ENGINEERING DESIGN GRAPHICS JOURNAL

WINTER 1978 VOLUME 42 NUMBER 1

ENGINEERING DESIGN GRAPHICS DIVISION

1928 1978

50TH ANNIVERSARY

VANCOUVER, B.C.

ENGINEERING GRAPHICS AND DESCRIPTIVE GEOMETRY IN 3-D

G. F. Pearce Professor, Faculty of Engineering, University of Waterloo, Canada

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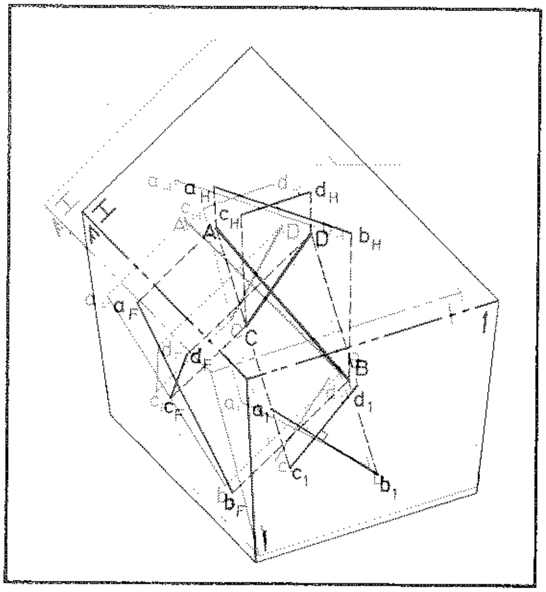
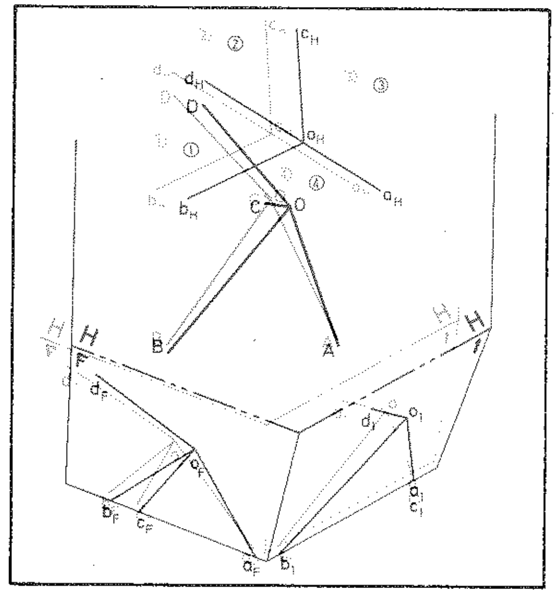


Two Intersecting Perpendicular Lines (reduced)



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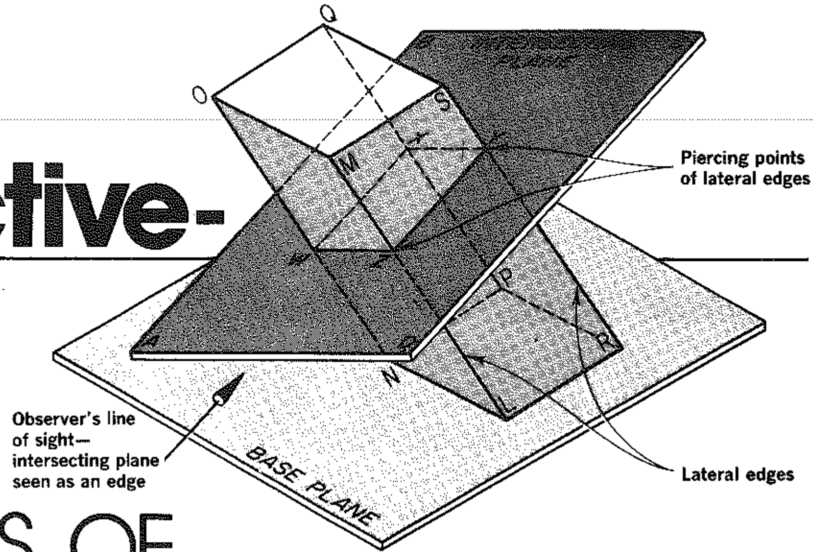

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ENGINEERING DESIGN GRAPHICS JOURNAL

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1978-University of British Columbia Vancouver. June 19-22

1979-Louisiana State University

1980-

1981-University of Southern California.

EDGD MIDYEAR CONFERENCES

1978-University of Alabama, January 1978

1979-Mississippi State

1980-Cogswell College

1981-North Carolina State

ENGINEERING DESIGN GRAPHICS JOURNAL is published - one volume per year, three numbers per volume, in Winter, Spring, and Fall - by the Engineering Design Graphics Division of the American Society for Engineering Education, for teachers and industrial practioners of Engineering Graphics, Computer Graphics, and Design Graphics, and Creative Design.

The views and opinions expressed by the individual authors do not necessarily reflect the editorial policy of the ENGINEERING DESIGN GRAPHICS JOURNAL or of the Engineering Design Graphics Division of ASEE. The editors make a reasonable effort to verify the technical content of the material published; however, final responsibility for opinions and technical accuracy rests entirely upon the author.

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The objectives of the JOURNAL are:
1. To publish articles of interest to teachers and practioners of Engineering Graphics, Computer Graphics and subjects allied to fundamentals of engineering.
2. To stimulate the preparation of articles and papers on topics of interest to its membership.
3. To encourage teachers of Graphics to innovate on, experiment with, and test appropriate techniques and topics to further improve quality of and modernize instruction and courses.
4. To encourage research, development, and refinement of theory and applications of engineering graphics for understanding and practice.

STYLE GUIDE FOR JOURNAL AUTHORS

The Editor welcomes articles submitted for publication in the JOURNAL. The following is an author style guide for the benefit of anyone wishing to contribute material to Engineering Design Graphics Journal. In order to save time, expedite the mechanics of publication, and avoid confusion, please adhere to these guidelines.

1. All copy is to be typed, double-spaced, on one side only, on white paper, using a black ribbon.

2. All pages of the manuscript are to be consecutively numbered.

3. Two copies of each manuscript are required.

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Illustrations cannot be redrawn; they are reproduced directly from submitted material and will be reduced to fit the columnar page.

Accordingly, be sure all lines are sharply drawn, all notations are legible, reproduction black is used throughout, and that everything is clean and unfolded. Do not submit illustrations larger than 8-1/2 x 11. If necessary, make 8-1/2 x 11 or smaller photo copies for submission.

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7. Enclose all material unfolded in large size envelope. Use heavy cardboard to prevent bending.

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REVIEW OF ARTICLES

All articles submitted will be reviewed by several authorities in the field associated with the content of each paper before acceptance. Current newsworthy items will not be reviewed in this manner, but will be accepted at the discretion of the editors.

deadlines for author

DEADLINES FOR AUTHORS AND ADVERTISERS
The following deadlines for the submission of articles, announcements, or advertising for the three issues of the JOURNAL:
Fall--September 15
Winter--December 1
Spring--February 15

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Engineering Design Graphics Journal

WINTER 1978 VOLUME 42 NUMBER 1

EDITORIAL

Everywhere we hear and read about the necessity of "going metric" in the United States.

This Division generally and the Journal specifically both support this effort, but support alone is not enough. It seems natural that the Division and the Journal should provide leadership in this effort. Excellent articles on the subject continue to be received and definitely contribute to that leadership. We hope that this proposal reflects another aspect of some leadership, in that it may not be the first, but it is one of the few U.S. periodicals using the "metric" format and perhaps the only one using "rational" metric dimensions. The term "rational" is my own and does not imply the endorsement of any group. (or anyone else in their right mind, for that matter) The idea, so far as I know, is my own-good or bad.

The dimensions of future issues will be 198 mm x 280 mm, roughly equivalent to a metric size A-4. (see below table)

These dimensions preserve the principal advantage of the metric format, which defines a constant aspect ratio ($1:\sqrt{2}$) when any given sheet size is cut in half. Perhaps more important, the length of this paper is short enough to permit continued use of many existing printing presses, which cannot economically produce 297 mm paper. Finally, this size is selected to permit rational (whole number) sizes of paper throughout the A-1 to A-6 range of sizes, whereas the metric sizes are really approximations of the true size.

They say the turtle only progresses when his neck is out. Well, ours will be out and we hope you like the result. Either way, your comments and reactions would certainly be appreciated.

Paper Size	"European" Metric	"Rational" Metric
A-1	594 x 841	560 x 792
A-2	420 x 594	396 x 560
A-3	297 x 420	280 x 396
A-4	210 x 297	198 x 280
A-5	148 x 210	140 x 198
A-6	105 x 148	99 x 140

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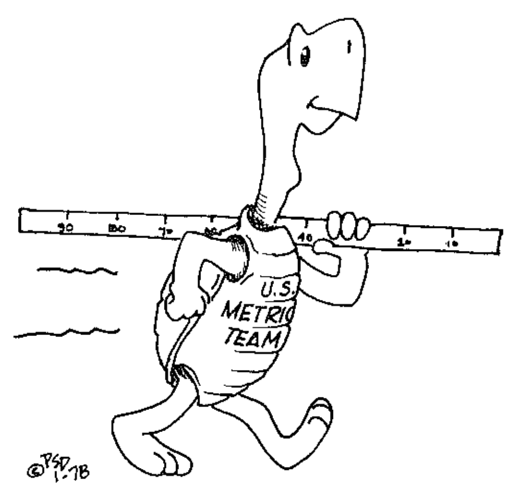

Involved?

Want to become more personally involved (PI) in the Engineering Design Graphics Division? Join a Technical-Professional Committee. Technical-Professional Committees are the means for accomplishing what is sometimes in-depth research, and at other times, superficial examination of questions that arise in the course of events. Not all committees can be expected to be active all of the time; but when a committee is active, the committee members gain knowledge, and when that knowledge is shared with the Division members at annual and semi-annual meetings, the Division members are also rewarded.

Of the approximately 200 Division members who have indicated that the EDGD is their first choice, a fair estimate of the number involved in Technical-Professional Committees is in the neighborhood of 50-75. Don't let a few have all the fun! If you are not now involved, or if you wish to change your involvement to another committee, or if you wish to join an additional committee, drop a line to the chairman of the committee in which you are interested. The following list of Technical-Professional Committees contains the names and addresses of the current chairmen.

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Medford, Massachusetts 02155

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Indiana State University
Evansville, Indiana 47712

FRESHMAN ENGINEERING
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104 Marston Hall
Iowa State University
Ames, Iowa 50011 (515) 294-5933

Chairman's Page

Amogene F. DeVaney
Amarillo College

As Chairman of this Division, one of the duties which I enjoy very much is representing you to Deans, Department Heads, other Divisions of ASEE, and people in industry. However, in much of my conversation with Deans and Department Heads, I have found a very negative attitude toward graphics. I have asked myself several questions: "Why is this? What has caused these people to develop this attitude? Have graphics teachers contributed to it? If so, in what way have they contributed? Can we do anything to change this attitude?" I will let you attempt to answer the questions. However, I should like to suggest several things we might do to improve the attitude toward graphics.

We might present a positive approach--toward ourselves, our colleagues, but more importantly, toward our discipline. If we like graphics, enjoy teaching the subject, and believe that it is an important element of engineering education, we might tell everyone about it. Who will think it is important if we do not?

We might keep up with the changing times, read the current literature on engineering education, and anticipate the trends. Let the suggestions for change in graphics come from us rather than have change forced upon us by Deans and Department Heads of other areas of engineering. Let us act; not merely react!

We might keep our courses current. Choices must be made as to subject matter to include in graphics courses. Such subject matter should reflect teaching concepts rather than merely how to draw and dimension machine parts. What do I mean by "concepts"? In a basic course I have in mind the concepts of location in a three-dimensional coordinate system, of orthographic projection of points, lines, planes, and solids, and of spatial relationships. Further, I mean the concepts of design. Errors have been made in the past in teaching manipulation of views rather than space and design concepts. We have tried to make learning easy by taking out reasons why--such as, the theory of projection. We must keep in mind that to complete an engineering degree, the student must have an IQ of about 120. With such an IQ he may still have to struggle. Most of our students have IQ ratings of 125 and higher. We should not diminish intellectual content of graphics. Nor should we apologize when students find graphics difficult and time-consuming.

We might try new teaching strategies and educational technology. Have you tried PSI (Personalized System of Instruction)? Have you developed an instructional system? How long since you have designed new tests, tried new types of questions? Have you used video tapes to replace your lectures? Do you use the computer to aid in clerical work? Have you suggested to your Dean some method to reduce the cost of teaching graphics?

Let us all do some of these things I've suggested. I believe the image of the graphics teacher and the Division will be improved, and Deans and Department Heads will no longer say to me, "I need to upgrade graphics at my school. I have people who won't change. What can I do?"

International Conference on Descriptive Geometry

The INTERNATIONAL CONFERENCE ON DESCRIPTIVE GEOMETRY sponsored by the Engineering Design Graphics Division, ASEE, in commemoration of the fiftieth anniversary of the Division will be held in Vancouver, British Columbia on June 14-18, 1978.

The General Sessions of the conference will feature four recognized authorities on spatial geometry as speakers. Two concurrent paper sessions on Thursday cover topics on applications of descriptive geometry, theoretical graphics and the teaching of descriptive geometry in universities outside the United States. Most of the presenters for the sessions will be from countries other than the United States. On Friday morning a session called "Breakfast with the Experts" will give the conferees an opportunity to discuss the topics which were presented on Thursday.

On Friday and Saturday three workshops will run concurrently. A participant would be expected to attend one of the workshops for both days. In one of the workshops the participants will solve problems on the applications of descriptive geometry and graph theory. In another, on computer graphics, the participants will be divided into two groups--elementary and advanced. The elementary workshop assumes no knowledge of a computer language. The work of this group will consist of learning to write simple programs for computer display of graphical representation of data. The advanced workshop assumes knowledge of a computer language and some work with computer graphics. This group will work with advanced techniques in computer graphics. The participants in the third workshop will design an instructional module and consider the use of modules in teaching engineering graphics.

