAPE TRUNK  10 ;;        OUTPUT TAPE TRUNKS   9 =0 =0 =0
                                                    END SETS.
```

Figure 6.1

(Page 2 of 7)

PATTERN	ORIENTATION	X	Y
9004	5	0.11000	0.07600
9004	5	0.17000	0.07600
9004	5	0.23000	0.07600
9004	5	0.29000	0.07600
9004	5	0.35000	0.07600
9004	5	0.41000	0.07600
210	0	0.11000	0.21400
10	4	0.22400	0.21400
60	4	0.27200	0.21400
60	0	0.27200	0.21400
80	4	0.40200	0.21400
190	0	0.40800	0.21400
210	0	0.52200	0.21400
350	4	0.66400	0.21400
10	4	0.69900	0.21400
10	4	0.73700	0.21400
370	4	0.81800	0.21400
7010	0	0.52600	0.15500
7010	0	0.71100	0.15500
7010	0	0.19800	0.16400
7010	0	0.21400	0.16400
7010	0	0.27600	0.18200
7010	0	0.46800	0.18200
7010	0	0.57400	0.18200
7010	0	0.35000	0.20000
7010	0	0.36800	0.20000
7010	0	0.39000	0.20000
7010	0	0.67300	0.20000
7010	0	0.72700	0.20000
420	2	0.29800	0.46400
60	2	0.34600	0.46400
10	2	0.39400	0.46400
10	2	0.80400	0.46400
10	2	0.84200	0.46400
7010	0	0.49000	0.46900
7010	0	0.50600	0.46900
7010	0	0.17600	0.47800
7010	0	0.55800	0.47800
7010	0	0.68400	0.47800
7010	0	0.70000	0.47800
7010	0	0.71600	0.47800
7010	0	0.29400	0.48700
7010	0	0.50600	0.48700
7010	0	0.81600	0.48700
7010	0	0.17600	0.49600
7010	0	0.32400	0.50500
7010	0	0.49000	0.50500
7010	0	0.12400	0.51400
7010	0	0.29400	0.51400
7010	0	0.77800	0.51400
7010	0	0.68400	0.52300
7010	0	0.71600	0.52300
7010	0	0.54000	0.53200
7010	0	0.70000	0.55000
7010	0	0.65800	0.55900
7010	0	0.74200	0.55900
10	0	0.11000	0.62700
190	0	0.14800	0.62700
250	0	0.26100	0.62700
10	0	0.29100	0.62700
190	4	0.43600	0.62700

Figure 6.1

```
 190        4          0.55000      0.62700
 150        4          0.64300      0.62700
 150        4          0.73600      0.62700
 250        4          0.74600      0.62700
  80        0          0.77200      0.62700
7010        0          0.56500      0.56800
7010        0          0.31700      0.58600
7010        0          0.78400      0.58600
7010        0          0.82400      0.58600
7010        0          0.12000      0.59500
7010        0          0.67200      0.60400
7010        0          0.72800      0.60400
7010        0          0.31700      0.61300
7010        0          0.70800      0.61300
7010        0          0.84000      0.61300
7010        0          0.65800      0.63100
9004        4          0.17000      0.60600
9004        4          0.23000      0.60600
9004        4          0.29000      0.60600
9004        4          0.35000      0.60600
 420        5          0.38400      0.46400
 420        5          0.57600      0.46400
9004        0          1.04100      0.30000
9004        0          1.04100      0.42200
9004        0          1.04100      0.54400
9004        0          1.04100      0.66600
                                                END COMPONENTS
```

Figure 6.1

LEVEL 1 PATTERN	ORIENTATION	X	Y