At the conclusion of the workshops the participants of each workshop will consider how the topic of that workshop may be used to enhance the teaching of engineering graphics and will make recommendations in this regard at the final session of the conference on Sunday morning.

Individuals who are not members of the Engineering Design Graphics Division and would like to receive the official program may do so by sending their name and address to Dr. Clarence E. Hall, Program Chairman, ICDG, 142 Atkinson Hall, Louisiana State University, Baton Rouge, Louisiana 70803. Telephone (503) 388-2022.

CONFERENCE INFORMATION

Speakers on June 15: A.L. Loeb, Harvard; A. Rotenburg, Australia; Paul DeGuise, Canada; F.L. Almgren, Princeton; L. Alting, Denmark; H. Osers, Venezuela; H. Niayesh, Iran; Y. Charit, Israel.

Three Workshops on June 16-17:

1. Appilcation of Descriptive Geometry to the Solution of Space Problems, Mary Blade, Cooper Union.

2. Computer Graphics (Elementary and Advanced), Robert LaRue, Ohio State University.

3. The Design and Use of Instructional Modules, Amogene DeVaney, Amarillo College.

Conference will be held at:

UBC Conference Center, 2075 Westbrook Place, Vancouver, B.C. Canada V6T 1W2, Telephone (604) 228-5441

Lodging:

Rooms may be obtained at the Walter Gage Residence Hall, UBC Conference Center. Indicate if you want the room through the ASEE Annual Conference. All rooms single $12 (a change from $10.50), husband and wife in two rooms $21, child $6. Plus 5% tax. No credit cards. First night payable with registration by April 25, 1978.

Registration fee:

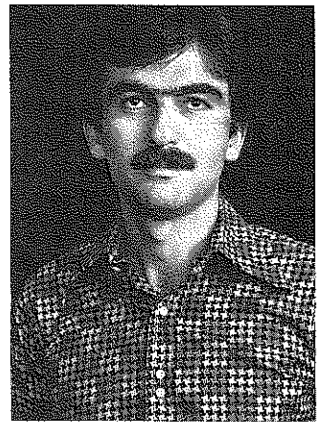
$60 for Conferee and $2 for spouse. The Conferee Registration includes a copy of the Proceedings which will be mailed to you after the conference, material for one workshop, refreshments at breaks, Danish and coffee on Friday breakfast, and building and equipment costs at UBC. Programs will be mailed February 1, 1978. Registration after April 25, 1978, $75.

Dr. Amogene F. DeVaney, General Chairman
Box 447, Amarillo, Texas 79178 (806) 376-5111

Tim A. Jur

University of South Carolina

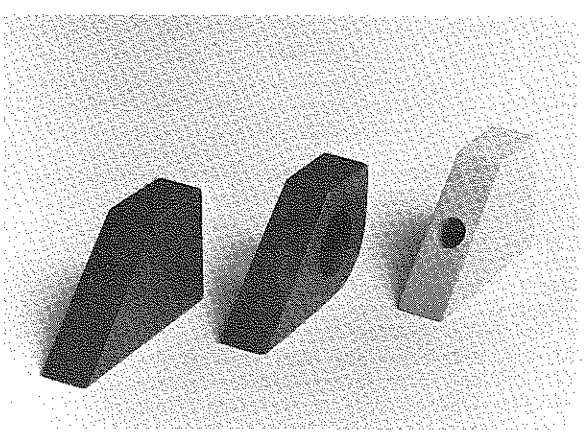
Mohammad Sarraf



A VISUAL AID FOR INSTRUCTION IN ORTHOGRAPHIC PROJECTION

This brief note has to do with the educational side of engineering drawing, in particular, those first and important series of lectures on orthographic projection. Students who are exposed to this material for the first time usually have to struggle a bit before they are able to grasp the principles involved. At this early stage in the course, a liberal use of visual aids can be very helpful. In the following paragraphs a very simple yet effective visual aid is described for use in teaching orthographic projection.

Shown in the photograph below are blocks of wood cut from the end of a 2 x 4. No doubt many graphics instructors have carried similar blocks or other objects into the classroom with the various surfaces identified as top, front and right-side views. The blocks shown here, however, are slightly different in that they are designed specifically (a) for use with an overhead projector and (b) for use in a series of lectures, each covering slightly more complex material. Use of the blocks on an overhead projector is surprisingly effective. The alternative is simply holding a block in your hand and leaves much to be desired. The block is small and all but two or three in the audience see an oblique rather than a projected view. But once the views are projected onto a screen, everyone easily sees what they are supposed to see. A projected view is really a projected view.



Wooden blocks of almost any configuration can be cut to suit the imagination of the instructor. Those shown in the photograph have been designed for use in sequence. The first block involves only straight lines, whereas the second introduces holes, radii and hidden lines. The third block is used to demonstrate auxiliary views. Together the three blocks roughly correspond to the first three lectures in the drawing course we teach to freshman engineering students who have arrived without a graphics background.

James A. Hardell
Virginia Polytechnic Institute and State Univ.
Blacksburg, Virginia

TESTING STUDENT UNDERSTANDING OF THREE-DIMENSIONAL SPACE

After working with engineering graphics students for the past fourteen years, one begins to wonder if there is not some simple indication which shows if students are really understanding the visual three-dimensional world rather than the standard solutions to the usual engineering graphics problems.

There seems to be a simple problem which does indicate a student's ability to understand and analyze problems in a three-dimensional sense. It is the problem of determining the angles an oblique line makes with each of the principal viewing planes (H, F and P) as shown in Figure 1.

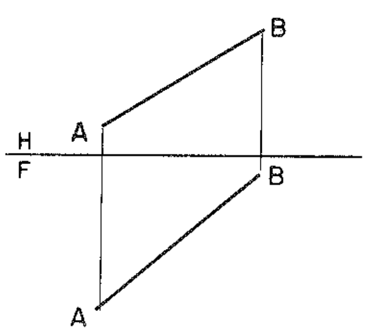


FIGURE 1

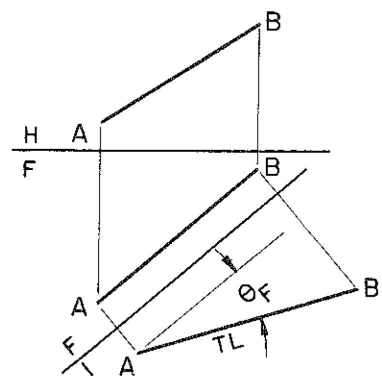


FIGURE 2

The student who has been taught to visualize the mutually perpendicular reference planes will readily know where they appear in true shape and as edges in the principal views. He will also be aware of where the principal planes will appear as edges in the auxiliary views. For example, the student will be aware that an auxiliary view taken off the front view to establish the true length (TL) will also establish the edge view of the frontal plane (F) and thus give the angle between frontal plane and line AB (θ_F) as shown in Figure 2.

Given this type problem, one becomes readily aware of the student's difficulty in being able to interpret the viewing reference planes if he is unable to establish all three angles (Θ_H, Θ_F and Θ_P) without hesitation as shown in Figure 3. If the student has difficulty, it appears to be a reasonable indication that in first learning to establish auxiliary views he has not had emphasis placed upon developing a logical visual relationship in the spatial reference framework. Rather, he has been taught the mechanical method of counting two views away to obtain distances for establishing a given view.

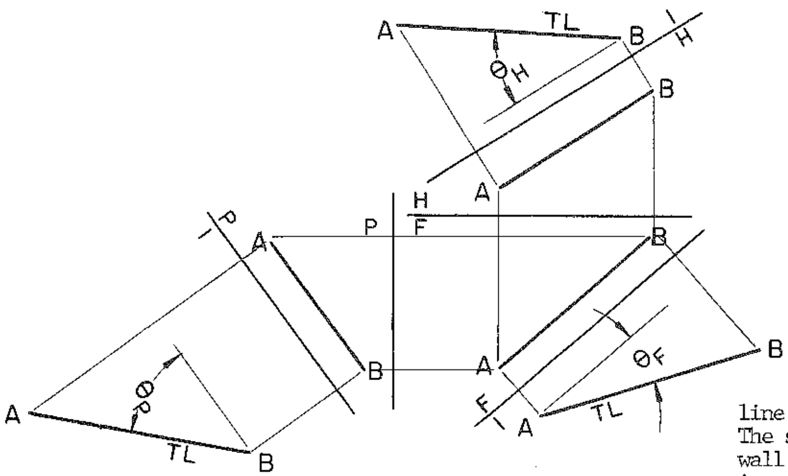


FIGURE 3

For example, in finding the true length (TL) of the line by taking an auxiliary view off of the profile view the student can readily count back two views and determine distances from the reference for establishing the view. However, when he knows that he is really trying to establish the distances from the edges of the profile reference plane (P), then he will automatically relate to any view perpendicular to the profile view. The front view, for example, would establish distances relative to the profile reference plane as seen in Figure 4.

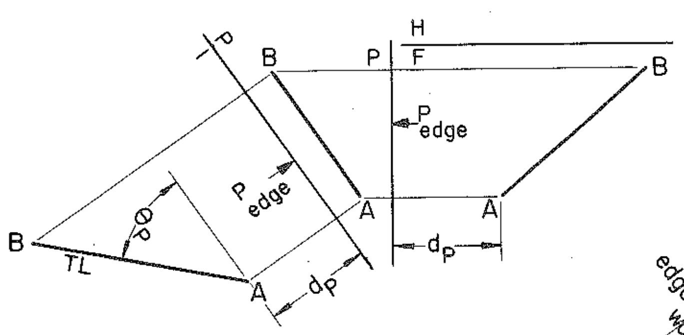


FIGURE 4

After the student understands the concept of where and when the principal planes appear as reference edges, he should be involved next with solving problems dealing with real planes which relate to the principal planes. A problem of this type is shown in Figure 5.

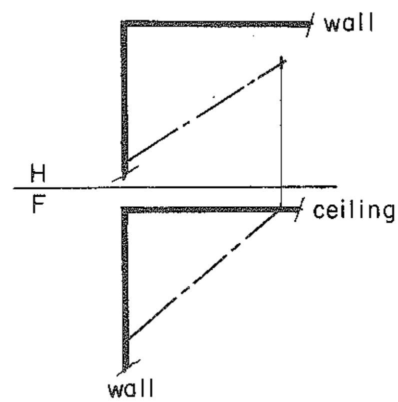


FIGURE 5

The problem is to determine the angles the line makes with the principal planes of attachment. The student is now required to identify the side wall as a profile plane and the ceiling as a horizontal plane. He also must know where to establish both planes as edges along with the true length of the line so that the angles of interest can be measured. A solution similar to that shown in Figure 6 should be expected if the student has a good understanding of the spatial relationship of lines and planes in space.

Presenting other material to the student to further develop his sense of visual logic and stimulate his basic abilities in engineering creativity appears to be much easier once he has mastered the spatial orientation of the principal planes (H, F and P).

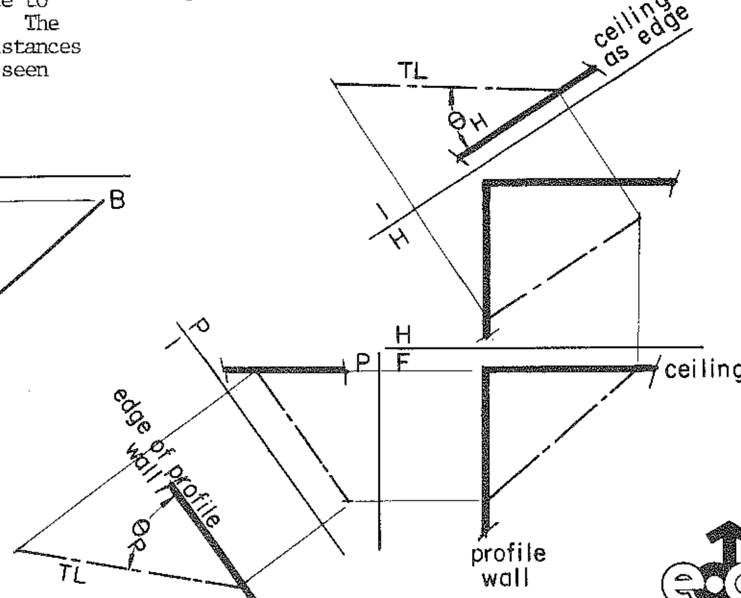


FIGURE 6

Mohammad H. Asghar
Western Electric Company
Columbus Works
Columbus, Ohio

AN APPLICATION OF PACKAGING TECHNOLOGY

Abstract:

Printed circuit boards are extensively used in the Bell System for packaging the discrete and small to medium scale Integrated Circuit Devices. This paper describes the use of Interactive Computer Graphics to support the design and manufacturing processes of Printed Circuit Boards.

I. INTRODUCTION

One of the many challenges for the Bell Telephone Laboratories and Western Electric lies in transforming the circuit-level design of a system from the bread board state into a well packaged and reliable hardware product to be produced by mass production techniques. In order to meet this challenge a prototype of the system must be built and tested in the real or simulated environment in which it must function. The printed circuit board (PCB) serves as a basic building block for packaging electronic devices into a total system. Interactive computer Graphic Systems play an important role in the design of Printed Circuit Boards. Once a system is built and tested, the manufacturing responsibility is passed onto Western Electric, where Interactive Computer Graphics facilities are used in implementing the necessary changes in the existing printed circuit designs.