211.	5	0.66000	1.28400
11	4	1.34400	1.28400
61	4	1.63200	1.28400
61	3	1.63200	1.28400
61	4	2.41200	1.28400
191	5	2.44800	1.28400
211	5	3.13200	1.28400
551	4	3.08400	1.28400
11	4	4.19400	1.28400
11	4	4.42200	1.28400
371	4	4.90800	1.28400
7011	3	3.15600	0.93000
7011	0	4.26600	0.93000
7011	0	1.16800	0.88400
7011	5	1.28400	0.88400
7011	5	1.66800	1.09200
7011	0	2.00400	1.09200
7011	0	3.44400	1.09200
7011	0	2.10000	1.20000
7011	0	2.70000	1.20000
7011	0	2.34000	1.20000
7011	0	4.03200	1.20000
7011	0	4.36200	1.20000
421	2	1.78800	2.78400
61	2	2.07600	2.78400
11	2	2.30400	2.78400
11	2	4.82400	2.78400
11	2	5.05200	2.78400
7011	0	2.94000	2.81400
7011	0	3.03600	2.81400
7011	0	1.05600	2.86800
7011	0	3.34800	2.86800
7011	0	4.10400	2.86800
7011	0	4.20000	2.86800
7011	0	4.29600	2.86800
7011	0	1.76400	2.92200
7011	3	3.03600	2.92200
7011	0	4.29600	2.92200
7011	0	1.05600	2.97600
7011	0	1.94400	3.03000
7011	0	2.04000	3.03000
7011	0	0.74400	3.08400
7011	0	1.76400	3.08400
7011	0	4.66800	3.08400
7011	0	4.10400	3.13800
7011	0	4.29600	3.13800
7011	0	3.24000	3.19200
7011	0	4.20000	3.19200
7011	0	3.94800	3.35400
7011	0	4.57200	3.35400
11	0	0.66000	3.76200
191	0	0.88800	3.76200
251	0	1.56600	3.76200
11	0	1.74000	3.76200
191	0	2.61600	3.76200
191	0	3.30000	3.76200
151	0	3.85800	3.76200
151	0	4.41600	3.76200
251	0	4.59600	3.76200
11	0	4.63200	3.76200
7011	0	3.39000	3.40800

Figure 6.1

7011	0	1,90200	3,51600
7011	0	4,70400	3,51600
7011	0	4,94400	3,51600
7011	0	0,72000	3,57000
7011	0	4,03200	3,62400
7011	0	4,36800	3,62400
7011	0	1,90200	3,67800
7011	0	4,24800	3,67800
7011	0	5,04000	3,67800
7011	0	3,94800	3,78600
421	5	2,30400	2,78400
421	5	3,46800	2,78400

PATTERNS IN ORDER OF OUTPUT FROM LIBRARY

PATTERN	211	0	X	0,66060	Y	1,28400
PATTERN	211	0	X	3,13200	Y	1,28400
PATTERN	351	4	X	3,98400	Y	1,28400
PATTERN	371	4	X	4,90800	Y	1,28400
PATTERN	11	4	X	1,34400	Y	1,28400
PATTERN	11	4	X	4,19400	Y	1,28400
PATTERN	11	4	X	4,42200	Y	1,28400
PATTERN	11	2	X	2,30400	Y	2,78400
PATTERN	11	2	X	4,92400	Y	2,78400
PATTERN	11	2	X	5,05200	Y	2,78400
PATTERN	11	0	X	0,66000	Y	3,76200
PATTERN	11	0	X	1,74600	Y	3,76200
PATTERN	151	4	X	3,85800	Y	3,76200
PATTERN	151	4	X	4,41600	Y	3,76200
PATTERN	421	2	X	1,78800	Y	2,78400
PATTERN	421	5	X	2,30400	Y	2,78400
PATTERN	421	5	X	3,46800	Y	2,78400
PATTERN	251	0	X	1,56600	Y	3,76200
PATTERN	271	4	X	4,59600	Y	3,76200
PATTERN	61	4	X	1,63200	Y	1,28400
PATTERN	61	0	X	1,63200	Y	1,28400
PATTERN	61	2	X	2,07600	Y	2,78400
PATTERN	81	4	X	2,41200	Y	1,28400
PATTERN	81	0	X	4,63200	Y	3,76200
PATTERN	191	0	X	2,44800	Y	1,28400
PATTERN	191	0	X	0,88800	Y	3,76200
PATTERN	191	4	X	2,61600	Y	3,76200
PATTERN	191	4	X	3,30000	Y	3,76200
PATTERN	7011	0	X	3,15600	Y	0,93000
PATTERN	7011	0	X	4,26600	Y	0,93000
PATTERN	7011	0	X	1,18800	Y	0,98400
PATTERN	7011	0	X	1,28400	Y	0,98400