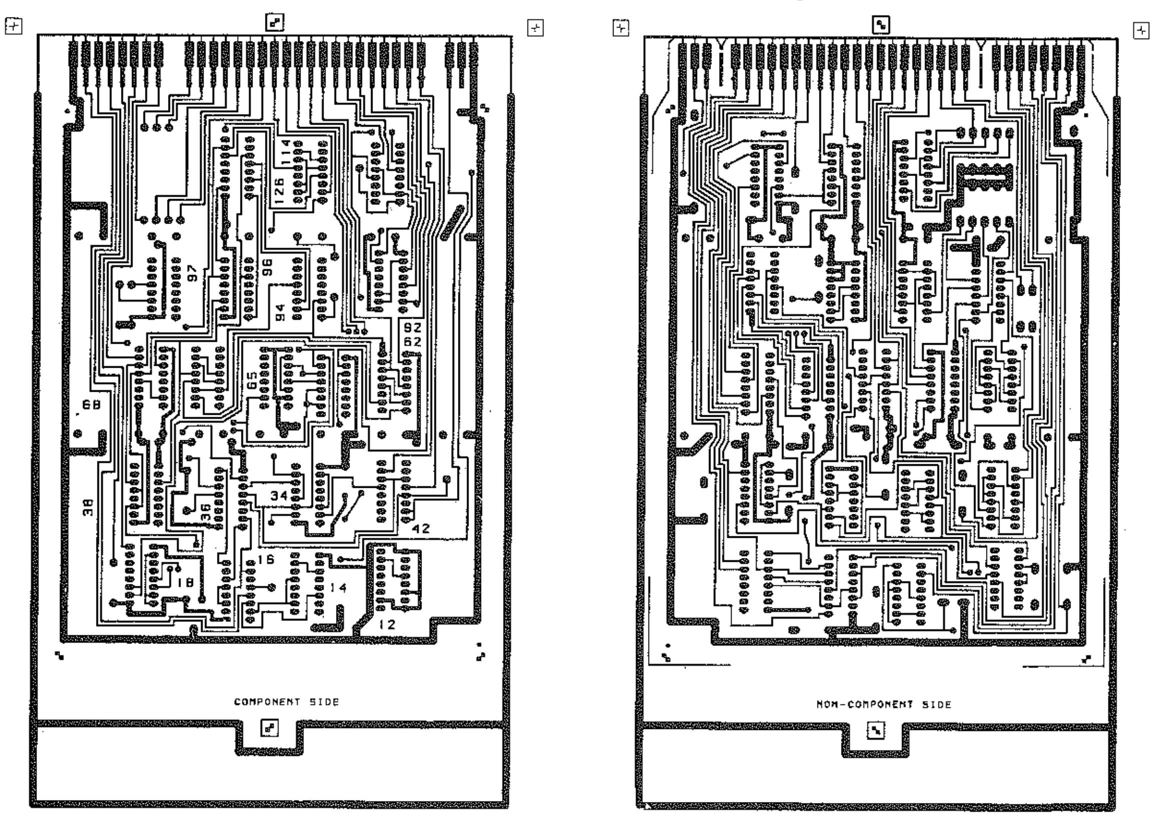


FIG 1. ARTWORK

COMPUTER GRAPHICS IN THE OF ELECTRONIC DEVICES

2. DOCUMENTATION NEEDS OF THE MANUFACTURING PROCESSES

As a standard practice, the design documentation created at Bell Labs for building prototypes is passed onto Western Electric. However, the information required by the manufacturing processes is different from that required by the design environment. A brief summary of the information necessary for supporting the mass production processes in Western Electric is given below.

A. ARTMASTER

An artmaster (Figure 1) is a photographic image of the geometries representing all the interconnections of a circuit. The artmaster finds its use in the Printed Circuit Board manufacturing process in removing all copper from the thin layer deposited on a hard board material, except for thin strips, which are used for interconnecting various devices like diodes, resistors, and Integrated Circuits, etc.

B. DRILL TABLE

A drill table is shown in Figure 2. Here the coordinates and the diameter of each hole to be drilled in the PCB are tabulated. The information in this table is used as input to the drilling operations. These holes are drilled for inserting leads of various components to be mounted on a PCB.

C. PIECE PART GRAPHICS

In this drawing (Figure 3), all metallized areas appear as slashed, and the holes can be seen as dark spots in the land areas. Dot grid is coordinate system for pinpointing the exact location of holes. Except for the grid, this information in this sheet is used for inspecting piece parts in the manufacturing shops.

HOLE DATA TABLE

	DIMENSIONS FROM DATUM LINE		HOLE
LINE	A-C	A-B	DIA
1	0.350	0.025	.096
2	0.350	2.590	.052
3	0.650	4.950	.052
4	1.150	4.950	.052
5	1.700	0.450	.052
6	1.800	1.500	.052
7	2.000	2.700	.052
8	2.300	1.500	.052
9	2.300	2.700	.052
10	2.625	2.001	.052
11	2.650	1.325	.052
12	2.850	2.795	.052
13	5.100	3.326	.052
14	5.350	1.850	.052
15	5.350	2.350	.052
16	5.350	2.975	.052
17	5.375	5.000	.052
18	5.400	3.600	.052
19	5.431	0.981	.052
20	5.431	1.481	.052
21	5.550	1.950	.052
22	5.900	3.600	.052
23	5.900	3.750	.052
24	5.900	3.900	.052
25	5.900	4.050	.052
26	5.900	4.200	.052
27	6.050	3.600	.052
28	6.050	3.750	.052
29	6.050	3.900	.052
30	6.050	4.050	.052
31	6.050	4.200	.052
32	6.550	3.600	.052
33	6.550	3.750	.052
34	6.750	5.150	.096
35	0.350	1.550	.052*
36	0.350	2.050	.052*
37	0.350	3.350	.043*
38	0.450	2.850	.043*
39	0.450	3.150	.043*
40	0.550	2.000	.043*
41	0.550	2.300	.043*
42	0.550	2.850	.043*
43	0.550	3.150	.043*
44	0.600	0.950	.043*
45	0.600	1.250	.043*
46	0.600	1.750	.043*
47	0.650	2.000	.043*
48	0.650	2.300	.043*
49	0.650	2.850	.043*
50	0.650	3.150	.043*
51	0.650	4.050	.043*
52	0.650	4.350	.043*
53	0.650	4.550	.052*
54	0.700	0.950	.043*
55	0.700	1.250	.043*
56	0.700	3.450	.052*
57	0.700	3.650	.052*
58	0.750	2.000	.043*
59	0.750	2.300	.043*
60	0.750	2.850	.043*
61	0.750	3.150	.043*
62	0.750	4.050	.043*
63	0.750	4.350	.043*
64	0.800	0.950	.043*
65	0.800	1.250	.043*
66	0.850	2.000	.043*
67	0.850	2.300	.043*
68	0.850	2.390	.052*
69	0.850	2.850	.043*
70	0.850	3.150	.043*
71	0.850	4.050	.043*
72	0.850	4.350	.043*
73	0.900	0.950	.043*
74	0.900	1.250	.043*
75	0.950	2.000	.043*
76	0.950	2.300	.043*
77	0.950	2.850	.043*
78	0.950	3.150	.043*
79	0.950	4.050	.043*
80	0.950	4.350	.043*
81	1.000	0.950	.043*
82	1.000	1.250	.043*
83	1.050	2.000	.043*
84	1.050	2.300	.043*
85	1.050	2.850	.043*
86	1.050	3.150	.043*
87	1.050	4.050	.043*
88	1.050	4.350	.043*
89	1.075	3.750	.043*
90	1.075	3.850	.043*
91	1.100	0.950	.043*
92	1.100	1.250	.043*
93	1.150	2.000	.043*
94	1.150	2.300	.043*
95	1.150	2.850	.043*
96	1.150	3.150	.043*
97	1.150	4.050	.043*
98	1.150	4.350	.043*
99	1.150	4.550	.052*
100	1.200	0.950	.043*
101	1.200	1.250	.043*
102	1.200	1.750	.043*
103	1.250	2.000	.043*
104	1.250	2.300	.043*
105	1.250	4.050	.043*
106	1.250	4.350	.043*
107	1.300	0.950	.043*
108	1.300	1.250	.043*
109	1.350	4.050	.043*
110	1.350	4.350	.043*
111	1.375	3.525	.043*
112	1.600	2.950	.043*
113	1.600	3.250	.043*
114	1.650	2.000	.043*
115	1.650	2.300	.043*
116	1.650	2.600	.043*
117	1.650	4.000	.043*
118	1.650	4.300	.043*
119	1.700	0.950	.043*
120	1.700	1.250	.043*
121	1.700	1.700	.043*
122	1.700	2.950	.043*
123	1.700	3.250	.043*
124	1.750	2.000	.043*
125	1.750	2.300	.043*
126	1.750	4.000	.043*
127	1.750	4.300	.043*
128	1.800	0.950	.043*
129	1.800	1.250	.043*
130	1.800	2.950	.043*
131	1.800	3.250	.043*
132	1.800	3.450	.052*
133	1.850	2.000	.043*
134	1.850	2.300	.043*
135	1.850	4.000	.043*
136	1.850	4.300	.043*
137	1.900	0.950	.043*
138	1.900	1.250	.043*
139	1.900	2.950	.043*
140	1.900	3.250	.043*
141	1.950	2.000	.043*
142	1.950	2.300	.043*
143	1.950	4.000	.043*
144	1.950	4.300	.043*
145	1.990	1.700	.043*
146	2.000	0.950	.043*
147	2.000	1.250	.043*
148	2.000	2.950	.043*
149	2.000	3.250	.043*
150	2.025	1.300	.043*
151	2.050	2.000	.043*
152	2.050	2.300	.043*
153	2.050	4.000	.043*
154	2.050	4.300	.043*
155	2.100	0.950	.043*
156	2.100	1.250	.043*
157	2.100	2.950	.043*
158	2.100	3.250	.043*
159	2.150	2.000	.043*
160	2.150	2.300	.043*
161	2.150	4.000	.043*
162	2.150	4.300	.043*
163	2.200	0.450	.052*
164	2.200	0.950	.043*
165	2.200	1.250	.043*
166	2.200	2.950	.043*
167	2.200	3.250	.043*
168	2.250	2.000	.043*
169	2.250	2.300	.043*
170	2.250	4.000	.043*
171	2.250	4.300	.043*
172	2.300	0.950	.043*
173	2.300	1.250	.043*
174	2.300	2.950	.043*
175	2.300	3.250	.043*
176	2.300	3.450	.052*
177	2.330	2.600	.043*
178	2.330	2.300	.043*
179	2.330	4.000	.043*
180	2.330	4.300	.043*
181	2.400	0.950	.043*
182	2.400	1.250	.043*
183	2.450	3.425	.052*
184	2.475	2.375	.043*
185	2.625	1.301	.052*
186	2.650	0.825	.052*
187	2.650	3.395	.052*
188	2.650	3.395	.052*
189	2.650	4.000	.052*
190	2.650	4.200	.052*
191	2.750	0.200	.052*
192	2.750	0.950	.043*
193	2.750	0.950	.052*
194	2.750	1.250	.052*
195	2.750	1.700	.052*
196	2.750	2.000	.052*
197	2.750	2.450	.052*
198	2.750	2.750	.052*
199	2.750	3.250	.052*
200	2.750	3.500	.052*
201	2.750	3.950	.052*
202	2.750	4.250	.052*
203	2.750	4.700	.052*
204	2.750	5.000	.052*
205	2.775	3.705	.043*
206	2.775	3.075	.043*
207	2.850	3.395	.052*
208	2.875	1.775	.043*
209	2.985	3.075	.043*
210	3.000	1.700	.043*
211	3.000	2.000	.043*
212	3.050	0.950	.043*
213	3.050	1.250	.043*
214	3.100	1.700	.043*
215	3.100	2.000	.043*
216	3.100	2.400	.043*
217	3.100	2.700	.043*
218	3.100	3.250	.043*
219	3.100	3.550	.043*
220	3.100	3.950	.043*
221	3.100	4.250	.043*
222	3.125	4.175	.043*
223	3.150	0.950	.043*
224	3.150	1.250	.043*
225	3.200	1.700	.043*
226	3.200	2.000	.043*
227	3.200	2.400	.043*
228	3.200	3.700	.043*
229	3.200	3.050	.043*
230	3.200	3.350	.043*
231	3.200	3.950	.043*
232	3.200	4.250	.043*
233	3.250	0.950	.043*
234	3.250	1.250	.043*
235	3.300	1.700	.043*
236	3.300	2.000	.043*
237	3.300	2.400	.043*
238	3.300	2.700	.043*
239	3.300	3.250	.043*
240	3.300	3.550	.043*
241	3.300	3.950	.043*
242	3.300	4.250	.043*
243	3.350	0.950	.043*
244	3.350	1.250	.043*
245	3.400	1.700	.043*
246	3.400	2.000	.043*
247	3.400	2.400	.043*
248	3.400	2.700	.043*
249	3.400	3.250	.043*
250	3.400	3.550	.043*
251	3.400	3.950	.043*
252	3.400	4.250	.043*
253	3.450	0.950	.043*
254	3.450	1.250	.043*
255	3.500	1.700	.043*
256	3.500	2.000	.043*
257	3.500	2.225	.043*
258	3.500	2.400	.043*
259	3.500	2.700	.043*
260	3.500	3.250	.043*
261	3.500	3.550	.043*
262	3.500	3.950	.043*
263	3.500	4.250	.043*
264	3.550	0.950	.043*
265	3.550	1.250	.043*
266	3.600	1.700	.043*
267	3.600	2.000	.043*
268	3.600	2.400	.043*
269	3.600	2.700	.043*
270	3.600	3.250	.043*
271	3.600	3.550	.043*
272	3.600	3.950	.043*
273	3.600	4.250	.043*
274	3.650	0.950	.043*
275	3.650	1.250	.043*
276	3.700	1.700	.043*
277	3.700	2.000	.043*
278	3.700	2.400	.043*
279	3.700	2.700	.043*
280	3.700	3.250	.043*
281	3.700	3.550	.043*
282	3.700	3.950	.043*
283	3.700	4.250	.043*
284	3.750	0.950	.043*
285	3.750	1.250	.043*
286	3.800	2.275	.043*
287	3.800	2.400	.043*
288	3.800	2.700	.043*
289	3.800	3.250	.043*
290	3.800	3.550	.043*
291	3.800	3.950	.043*
292	3.800	4.250	.043*
293	3.875	4.400	.043*
294	4.025	1.475	.043*
295	4.025	1.575	.043*
296	4.025	1.475	.043*
297	4.075	1.675	.043*
298	4.100	1.350	.052*
299	4.100	1.700	.043*
300	4.200	2.000	.043*
301	4.200	2.300	.043*
302	4.200	2.600	.043*
303	4.200	3.200	.043*
304	4.200	3.800	.043*
305	4.200	4.100	.043*
306	4.300	1.000	.043*
307	4.300	1.300	.043*
308	4.300	2.000	.043*
309	4.300	2.300	.043*
310	4.300	2.900	.043*
311	4.300	3.200	.043*
312	4.300	3.800	.043*
313	4.300	4.100	.043*
314	4.400	1.000	.043*
315	4.400	1.300	.043*
316	4.400	2.000	.043*
317	4.400	2.300	.043*
318	4.400	2.900	.043*
319	4.400	3.200	.043*
320	4.400	3.800	.043*
321	4.400	4.100	.043*
322	4.450	1.325	.052*
323	4.450	1.850	.052*
324	4.500	1.000	.043*
325	4.500	1.300	.043*
326	4.500	2.000	.043*
327	4.500	2.300	.043*
328	4.500	2.900	.043*
329	4.500	3.200	.043*
330	4.500	3.800	.043*
331	4.500	4.100	.043*
332	4.600	1.000	.043*
333	4.600	1.300	.043*
334	4.600	2.000	.043*
335	4.600	2.300	.043*
336	4.600	2.900	.043*
337	4.600	3.200	.043*
338	4.600	3.800	.043*
339	4.600	4.100	.043*
340	4.600	4.350	.052*
341	4.600	4.500	.052*
342	4.700	1.000	.043*
343	4.700	1.300	.043*
344	4.700	2.000	.043*
345	4.700	2.300	.043*
346	4.700	2.900	.043*
347	4.700	3.200	.043*
348	4.700	3.800	.043*
349	4.700	4.100	.043*
350	4.800	1.000	.043*
351	4.800	1.300	.043*
352	4.800	2.000	.043*
353	4.800	2.300	.043*
354	4.800	2.900	.043*
355	4.800	3.200	.043*
356	4.800	3.800	.043*
357	4.800	4.100	.043*
358	4.900	1.000	.043*
359	4.900	1.300	.043*
360	4.900	2.000	.043*
361	4.900	2.300	.043*
362	4.900	2.900	.043*
363	4.900	3.200	.043*
364	4.900	3.800	.043*
365	4.900	4.100	.043*
366	4.950	1.850	.052*
367	5.000	1.000	.043*
368	5.000	1.300	.043*
369	5.100	4.026	.052*
370	5.200	0.200	.052*
371	5.200	0.500	.052*
372	5.200	1.100	.052*
373	5.200	1.400	.052*
374	5.200	2.000	.052*
375	5.200	2.300	.052*
376	5.200	2.900	.052*
377	5.200	3.200	.052*
378	5.200	3.800	.052*
379	5.200	4.100	.052*
380	5.200	4.700	.052*
381	5.200	5.000	.052*
382	5.275	1.275	.043*
383	5.275	2.425	.043*
384	5.350	3.175	.052*
385	5.400	3.750	.052*
386	5.400	3.900	.052*
387	5.400	4.050	.052*
388	5.400	4.200	.052*
389	5.550	0.300	.052*
390	5.635	1.050	.043*
391	5.635	1.350	.043*
392	5.650	2.000	.043*
393	5.650	2.300	.043*
394	5.700	2.900	.043*
395	5.700	3.200	.043*
396	5.735	1.050	.043*
397	5.735	1.350	.043*
398	5.750	2.000	.043*
399	5.750	2.300	.043*
400	5.800	2.900	.043*
401	5.800	3.200	.043*
402	5.835	1.050	.043*
403	5.835	1.350	.043*
404	5.850	2.000	.043*
405	5.850	2.300	.043*
406	5.900	2.900	.043*
407	5.900	3.200	.043*
408	5.935	1.050	.043*
409	5.935	1.350	.043*
410	5.950	2.000	.043*
411	5.950	2.300	.043*
412	6.000	0.463	.043*
413	6.000	2.900	.043*
414	6.000	3.200	.043*
415	6.035	1.050	.043*
416	6.035	1.350	.043*
417	6.050	1.550	.052*
418	6.050	2.000	.043*
419	6.050	2.300	.043*
420	6.100	0.750	.043*
421	6.100	2.900	.043*
422	6.100	3.200	.043*
423	6.135	1.050	.043*
424	6.135	1.350	.043*
425	6.150	2.000	.043*
426	6.150	2.300	.043*
427	6.200	2.900	.043*
428	6.200	3.200	.043*
429	6.235	1.050	.043*
430	6.235	1.350	.043*
431	6.250	2.000	.043*
432	6.250	2.300	.043*
433	6.300	2.900	.043*
434	6.300	3.200	.043*
435	6.335	1.050	.043*
436	6.335	1.350	.043*
437	6.350	2.000	.043*
438	6.350	2.300	.043*
439	6.400	2.900	.043*
440	6.400	3.200	.043*
441	6.500	1.150	.043*
442	6.500	1.400	.043*
443	6.525	3.200	.043*
444	6.550	3.900	.052*
445	6.550	4.050	.052*
446	6.550	4.200	.052*
447	6.575	5.000	.052*
448	6.750	0.300	.052*