PATTERN	7011	0	X	1,66800	Y	1,09200
PATTERN	7011	0	X	2,80800	Y	1,09200
PATTERN	7011	0	X	3,44400	Y	1,09200
PATTERN	7011	0	X	2,10000	Y	1,20000
PATTERN	7011	0	X	2,20800	Y	1,20000
PATTERN	7011	0	X	2,34000	Y	1,20000
PATTERN	7011	0	X	4,03800	Y	1,20000
PATTERN	7011	0	X	4,36200	Y	1,20000
PATTERN	7011	0	X	2,94000	Y	2,81400
PATTERN	7011	0	X	3,03600	Y	2,81400
PATTERN	7011	0	X	1,05600	Y	2,86800
PATTERN	7011	0	X	3,34800	Y	2,86800

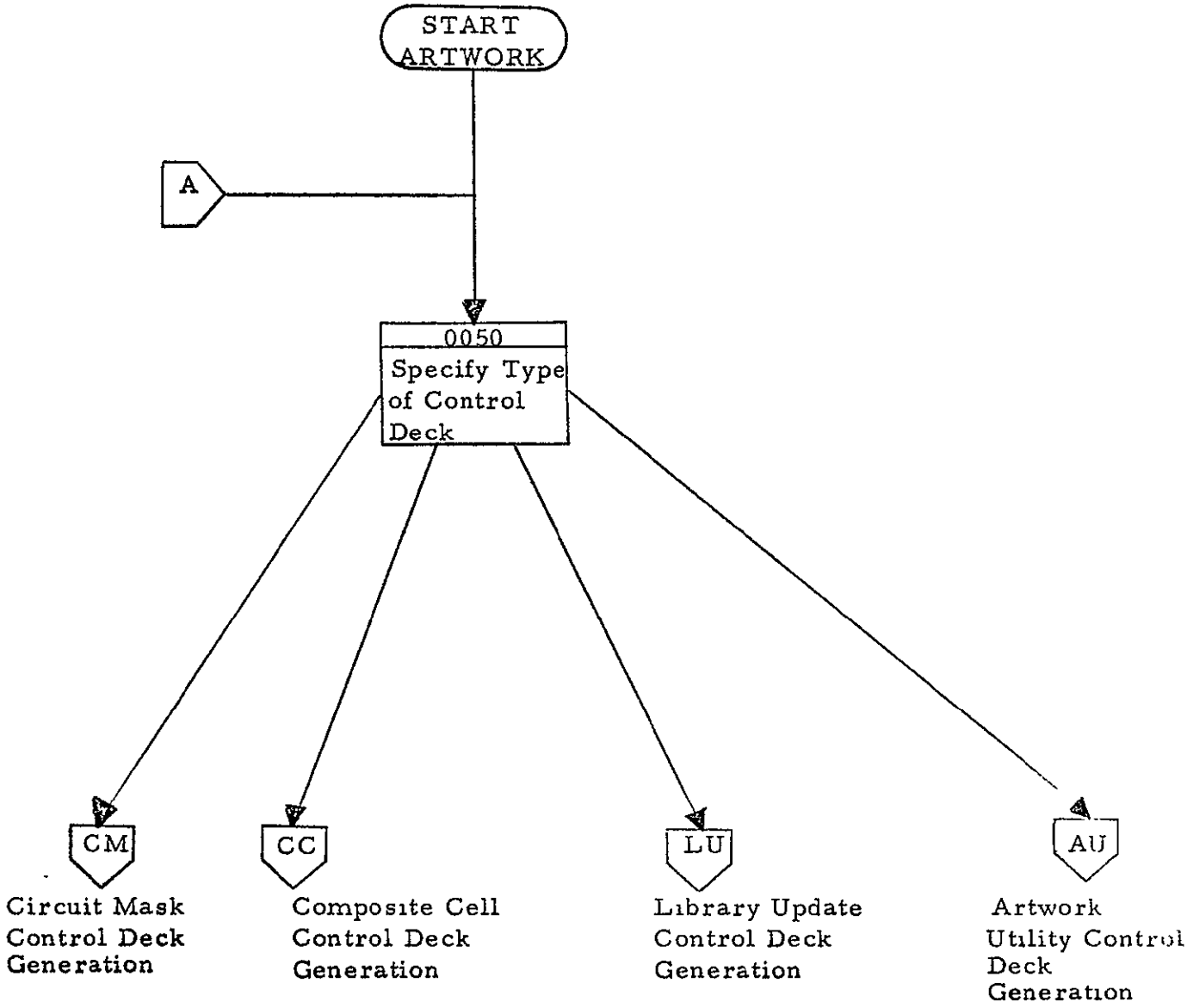
Figure 6.1

```
PATTERN  7011    0          X   4.10400          Y   2.86800
PATTERN  7011    0          X   4.20000          Y   2.86800
PATTERN  7011    0          X   4.29600          Y   2.86800
PATTERN  7011    0          X   1.76400          Y   2.92200
PATTERN  7011    0          X   3.03600          Y   2.92200
PATTERN  7011    0          X   4.89600          Y   2.92200
PATTERN  7011    0          X   1.05600          Y   2.97600
PATTERN  7011    0          X   1.94400          Y   3.03000
PATTERN  7011    0          X   2.94000          Y   3.03000
PATTERN  7011    0          X   0.74400          Y   3.08400
PATTERN  7011    0          X   1.76400          Y   3.08400
PATTERN  7011    0          X   4.66800          Y   3.08400
PATTERN  7011    0          X   4.10400          Y   3.13800
PATTERN  7011    0          X   4.29600          Y   3.13800
PATTERN  7011    0          X   3.24000          Y   3.19200
PATTERN  7011    0          X   4.20000          Y   3.30000
PATTERN  7011    0          X   3.94800          Y   3.35400
PATTERN  7011    0          X   4.57200          Y   3.35400
PATTERN  7011    0          X   3.39000          Y   3.40800
PATTERN  7011    0          X   1.90200          Y   3.51600
PATTERN  7011    0          X   4.70400          Y   3.51600
PATTERN  7011    0          X   4.94400          Y   3.51600
PATTERN  7011    0          X   3.72000          Y   3.57000
PATTERN  7011    0          X   4.03200          Y   3.62400
PATTERN  7011    0          X   4.36800          Y   3.62400
PATTERN  7011    0          X   1.90200          Y   3.67800
PATTERN  7011    0          X   4.24800          Y   3.67800
PATTERN  7011    0          X   5.04000          Y   3.67800
PATTERN  7011    0          X   3.94800          Y   3.78600
                                  663 COMMANDS          0 ERRORS        0.12843966 03 INCHES MOTION
                                    1 APERTURE SELECTS                        0.01 APERTURE SELECT TIME
                                 6.42 MINUTES TRAVEL TIME                     6.43 MINUTES TOTAL TIME

                                                    SYMBOL
X=  -0.      Y=  -2.50   APERTURE 012    H    SCALE 51    TEXT  RANNING TEST CHIP LEVEL 1

                                                END LEVEL

TOTAL PLOTTER TIME FOR LEVEL 1      6.43 MINUTES.
LIMITS OF PLOT X      0.      TO      4.97          Y     -2.50     TO      4.32
```

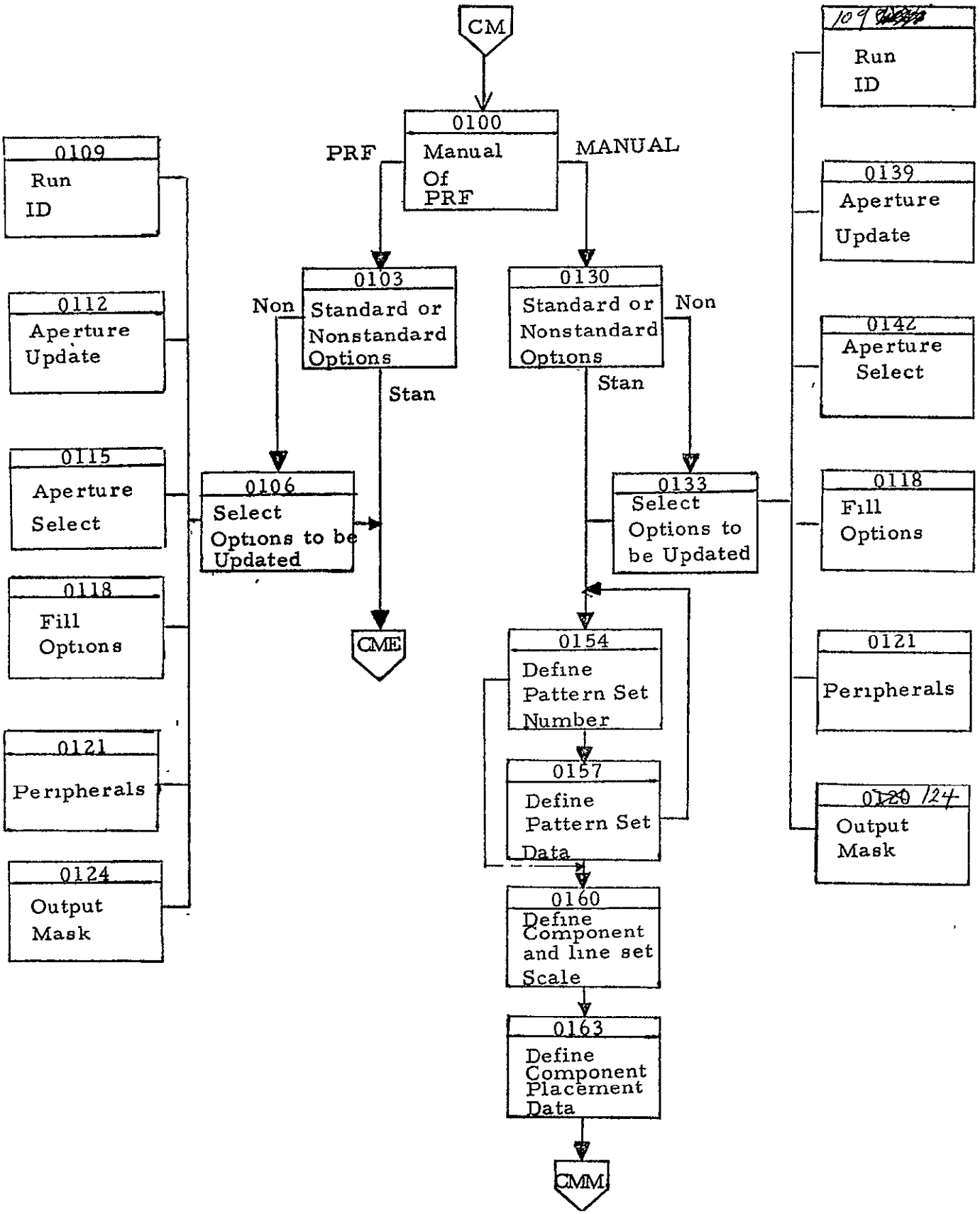
Figure 6.1

(Page 7 of 7)

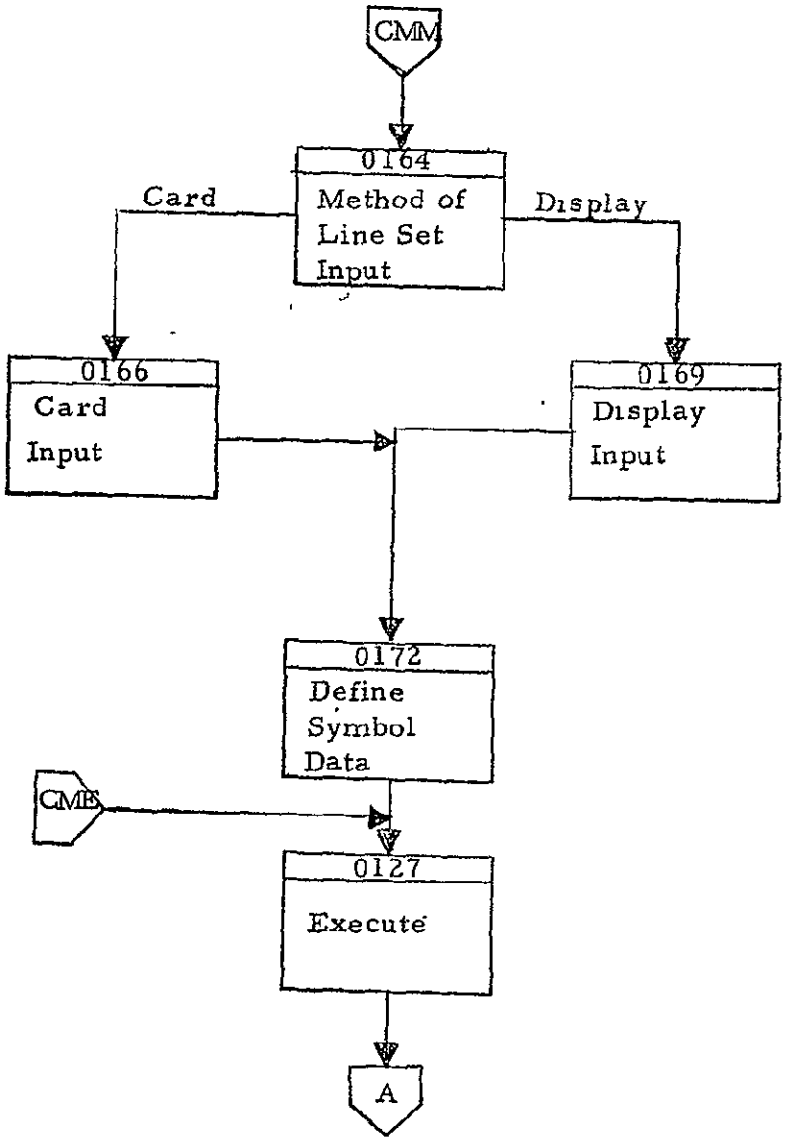
ARTWORK CONTROL DECK SYSTEM DISPLAY TREE



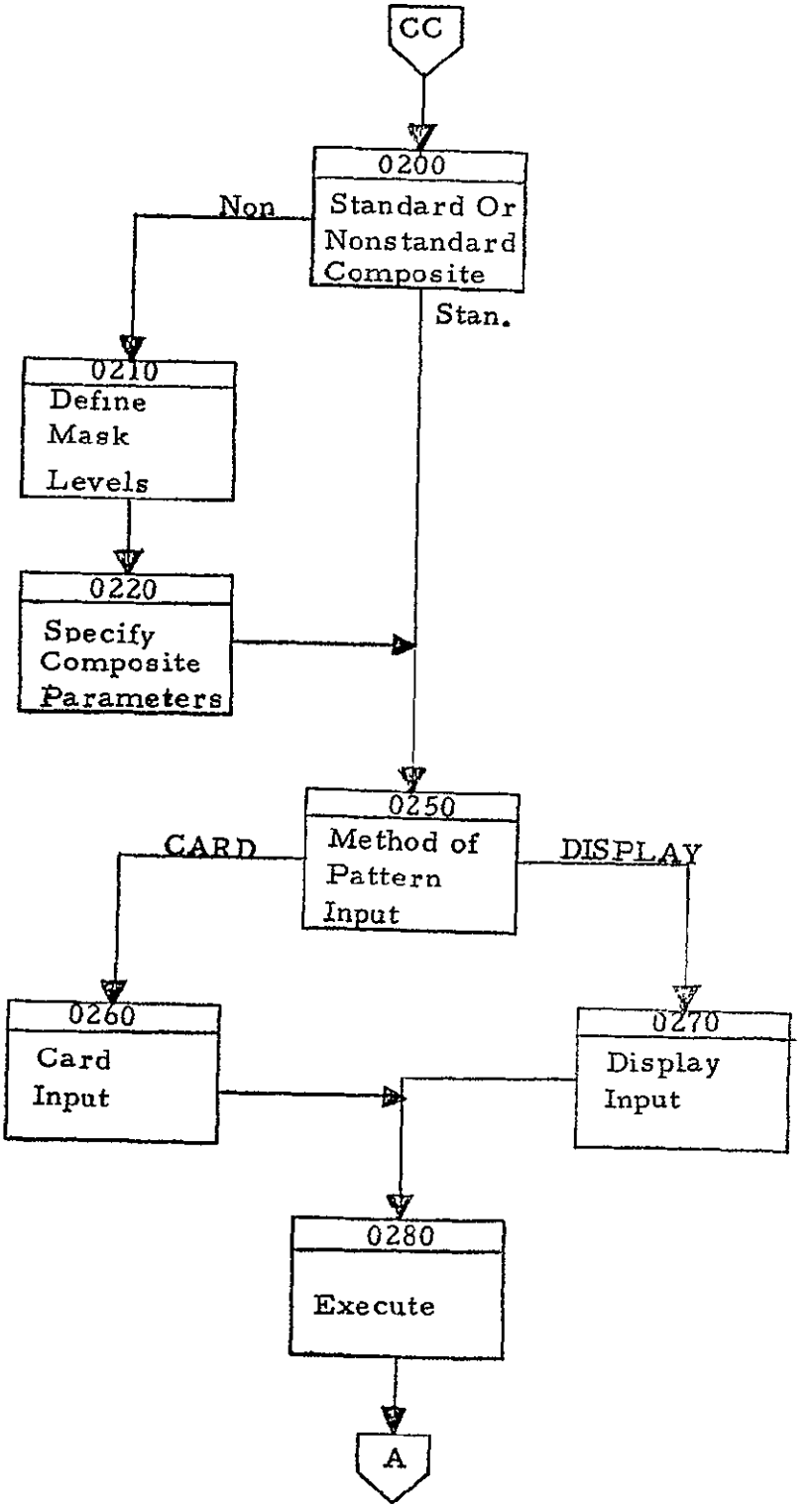
ARTWORK QUICKLOOK - - - - - CIRCUIT MASK GENERATION



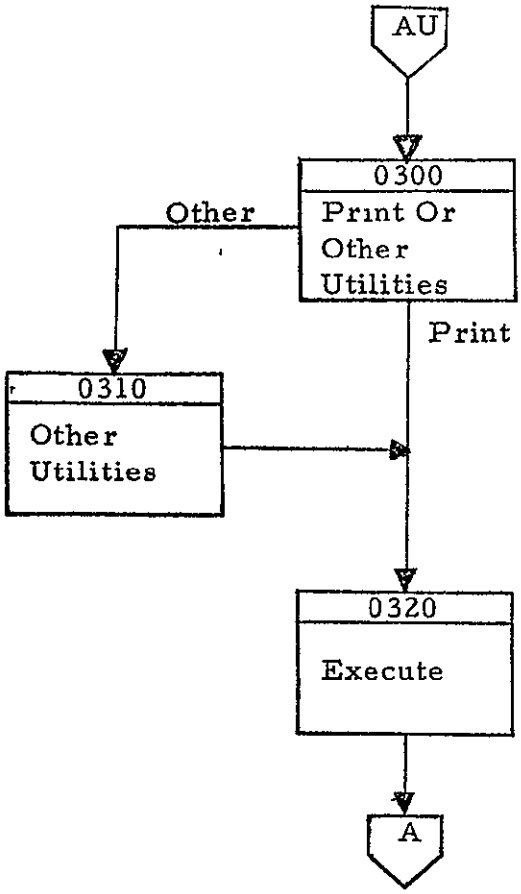
ARTWORK QUICKLOOK - CIRCUIT MASK GENERATION



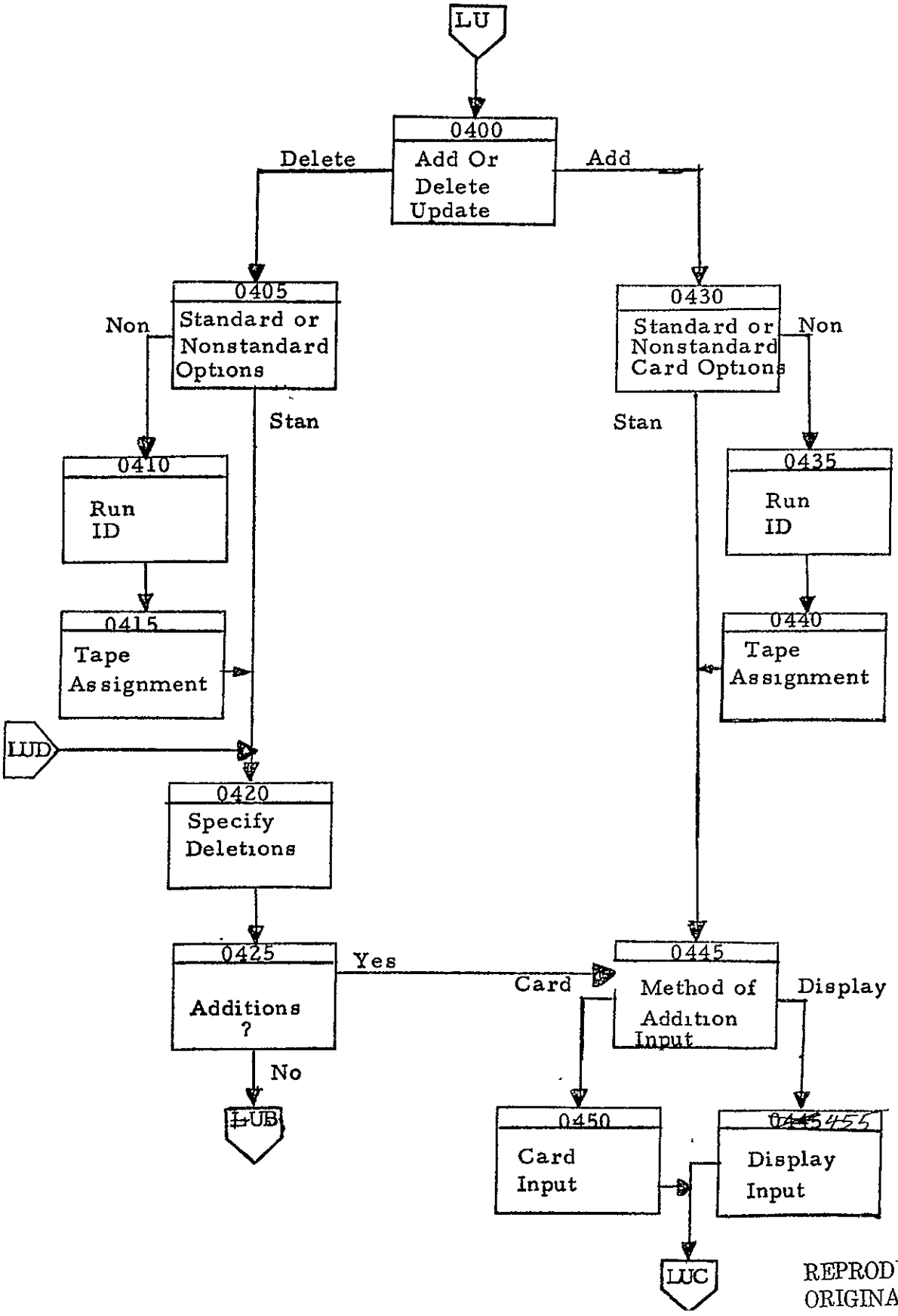
ARTWORK QUICKLOOK---- COMPOSITE CELL GENERATION