SIZE	QNTY	PTH
.096	2	0
.052	94	62
.043	352	352

FIG 2. DRILL TABLE

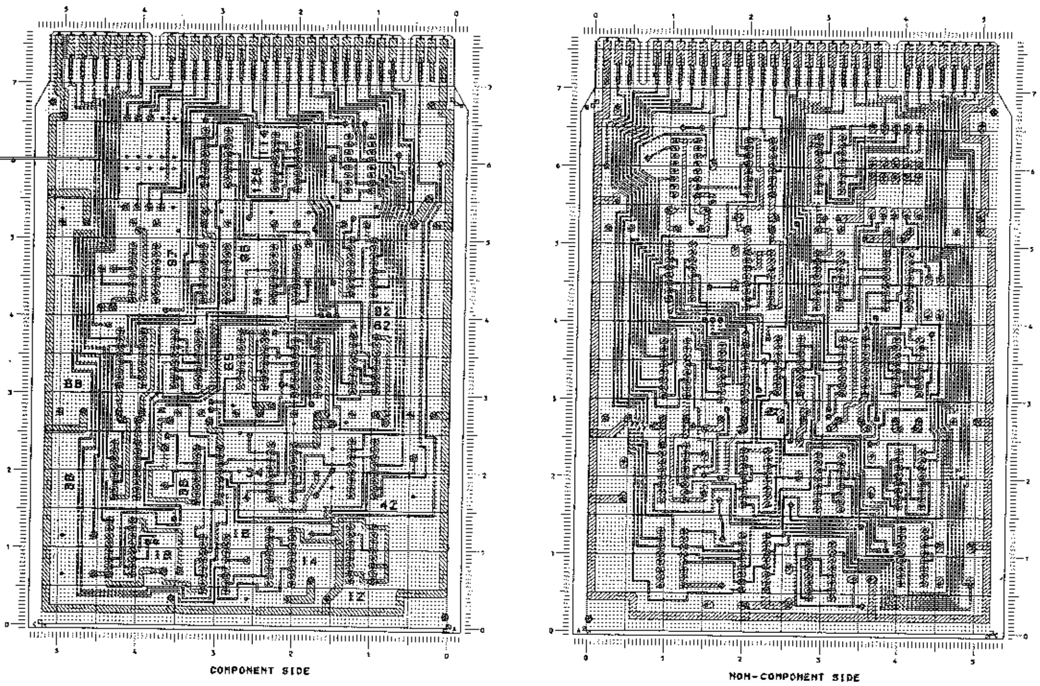
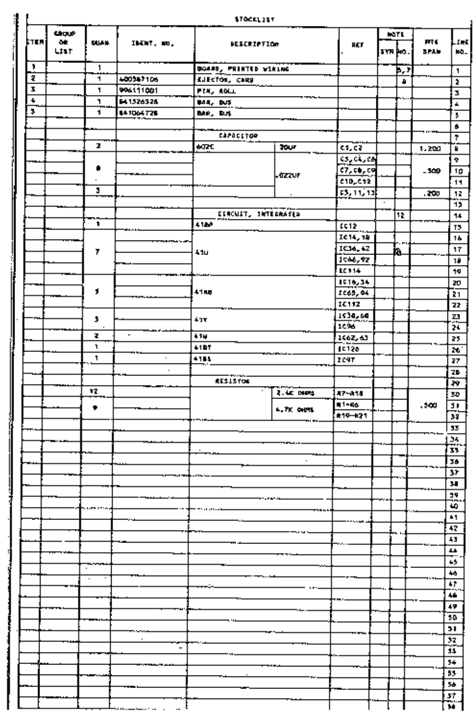


FIG 3. PIECE PART GRAPHICS

D. STOCK LIST

This (Figure 4) provides information on the quantities, supplier, mounting centers, and other information concerning each device to be mounted on the given PCB.



STOCKLIST

ITEM	GROUP OR LIST	QUAN	IDENT. NO.	DESCRIPTION	REF	NOTE SYM	NOTE NO.	MTG SPAN	LINE NO.
1		1		BOARD, PRINTED WIRING			5,7		1
2		1	400387106	EJECTOR, CARD			8		2
3		1	906111001	PIN, ROLL					3
4		1	841326326	BAR, BUS					4
5		1	841064728	BAR, BUS					5
									6
				CAPACITOR					7
		2		602C 20UF	C1,C2			1.200	8
		8		.022UF	C5,C4,C6			.300	9
					C7,C8,C9				10
					C10,C12				11
		3			C3,11,13			.200	12
									13
				CIRCUIT, INTEGRATED			12		14
		1		41AP	IC12				15
		7		41U	IC14,38				16
					IC36,42				17
					IC46,92				18
					IC114				19
		5		41AQ	IC16,34				20
					IC65,84				21
					IC112				22
		3		41Y	IC38,68				23
					IC96				24
		2		41W	IC62,63				25
		1		41BT	IC120				26
		1		41BS	IC97				27
									28
				RESISTOR					29
		12		2.4K OHMS	R7-R18				30
		9		4.7K OHMS	R1-R6			.300	31
					R19-R21				32
									33
									34
									35
									36
									37
									38
									39
									40
									41
									42
									43
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									54
									55
									56
									57
									58

FIG 4. STOCK LIST

E. ASSEMBLY DRAWINGS

In these drawings (Figure 5), the component designations and interconnections are shown for pinpointing exactly what goes where. This information is used in building a prototype to be used as a model for mounting components onto the PCB either manually or by an automatic insertion machine.

In order to fulfill these needs effectively, the drafting practices have undergone a great deal of changes over the years. A brief overview of these changes is presented next.

3. EVOLUTION OF AUTOMATED DRAFTING IN THE BELL SYSTEM

Some of the key developments and changes that have taken place in the drafting practices in the Bell Labs and Western Electric are shown in Figure 6.

A. OLD METHOD OF CREATING NEEDED DOCUMENTATION

In manual drafting the artmaster was constructed by laying black tape on mylar sheets to form the conductor patterns. Once done, the information on the artmaster was transferred photographically to glass for use in the manufacturing process. The same pattern was used to photographically construct piece part and assembly drawing graphics by selective addition of half tone grids and other information. Such a process, due to its manual nature and frequent need for revisions to correct errors or to introduce enhancements, became increasingly expensive and inefficient.

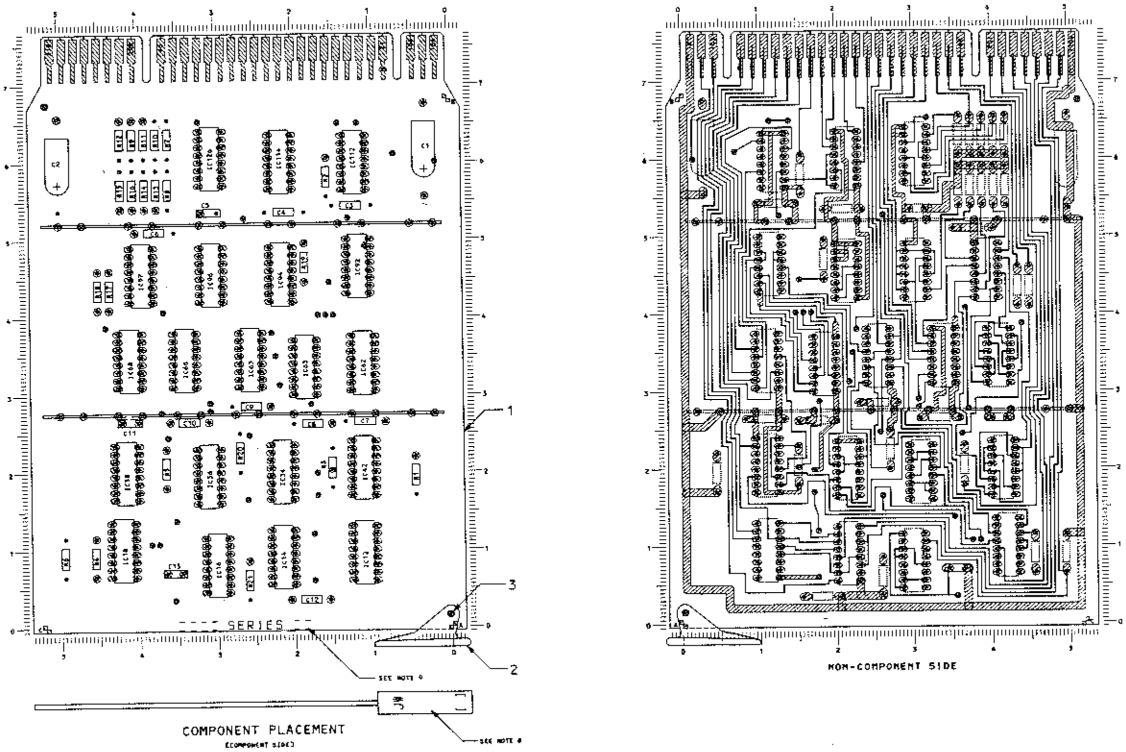

FIG 5. ASSEMBLY VIEWS

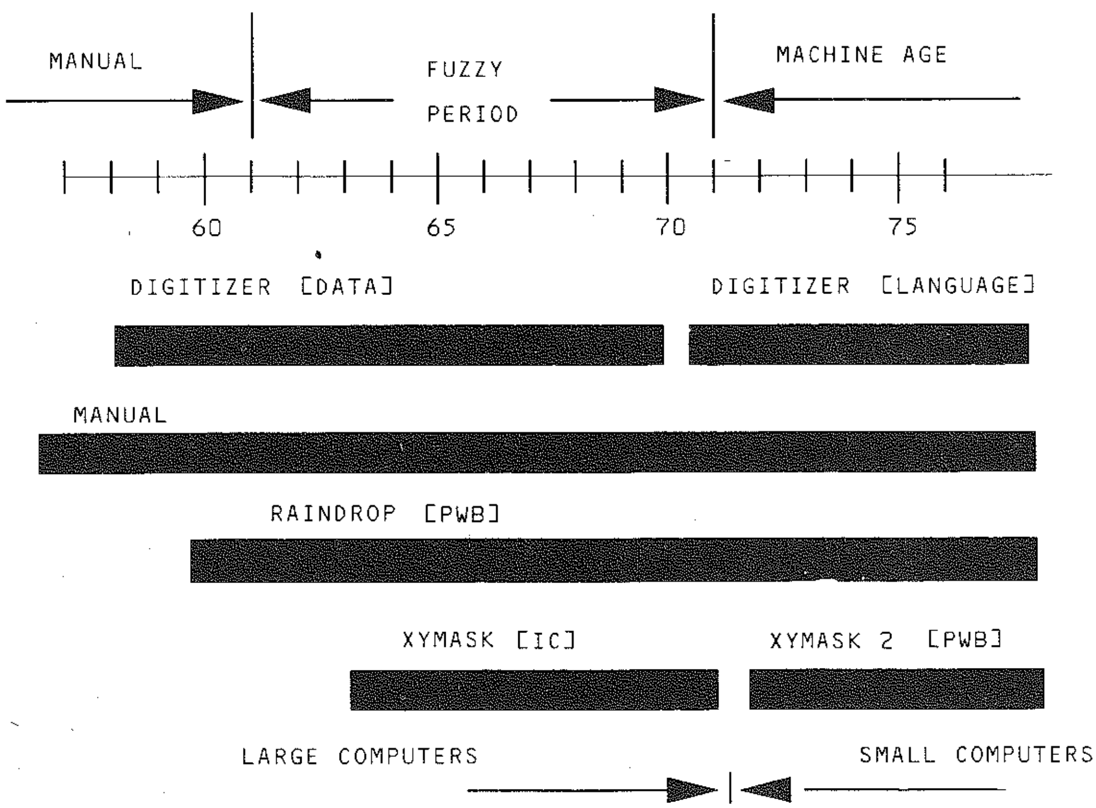

FIG 6. EVOLUTION OF COMPUTER GRAPHICS

B. NEW METHODS OF DESIGN AND MANUFACTURING DOCUMENTATION

The earliest attempts at harnessing computer technology for the design and documentation of PCB's dates back to the late 50's. The first significant step was the development of a high level language suitable for communication PCB design and documentation parameters with a variety of computers. This development was further stimulated by the appearance of a variety of output machines for preparing Artwork and other drawings to handle the ever increasing density of components and ever decreasing widths of metallized areas representing the interconnections between devices to be mounted on a PCB. A few of these machines will be examined shortly. The first language developed was RAINDROP (Random Input Drafting Out Put). This language originated in the PCB technology developed to implement some of the defense projects. Shortly after this development, another language called XYMASK[1] was developed to the Integrated Circuits Fabrication Technology. The name is very suggestive for those of us familiar with doping process of Integrated Circuit manufacturing. XYMASK 2 was adopted as the language for PCB design and documentation tasks. There were many other developments directed at achieving the same goal of the automation of PCB design process. It took over a decade for the technology to mature into a viable, cost-effective total machine environment. During the same period, the transition from large computers to small computers became economical. Thus evolved stand-alone Interactive Graphics Systems. (Figure 6)

4. INTERACTIVE GRAPHICS IN THE MANUFACTURING ENVIRONMENT

A. HARDWARE CONFIGURATION AND ITS USES

The interactive Graphics Systems predominantly used in Bell Labs and Western is based on a PDP-15 and a graphics display processor known as Graphics 2. The hardware organization of a typical Graphics-2 System is illustrated in Figure 7. This system is based on a DEC PDP/15 computer with 32K words of 18-bit-core memory and 1/2 million words of disk storage. The system also includes a card reader, a paper reader/punch, a 9-track magnetic tape unit, a dual dectape unit, a 30 CPS printer and a 202 Dataphone 1200-baud communication link with IBM 370 computer. Now the design information on all Printed Circuit Packs from Bell Labs is received as a software program in XYMASK language. An artmaster used for building a prototype and a schematic for the electrical circuit- and an assortment of changes requests are also provided. The change requests generally reflect either a design change for the proper functioning of the device or a change dictated by the manufacturing processes. Western Electric is expected to modify this data in order to incorporate the requested changes in the design at hand and issue a new set of documentation, i.e., artmaster, drawings, drill tables, etc. for use in the manufacturing processes.

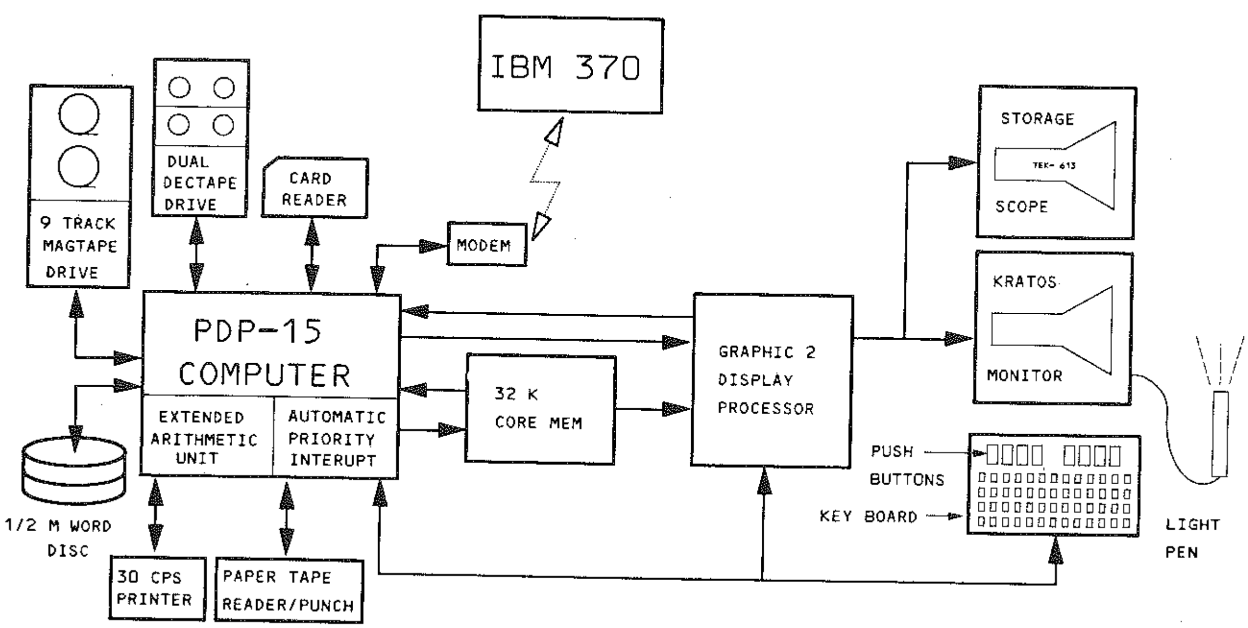

FIG 7. GRAPHIC 2 HARDWARE CONFIGURATION

It is easier to incorporate certain types of changes by modifying the XYMASK coding. However, the ability to change the coding, which at times may be necessary, requires an in depth understanding of the language and its coding practices. But complex changes where relationships of large geometries are involved are much easier and less error-prone if made to the geometric picture represented by the XYMASK coding. Hence, the XYMASK data is translated to its geometric data base and displayed on the refresh Cathode Ray Tube. All the necessary changes are made to the picture by using a keyboard, push buttons, and a light pen. The computer updates the data base to reflect all changes instantaneously.

After all the necessary changes are satisfactorily made, as shown in Figure 8, an array of post processors is used to prepare drive tapes for many different output devices.

B. OUTPUT DEVICES

Here is a brief summary of the commonly used output devices.

A. FR80

FR80® is a computer microfilm recorder offered by Information International, Inc. Its output consists of microfiche, and microfilm is used for preparing all documentation except artwork.

B. GERBER 40

Gerber 40® is a photoplotter offered by Scientific Instrument Co. of Connecticut. It directly plots on a large photographic film with a light source and maintains thousandth of an inch precision.

C. PRIMARY PATTERN GENERATOR[2,3,4,5]

The Primary Pattern Generator, developed internally for supporting the Integrated Circuits fabrication processes, now finds it uses in PCB technology. It is also a photoplotter, but uses a laser beam for exposing the photographic glass of film with ten-thousandth of an inch precision.

D. CAL-COMP® PLOTTERS

These are a family of flat-bed plotters offered by the Calif Computer Products of Anaheim, Calif. Its output, depending on the model, ranges from a drawing on a large sheet to a plot on a photographic film. It also finds its major uses in the I.C. Manufacturing processes.

5. INTERACTIVE GRAPHICS IN DESIGN ENVIRONMENT

The same hardware facility (Figure 7) is used for the design of the Printed Circuit Boards. The software system used for this purpose is called NOMAD[6] (Nonmodular or Modular Automated Design).

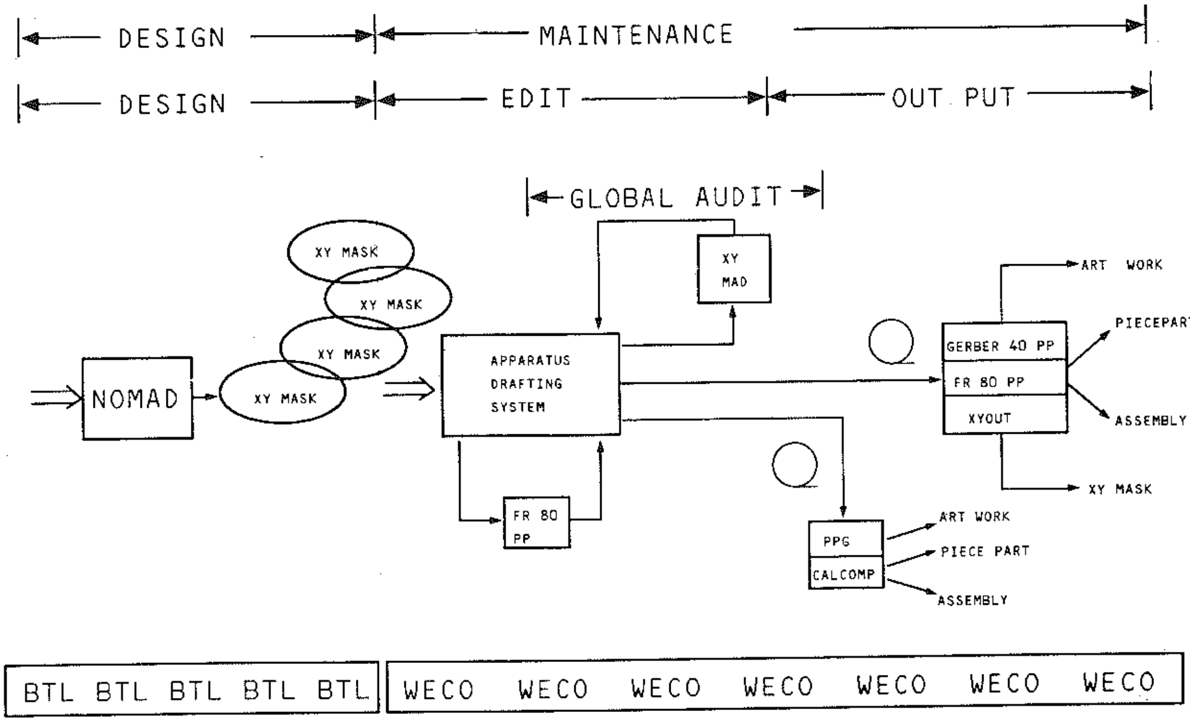

FIG 8. AN OVERVIEW OF THE DESIGN & MAINTENANCE PROCESS

A PCB design usually originates in the form of a rough schematic drawing and a stock list. Using specially designed Nomad input-language, an input deck is coded, reflecting the components needed from the system resident library and the circuit interconnections. After the input information is read into the system, the user activates the automatic placement program[7] resident on an IBM 370 via the date link. The results returned by the placement program are reviewed and adjustments are made if necessary.

Now the user begins the conductor path routing process. First using the air line router, all the interconnections as specified in the input are made. Next, with the aid of the Automatic and Dynamic routers, one untangles the mess created by the air line router, into an arrangement which meets minimum clearance requirements.

Once a design layout is complete, one is ready for output. It is possible now to prepare an artmaster, documentation for assembly operations, and the famous XYMASK coding for Western Electric (Fig.8).

6. COMPATABILITY WITH OLD DESIGNS

The existing documentation prepared manually can be converted into the machine environment by the use of a digitizer. Such a digitizer is interfaced to the same PDP-15 computer which provides the computing power for the Graphics Terminal. With the aid of a specially designed keyboard, a static display and an X,Y pointer, the geometric data is converted to digital data base in XYMASK and is entered into the normal work flow.

7. IMPACT OF INTERACTIVE COMPUTER GRAPHICS

A. INTRODUCTION OF A NEW TECHNOLOGY

This new technology is necessary to support the manufacturing processes for meeting the precision requirements of an ever increasing packaging density of electronic devices.

B. IMPROVEMENTS IN RESPONSE TIME

A complex change which used to be made in a week or more can be accomplished in less than a day.

C. COST EFFECTIVENESS

The new technology offers an average of 3.5:1 cost advantage over the old methods.