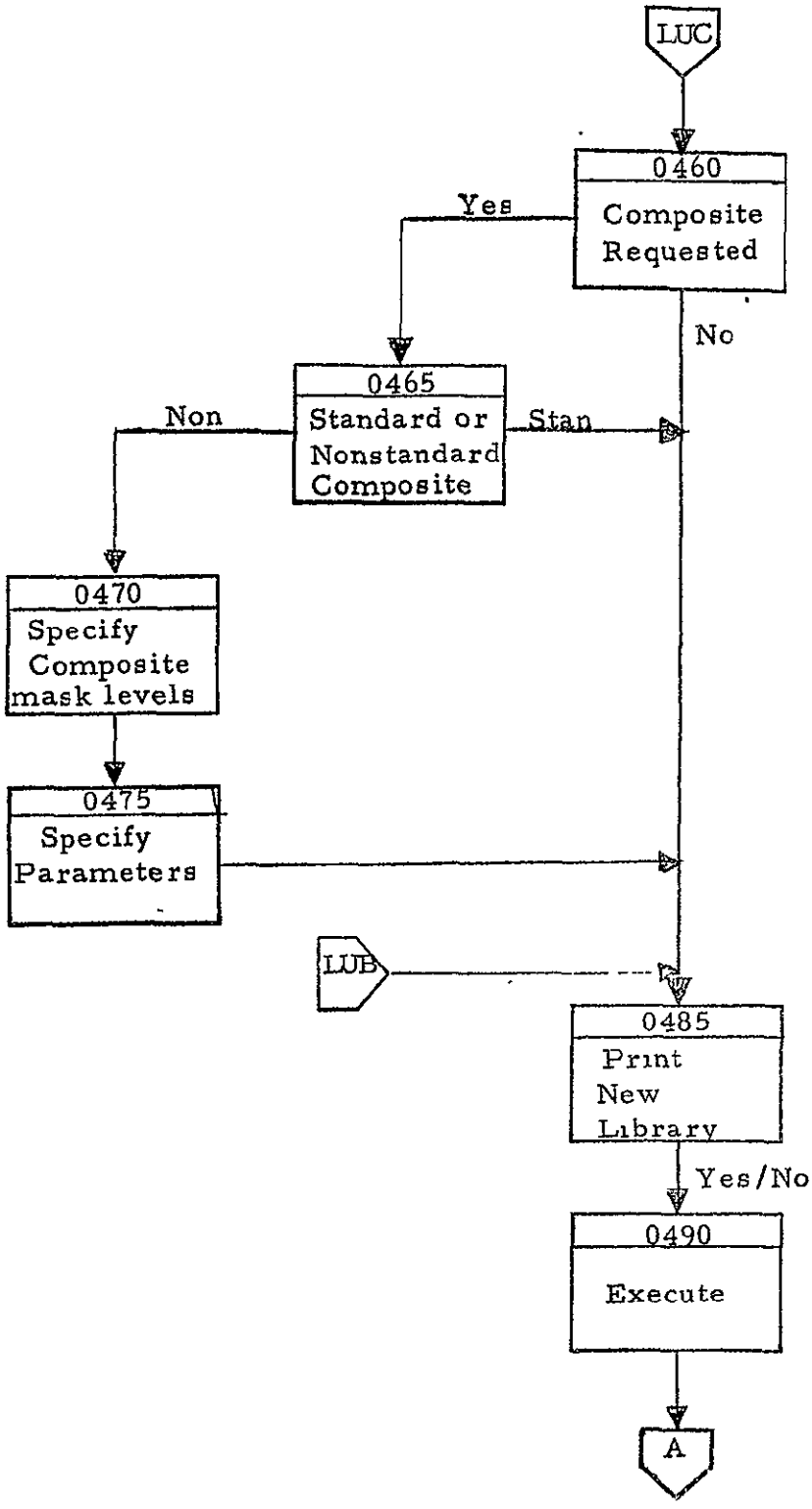
ARTWORK UTILITIES



ARTWORK QUICKLOOK - - - - NEW PATTERN LIBRARIAN GENERATION



ARTWORK QUICKLOOK- NEW PATTERN LIBRARY GENERATION



BANNING ARTWORK PROGRAM
OPERATOR'S GUIDE

STEP 1

Use the displays (ARTWORK QUICKLOOK) to create the input data required by the Banning Artwork Program. In order to execute the ARTWORK QUICKLOOK program you must:

(1) Load the program paper tape into the Sigma 2 computer. This is only required once a day and will be done by the computer operator.