D. CLEARANCE-VIOLATION FREE ENVIRONMENT[8]

The electrical characteristics of each family of devices require the maintenance of a specified clearance among all metalized elements of a PCB, which are not intended to be electrically common. Such an objective was extremely difficult to achieve by the mere visual examination of the artmaster in the old environment. The unchecked errors resulted in the production of unusable products hence, a great deal of economic loss. In the machine-aided drafting environment, clearance violation free artwork is obtained by performing a global audit. A global Auditor known as XYMAD[9] will automatically find the clearance violations and flat them (Figure 9). Here the system has clearly marked, with a heavier line, 2 geometries which violate the minimum clearance requirement.

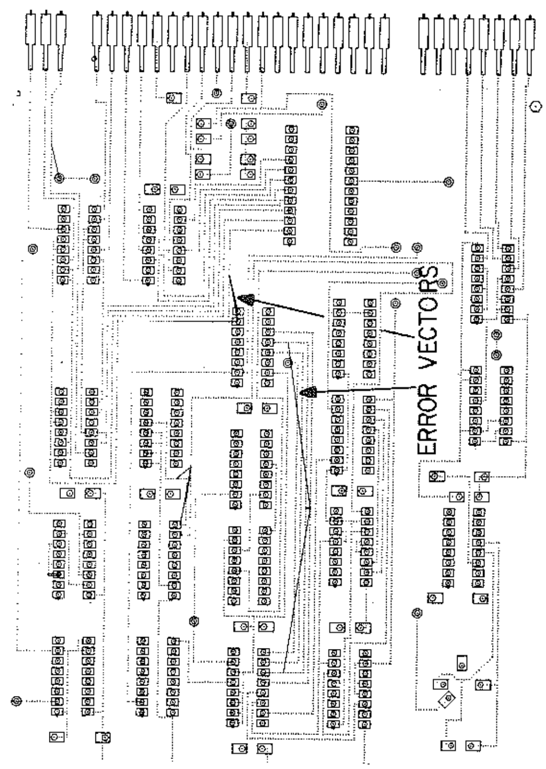

FIG 9. GLOBAL AUDIT RESULTS

E. DIRECT DIGITAL INPUT FOR DRILLING PROCESS

Under the old method a paper tape was manually prepared, reflecting the information contents of the drill table (Figure 2). A great deal of errors were made resulting in the manufacture of more unusable products. The economic losses in this area has now been completely eliminated. In the machine aided drafting environment, the drilling information imbeded in the design data is easily extracted and punched on tape. Drill tapes prepared now not only save the manual labor formerly expended in punching the tape, but are also error free.

8. SUMMARY

Printed Circuit Boards are extensively used for packaging electronic and electromagnetic devices in the Bell System. This paper describes:

- The information requirements of the manufacturing processes in Western Electric, the manufacturing arm of the Bell System.

- The use of Computer Graphics in the design process of the Printed Circuit Boards in the Bell Telephone Laboratories, the Research and Development arm of the Bell System.

- The use of Computer Graphics in satisfying the information needs of the manufacturing processes.

- The evolution of the technology within the Bell System to support the design and manufacturing of Printed Circuit Boards.

- The advantages and impact of Computer Graphics on the design and manufacturing processes.

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METRIC CONVERSION -- THE IMAGINARY PROBLEM

Conversion to the metric system is full of problems and pitfalls. (see We've Got Those Metrication Blues, Fred O. Leidel, Winter 1977). Many of them are imaginary. Being human, we invent problems to justify our resistance to change. The head of the Australian Metrication Board has commented, "A properly planned metrication project is a series of non-events". (Australia has almost completed their conversion to SI units.) Of course, the Australian situation is different from that in North America but their experience shows the importance of proper planning. It is the purpose of this article to give information on drawing scales used in Canada and experience at the University of British Columbia. I hope it may help you in your conversion plans.

The conversion to SI units is a once-in-a-lifetime chance to get rid of a cumbersome irrational system of units. Recall that there is more to metric conversion than simply measuring lengths in millimetres (Canadian spelling, spelled millimeter in U.S.) (at least by the U.S.G.P.O. - Ed.) The imperial system is completely arbitrary and units have no easily remembered relationship to each other. The inch was originally three barleycorns, round and dry, laid end to end. The yard is traditionally reported to be based on the distance from the tip of King Henry's nose to the end of his fingers with his arm outstretched. We have lengths measured in inches, feet, yards, furlongs, chains, miles and numerous others. Worse, the U.S. and Canadian gallon are different in size. How many hours of schooling are used up memorizing the relation between pints, quarts, pecks and bushels, (to name a few)?

Canada and the U.S.A. are the last major countries to convert to SI units and there are some advantages in this. (One reason for conversion is to maintain a trade position in a predominantly metric world. It will do us no good to use metric standards which are vastly different from those used by our major trading partners.) However, we can learn from the experience of others and avoid makiing the same mistakes. We can examine the standards, designs, and drawing scales used by the rest of the world and adopt them if they are suitable.

The metric system is a simple rational system. There are 7 basic units and all other quantities are derived from these. We can keep the system simple by not converting existing drawing scales to equivalent metric scales (i.e. soft conversion) but by selecting new rational scales (hard conversion). Mr. Leidel is correct in saying that there are no metric scales equivalent to existing imperial scales and I, for one, am not sorry. Do we want ratios like 1:96 (1/8" - 1'-0")? There are metric scales which are close to existing scales and these have been adopted in Canada and other countries. I have talked to European engineers who have used only one scaling instrument and simply moved the decimal point to get different scales. This works of course, but it is convenient to have other scales. Table I shows drawing scales which are preferred for Canadian building drawings. While these scales are not exact equivalents of imperial scales, they are close. Note that all scales follow the progression 1-2-5.

TABLE 1

Drawing	Recommended Scales	Use	Former Scales (Ratios)
Block Plan	1:20 000 1:10 000 1:500	To locate the site within the general district	1"=200' (1:2 400) 1"=100' (1:1 200)
Site Plan	1:500 1:200	To locate building work, including services and site works, on the site.	1"=40' (1:480) 1/16"=1' (1:192)
Sketch Plans General Location Drawings	1:200 1:100 1:50	To show the over-all design of the building. To indicate the juxtaposition of rooms and spaces, and to locate the position of components and assemblies.	1/16"=1' (1:192) 1/8" =1' (1:96) 1/4" =1' (1:48)
Special Area Location Drawings	1:50 1:20	To show the detailed location of components and assemblies in complex areas.	1/4" =1' (1:48) 1/2" =1' (1:24)
Construction Details	1:20 1:10 1:5 1:1	To show the interface of two or more components or assemblies for construction purposes.	1/2" =1' (1:24) 1" =1' (1:12) 3" =1' (1:4) Full size(1:1)
Range Drawings	1:100 1:50 1:20	To show in schedule form, the range of specific components and assemblies to be used in the project.	1/8" =1" (1:96) 1/4" =1' (1:48) 1/2" =1' (1:24)
Component and Assembly Details	1:10 1:5 1:1	To show precise information of components and assemblies for workshop manufacture.	1" =1' (1:12) 3" =1' (1:4) Full size(1:1)

Preferred Scales for Building Drawings (Ref.: Manual on Metric Building Drawing Practice, C.S. Strelka, L. Loshak, J.S. Torrance, National Research Council of Canada, NRCC 15234).

These scales have been used in the Engineering Graphics course for three years at the University of British Columbia. The civil engineers scale, mechanical engineers scale and architects scale have been replaced with one scaling instrument. Students are given some instruction in the use of these scales since drawings using them will be around for a while. The metric scaling instrument we use has 8 scales; 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:500 and 1:1 000. The absence of the 1:1 scale has not been a problem since the 1:10 scale can easily be used. Any other scales required (e.g. 1:2 000) are easily obtained by adding the required number of zeros. This scaling instrument is used for all assignments. All measurements are in metres or millimetres. The centimetres is only for force scales (e.g: 1 cm = 500 kN) in vector work. We do not use ratios like 1:10 560 or 1:2 880.

There have been no problems with conversion of our graphics course to metric units. In fact, it makes work easier for students. They do not have to struggle with the difference between the mechanical engineers scale and the architects scale. Considerable time is saved because metric scales require almost no instruction. Compare the space devoted in textbooks to instruction on conventional scales to that required for metric scales. This certainly emphasizes the simplicity of the metric system.

This simplicity of the metric system is something we must take advantage of. There is nothing to be gained but confusion, by using a civil engineers scale as a metric scale. Who needs (or wants) ratios like 1:78 744 ? That is certainly not in keeping with the concept of simplicity inherent in the metric system.

The only way to learn the metric system is to use it. We force this by having no dual dimensioning. Any problems done in metric units are done only in metric units. There is no conversion from one system to another. Australian and South African experience with metric conversion has shown that the complete elimination of imperial units mean faster learning of metric units. If dual dimensions are used we look only at the ones we are familiar with. The metric system is here to stay. Let"s take care not to inch into it.

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USE OF COMPUTER GRAPHICS IN PRODUCT ENGINEERING

Good Afternoon -

I want to thank you for the opportunity to be with you this afternoon to discuss the subject of computer graphics, and how we have used it in the Product Engineering Department of Saginaw Steering Gear - an automotive accessory division of General Motors. But first before I discuss the specific uses of graphics, I would like to give a brief description of Saginaw Steering Gear.

Seven manufacturing plants and the Divisional Offices are located in Saginaw, Michigan, about 90 miles north of Detroit. An eighth manufacturing plant, along with a soon to be built ninth plant, is located in north central Alabama, near Decatur. The divisional employment is just over 10,000. We produce a wide range of products which include -

- Manual and Power Steering Gears
- Rack & Pinion Steering
- Power Steering Hydraulic Pumps and Hoses
- Energy-Absorbing Steering Columns
- Tilt-Wheel and Tilt & Telescoping Driver Adjustable Steering
- Front-Wheel Drive Axles
- Exhaust Emission Control Air Pumps
- Propeller Shafts and Universal Joints
- Steering Linkages and Components
- High Efficiency, Low Friction Recirculating Ball Bearing Screws and Splines

In order to develop this broad range of products, we have a Product Engineering Department that is located in the Divisional Headquarters. It has design and development responsibility for both the current and future product lines. In order to accomplish this task the department has been divided into 2 major sections- the design activity and engineering services.

The design activity is further divided into approximately 24 project groups each with responsibility for some specific part of our product family.

The engineering services activity operates an extensive physical test laboratory, model shop, engineering information distribution center, and an analytical analysis group.

This paper by Mr. Brown and the paper by Mr. Asghar appearing in this issue were delivered at a joint Illinois-Indiana-North Central Section meeting held at Tri-State University in April of 1977. The session was cosponsored by the CoED and EDG divisions; a third paper by R. D. LaRue will appear in an early issue.

The Analytical Analysis Group is where we have introduced the computer aided graphics equipment for use by the Product Engineers. As supervisor over this area, I will describe in the rest of my presentation:

- what graphics equipment we use
- some of the typical applications for which it is used
- the general justification for obtaining the equipment
- some of the problems we have encountered in using it and in closing
- what I see as the future for computer aided graphics

II. Description of Graphics Equipment in Product Engineering

We have been involved in computer aided graphics for about 8 years. It started with the installation of an off-line tape-driven Calcomp drum plotter that was used to plot data generated by programs executed on a large scale Control Data Computer. The generated data was passed to special plot routines that converted it to a magnetic tape format readable by the plotter. Within the last year we upgraded to a newer and faster model 936 Calcomp drum plotter. It is still operated off-line, via a magnetic tape driven controller.

A second type of graphics equipment that we have installed within the last year is a Tektronix remote job entry terminal. It consists of a model 4012 video tube and keyboard, a 34x44 inch model 4954 digitizing board, and an 8 x 10 inch electrostatic hard copy output device, model 4610. This system was installed to allow communication with large time sharing computer networks so we can perform "finite element analysis" studies. The operator generates a graphic model, of the part to be studied, on the video screen by using the digitizer and/or keyboard. Once the model is completed, to the operators satisfaction, the data is transmitted for analysis. On completion of analysis the results are viewable in graphic form on the screen. Hard copies of this information are also available on command.

A third, and most advanced type of computer aided graphics equipment that we have, was installed just about 2 years ago. It is a complete system for design and drafting in both 2 and 3-dimension. We have a three work station system that is produced by Applicon Inc. of Burlington, Massachusetts. This system uses its own mini-computer to couple a video display, typewriter keyboard, and electronic sketch pad into a work station; that the designer can use to translate his ideas into the system. The desired shapes can be created on the video tube through the work station devices using a furnished design software package or user written commands. A disk drive is used to store active in process information while a magnetic tape drive is available to store completed drawings and historical information. A stored shape can be recalled at will, modified to suit by adding, changing, or deleting segments; and displayed in the conventional 2-dimension views or on command in a 3-dimension form. (Figure 1) Text and dimensions can be added to the design so a completed working drawing can be produced. The drawings are generated on a high speed 34x44 inch flatbed plotter which is also under the control of the mini-computer. The three work stations, along with a DEC writer terminal, time share with the computer. The DEC writer can be used to initiate background commands or as a programmers terminal.

The equipment that we use is by no means the only of its kind on the market. There are several other brands with similar capabilities that can be chosen, therefore, this is not an endorsement of the manufacturers listed.

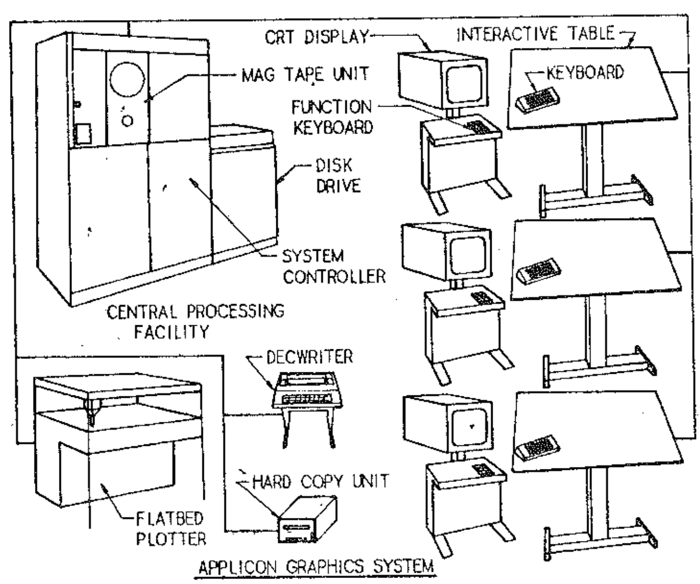


Figure 1

III. Typical Applications of the Graphics Equipment

I would now like to take a couple of minutes and quickly review some of the work we get as output of our graphics equipment.

From the off-line drum plotter we get such things as:

- Line and bar charts
- Data charts

From the dial up remote terminal we get such things as:

- Finite element analysis geometry plots (Figure 3)
- Deflection plots (Figure 4)
- Stress plots (Figure 5)

From the computer sided design system we get such things as:

- Text illustrations
- Technical illustrations (Figure 2)
- Interference studies
- Geometric form generations (Figure 6)
- Organizational charts
- Complex forging shapes (Figure 7)
- Bent tube assemblies (Figure 8)
- Complex component design (Figure 9)

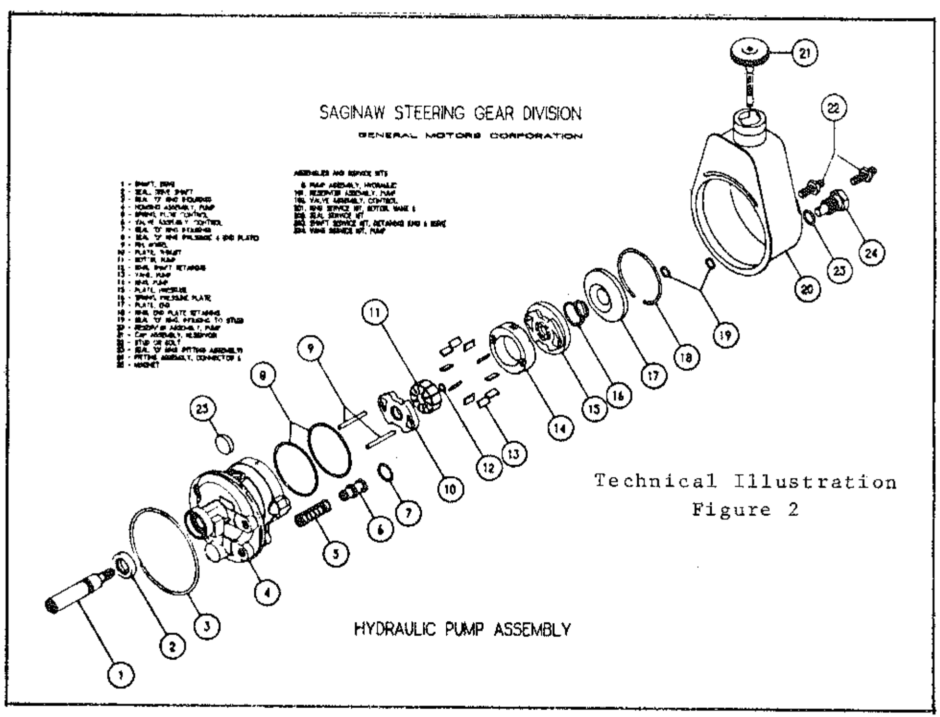
IV. Justification for Using Graphics Equipment

The three most important factors for adding any type of automated graphics equipment are speed, accuracy, and manpower utilization.

Speed or rate of throughput is a significant factor when we consider the time it takes to develop a product and place it on the market. Competitive position is often determined by the company that gets their product to the public first. Therefore, we have found that the graphics output devices, coupled with the power of the computer can save us many valuable days, weeks, or even months in this process. As an example, a typical finite element analysis can be performed in an average of 5 days where before getting the graphics terminal in house it was a 13 day cycle. A savings of 8 days per run. On the graphics design terminals we have seen improvements from 2:1 to over 10:1 on drafting work, compared to the conventional board method.

Accuracy of the graphics equipment can be measured in at least 2 ways. First, of course, is dimensional accuracy. The system can produce and reproduce time and time again any image with a maximum error of .0001 over 140 feet. Secondly, through the memory of the related computer, we can repeat a simple or complex design or a string of text, time and time again with a simple operator command. This is a great time saver in areas where the same or similar jobs are done on repetitive basis.

When considering computer graphics we must look at a third factor; that of improving the utilization of our manpower. The equipment with its available computer power and related software can increase productivity of the user over the conventional manual methods available. In many instances the graphics equipment is being used to produce output that was not even possible or economically feasible before its introduction. Items such as stress plots from a finite element analysis or a gear tooth form generation are just two examples of this fact.

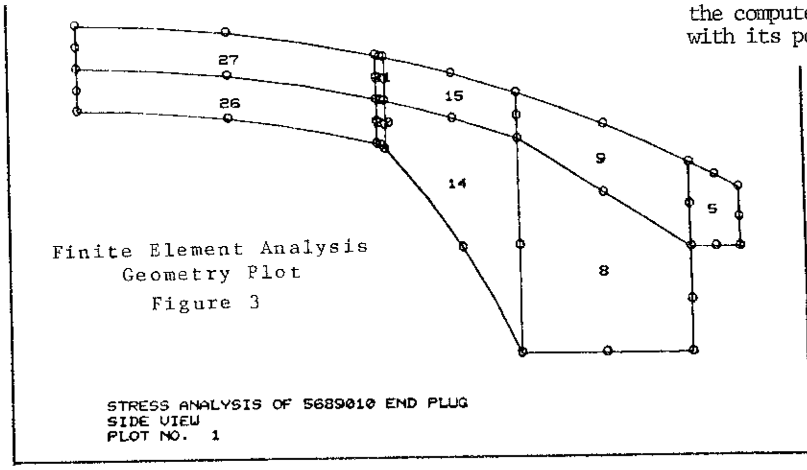


Technical Illustration
Figure 2

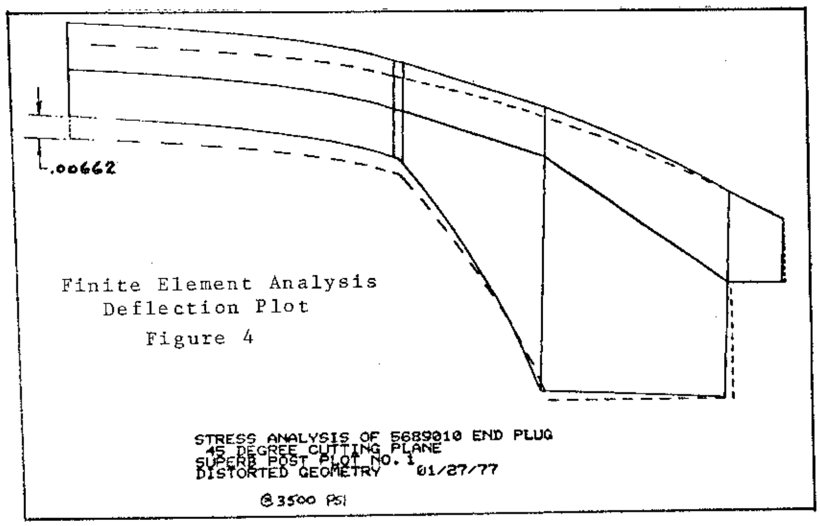
V. Problems Related to Use of Computer Aided Graphics

As with most new approaches to performing work, there were and still are a few problems with computer aided graphics. I will very briefly touch on six problems that we have encountered at Steering Gear since installing and using our Applicon equipment. I will not try to offer complete solutions at this time, because I don't feel I have the answers nor will time permit to explore each in depth.

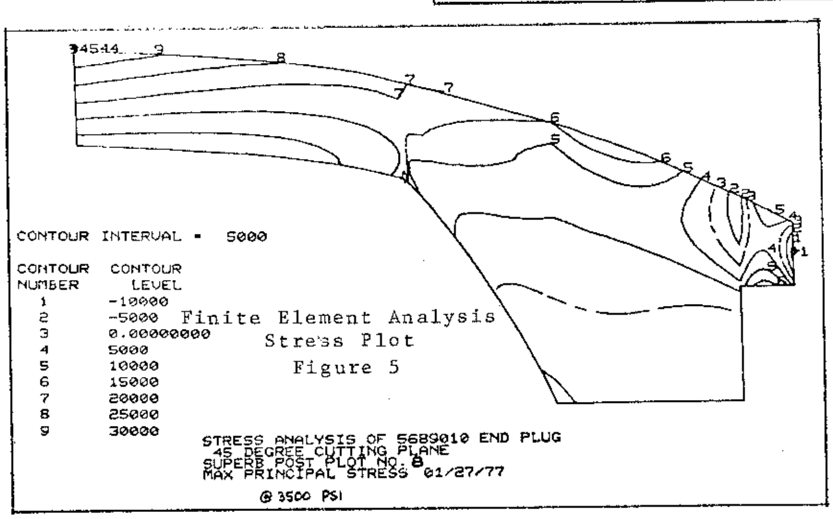
1. Acceptance by the Engineering Community- The acceptance of these concepts have been very slow, in my opinion. The fact that the computer is involved in the process gives it a mystic aura, and therefore, many people who don't understand the computer refuse to accept the value of computer graphics. Too many stories exist about the fallibility of computers to allow some to accept the results. We still have many engineers that received their formal education prior to the computer era and some are still not in tune with its potential.



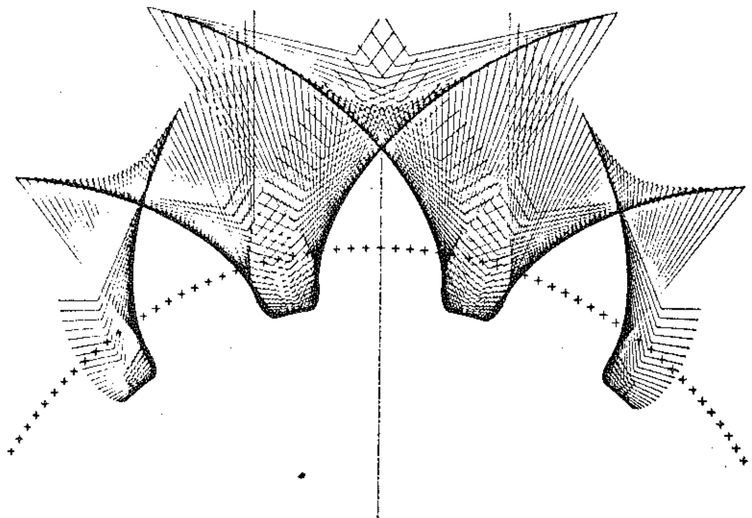
Finite Element Analysis
Geometry Plot
Figure 3



Finite Element Analysis
Deflection Plot
Figure 4



Finite Element Analysis
Stress Plot
Figure 5



Geometric Form Generation

Figure 6

2. Selection of Users - Contrary to what is commonly presented, not everyone is suited to working with graphics equipment. We have found these characteristics to be desirable in a person who is being considered to work with the system:

* Is interested in the concept
* Has initiative
* Is creative
* Has general drafting skills
* Is flexible
* Has perserverance
* Is a salesman
* Shows an aptitude for the system

Of course, it is a rare individual that possesses all of these traits; therefore, we look for a person with as many as possible. We have found that individuals with and without college degrees do equally well.

3. Learning Period - Learning the fundamentals of most graphics systems is a time consuming process and not as easy as may be presented at first glance. It is true that a person can sit down at a terminal and in a few minutes display some rudimentary figures; however, to become proficient with the system it takes a good

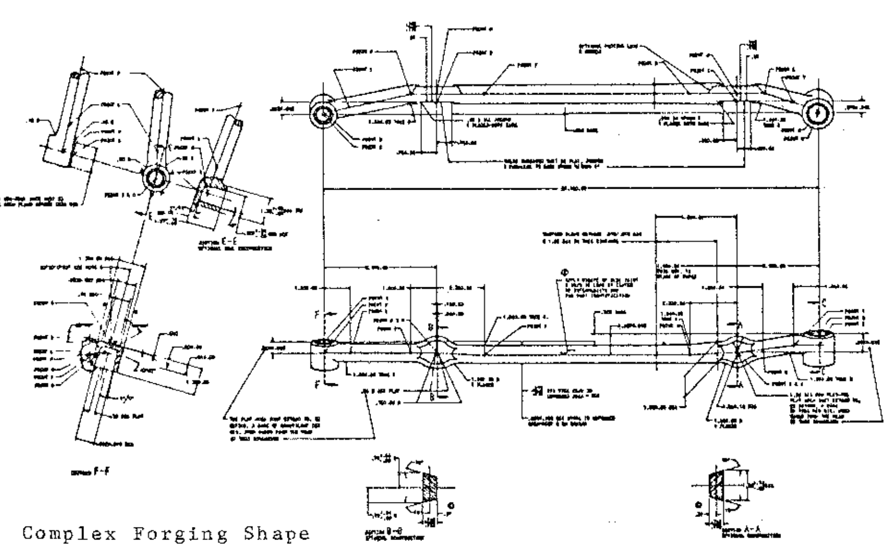
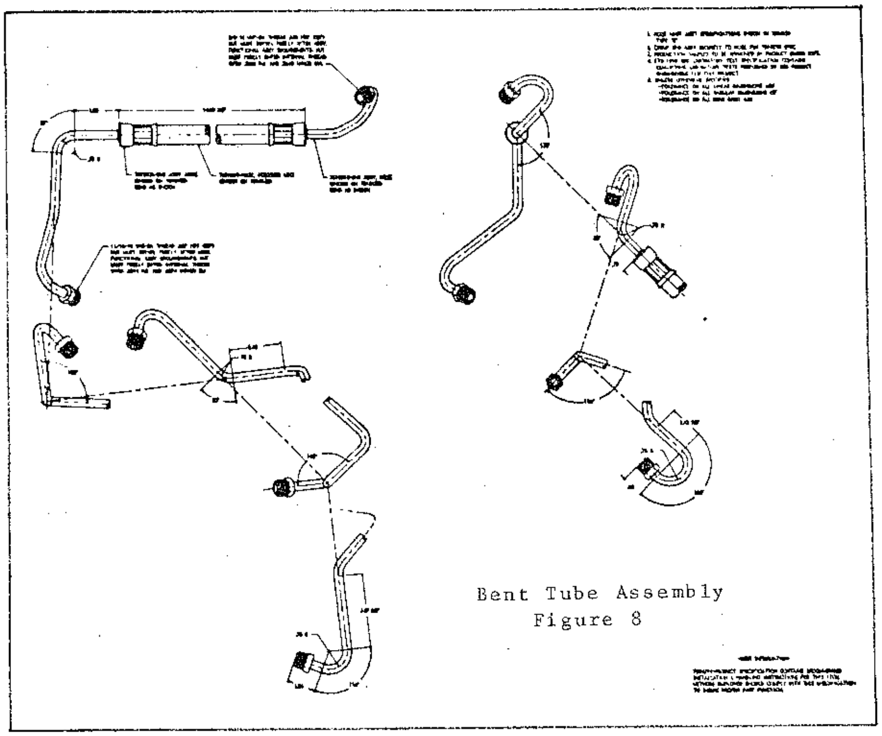