(2) Load the ARTWORK QUICKLOOK program into the Sigma 5 computer. This is done by placing the following control cards in the card reader:

```
!JOB    MSC, ARTQL
!RUN    (LMN, ARTQL), (STAPT, DCINIT), (INT, INIT)
!FIN
```

(3) When the first display is presented select 'ARTWORK QUICKLOOK'.

STEP 2

After your data deck has been generated, it will be written on the disk. In order to get the data punched on cards and listed on the line printer, load the following control cards in the card reader:

```
!JOB    MSC, PUNCH
!ASSIGN     M:EI, (FILE, QLARTWRK, :SYSRT)
!ASSIGN     M:PO, (DEVICE. CPA94)
!FMGE       (PUNCH)
!FMGE       (LIST)
!FIN
```

STEP 3

In order to run the Banning Artwork Program using the data cards punched in STEP 2, you must perform the following operations:

(1) Cancel the ARTWORK QUICKLOOK program,
KEYIN: !FØ ARTQL,R

(2) Release the computer memory dedicated to foreground programs. This is required in order to provide enough memory to hold the Banning Artwork Program.
KEYIN: !MEMORY Ø RELEASE

(3) Merge the data deck created in STEP 2 with the following control cards and place them in the card reader:

```
!JOB     MSC,ARTWORK
!ASSIGN      F:1,(DEVICE,7T),(OUTSN,ØØ1),(OUTIN)
!ASSIGN      F:2,(DEVICE,7T),(OUTSN,GERB),(OUTIN)
!ASSIGN      F:3,(FILE,TEMP),(OUTIN)
!ASSIGN      F:4,(DEVICE,9T),(OUTSN,LIB),(OUTIN)
!ASSIGN      F:5,(DEVICE,CRAØ3)
!ASSIGN      F:6,(DEVICE,LPAØ2)
!ASSIGN      F:7,(DEVICE,9T),(INSN,OLDL)
!RUN    (LMN,ARTWORK),(START,ARTGEN)
!DATA
```

Insert Data Deck created in STEP 2 here

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