Complex Forging Shape

Figure 7

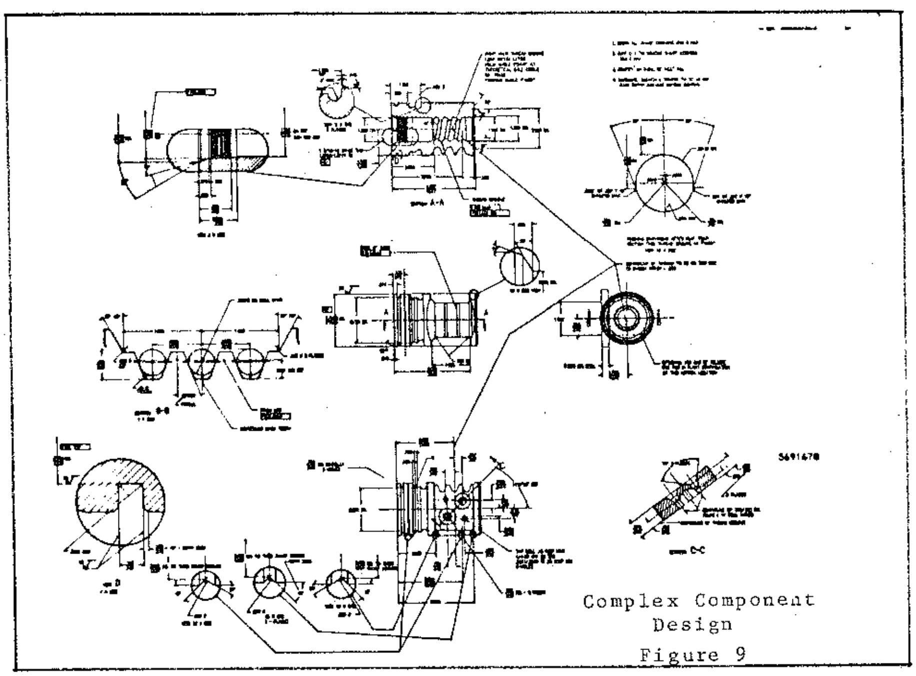


Bent Tube Assembly
Figure 8

teacher and usually a minimum of 3 months experience. In a location where there was no previous graphics equipment this learning period could easily extend to 6 or 9 months. Payback would begin after that point.

4. Limitation of Available Software - Most software that is furnished with a graphics design and drafting system has a basic set of user commands that allow for general geometric construction plus system housekeeping routines. It was soon discovered that in order to improve the efficiency of the users, it was necessary to develop special macro commands that would execute a series of repetitive instructions in one step instead of several. This required the use of higher level languages that were available for this purpose. Fortran is available for use in writing programs to improve system efficiency. These special macros and programs require the talent of a person in house with computer programming interest and knowledge or, if he is not available, money to pay the vendor to do the work.

5. Cost of the System - It is difficult to get even a single station graphics design and drafting system for under $150,000. This includes only one work station, the host computer and its required peripherals, and plotter.



Complex Component
Design
Figure 9

Additional work stations are typically about $40,000 each. Therefore, this is not a system that every company can easily afford. Technological changes in hardware design should help to bring the cost down.

6. Speed of the System - Because each device on most graphics systems must share the resources of a common mini-computer, the more that are active at one time, the slower the total throughput. One activity per computer would be the best; however, due to cost, this is very prohibitive. Software and hardware features are available to minimize the appraent delays; however, the capacity of the computer is the current limitation. Savings on jobs performed on the computer graphics system, even with time delays, is still worth its use over manual methods.

VI. Summary

In closing, I would like to make a few comments that reflect my overall feelings of the future for the Computer Aided Graphics field.

First - Those of us who are using this tool in our business today are only scratching the surface of its total potential. We are really pioneers in developing each application. There are no text books or hoards of experts that we can call upon to help solve our problems, and vendors often don't realize the full capability of what they are offering. Therefore, because we are all reinventing the wheel, so to speak, there is need for establishment of standards and improved information interchange.

Next - I see the need for the current user community of Computer Aided Graphics to become involved in the definition of future system design. We cannot afford to wait for the vendor to think of all the ways we need to use the equipment. In my opinion the systems of the near future should:

- be man not machine controlled for throughput
- be easy to teach and use
- have a level of compatibility with other graphics systems

and - meet the needs of the users

Finally - and most important, we will need people who can envision the potential value of this as a tool and who are willing to dedicate their effort toward making it a success. This means they must be open minded to new ways of doing the routine as well as the most technical activities in engineering.

Computer Aided Graphics is not a toy developed to please people by making pretty pictures; but is a tool, when properly used, that will speed our quest for a better tomorrow.

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DIRECTING INSTRUCTION TO MEET JOB REQUIREMENTS - AN EXAMPLE USING TECHNICAL ILLUSTRATION

Though this example deals with identifying and ranking job variables for technical illustrators, those interested in any area of technical training will find valid and reliable tools for establishing specific job requirements. The use of these job analysis and market research tools, along with the knowledge and expertise of the staff, can provide for effective, efficient, and demand-based instruction.

The Need

Technical graphics which is illustrative in nature is produced in support of the technological process in the design, documentation, and marketing of a product. This activity is generally called "technical illustration" and those engaged in the activity are called "technical illustrators". In order to structure instruction which is valid, the author conducted a study to ascertain:

1) Who is producing technical illustration?

2) What are those necessary observable skills and attitudes from which employers choose to define the jobs of those producing technical illustration?

The methods used in the past to structure and guide instruction in technical illustration have, for the most part, been ono-generalizable local surveys and the personal experience and intuition of the faculty.[1] Mail surveys have often been rejected due to low return ratios or a lack of research experience on the part of the investigators.[2] But, if instruction is to be valid for both general and specific work situations, it must be designed around a reliable, valid, and generalizable base.

Techniques for building such a base begin with Frycklund's early instructional techniques[3] and continue into current market research and government publications on job analysis.[4] An indepth analysis of the aspects of a job must precede the organization of the training to fill the job,[5] therefore, the first stage in any training development program is a job study involving task analysis.[6] Of the many accepted job analysis techniques, the survey or interview offers the most effective method considering cost, time, and accuracy.[7] In order to produce practitioners who best meet or exceed the expectations of potential employers, and thereby enjoy the best chance for employment, the job requirements for those practitioners must be documented.

The Survey

The study sampled from 18,000 firms listed in the 1974 Ohio Directory of Manufacturers. A three-stage, stratified cluster sampling technique, with probability proportional to product cluster size, resulted in a final sample of 149 manufacturing firms in 64 distinct product groups. This sample represented the diverse manufacturing activity in Ohio in terms of 1) product produced, 2) number of employees, and 3) location of the firm geographically in the state. A validated survey instrument was sent to graphics supervisors in each of the surveyed companies to record their attitudes on technical illustrator job success and on the preparation, personal traits, and illustration skills of their illustrators. After follow-up a return rate of 50% was realized.

The data from the study were factor-analyzed[8] and the underlying factor structure was

Group A	Powerful and Valued (in order)	High School Diploma Layout, Paste-up, Lettering Post High School Cirtificate Principles of Manufacturing
Group B	Valued, not Powerful (in order)	Type Specification Assembly Drawing Marker Rendering Ink Rendering Pencil Rendering Principles of Design Idea Sketching Demonstrates Company Loyalty Punctuality Meticulous Work Habits Works Well Under Pressure Gets Along Well With Others Charts, Graphs, Visuals Draftsmanship Portfolio of Examples Freehand Perspective Drawing Engineering Drawing Descriptive Geometry Previous Experience Leader Figure, Takes Initiative Instrument Perspective Drawing
Group C	Powerful, Not Valued (in order)	Model Making Industrial Design Degree Associate Degree Dress, Appearance Architectural Principles
Group D	Not Valued or Powerful (in order)	Photography Landscape Drawing Photo Retouching Watercolor Rendering Sign Painting Zip-a-tone, Dry Transfer Axonometric Drawing Overhead Transparencies Keylining Cartooning Principles of Science Human Figure Drawing Four-Year Art Degree Airbrush Illustration

Figure 1

TECHNICAL ILLUSTRATOR JOB VARIABLES IN ORDER OF IMPORTANCE regressed on the dependent variable of attitude toward technical illustrator success.[9]

Survey Results

The job requirements of individuals producing technical illustration in manufacturing firms in Ohio were found to be described by eleven underlying factors. When this factor structure was regressed on the dependent attitude measure, the independent job variables were rated by:

1) How they account for variability in the attitude of supervisors toward what makes a successful illustrator. (POWER)

2) How the job variables were ranked by the supervisors on a 5-point unimportant-critical scale. (VALUE)

This rating of the job variables on the two dimensions of POWER and VALUE is presented in Figure 1. Keep in mind that a job variable may be very powerful but not highly valued. Those job variables which are powerful and highly valued would be most important in structuring instruction. Those job variables which are highly valued but not powerful would be less important. Job variables which are powerful but not valued would be important only as they are valued. Finally, job variables which are neither valued nor powerful would not be considered in structuring instruction. Figure 2 presents this evaluation scheme.

There were no differences in the ratings of the job variables when viewed in the following ways:

1) By how the respondent used technical illustration (to design, to document, or to persuade).

2) By the size of the company (number of employees).

3) By how many follow-ups were required to elicit response.

4) By comparing the response group with a sample of the non-response group.

Conclusions

Analyzing the data obtained from this study for training and instructional purposes, the following conclusions may be reached:

1) If a program were initiated to train individuals to produce technical illustration for manufacturing firms in Ohio, the curriculum would be structured to reflect the job variables as they are found in order in Figure 1. The job variables in Group D would be included only as they may be specifically requested, not as a general part of the instruction.

2) Technical illustration includes most technical art and engineering drawing, and is broader in scope than the accepted academic definition.

3) A substantial number (more than 60%) of manufacturing firms buy their technical illustration from outside agencies rather than produce it in-house. Programs training technical illustrators should reflect this in an agency or subcontractor emphasis, rather than in the prevalent in-house emphasis.

4) Those producing technical illustration are not expected to have a four-year degree.

5) Technical illustrators are a small percentage of the individuals producing the expanded definition of technical illustration.

6) Programs offering experiences in technical illustration and technical art should seek out the technologists, engineers, architects, designers, planners, and managers who are expected to have facility in technical illustration as it is used to design, document, and persuade.

7) Technical illustration will move toward a process orientation and away from a product (documentation) orientation. Technical illustration will be used more as an active design tool.

Group A	Powerful and Valued	Considered First for Instruction
Group B	Not Powerful but Valued	Considered Second for Instruction
Group C	Powerful but Not Valued	Considered Third for Instruction
Group D	Not Powerful, Not Valued	Not Considered for Instruction

Figure 2

SCHEME FOR EVALUATING THE IMPORTANCE OF TECHNICAL ILLUSTRATOR JOB VARIABLES

The method of investigating job requirements described here demonstrates the applicability of job analysis and market research models in guiding technical instruction. The results of this study should be generalized to other programs in technical illustration only as the population reflects the nature of manufacturing firms in Ohio. The tools used in the investigation are applicable across all technical training or educational situations.

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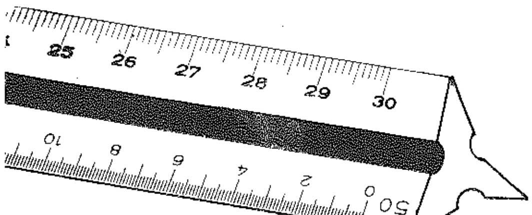

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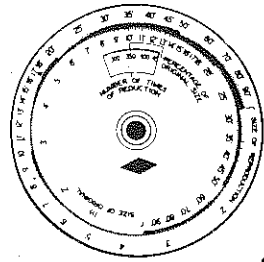

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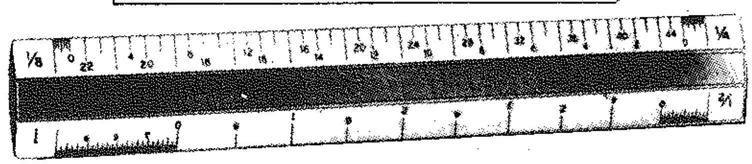

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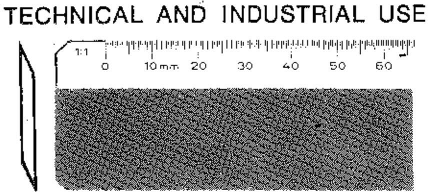

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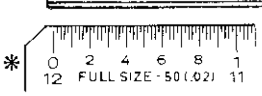

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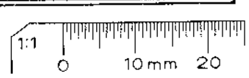

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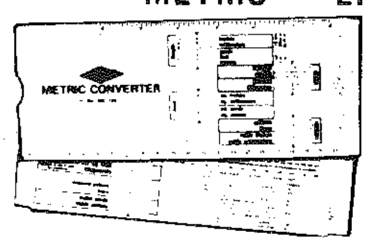

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