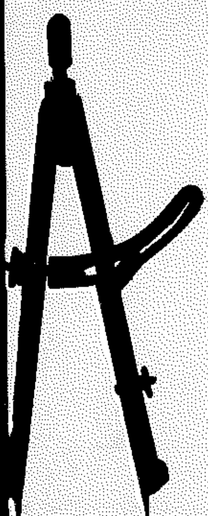
THE JOURNAL OF ENGINEERING GRAPHICS



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VOL. 28, NO. 1 SPRING 1964 SERIES NO. 82

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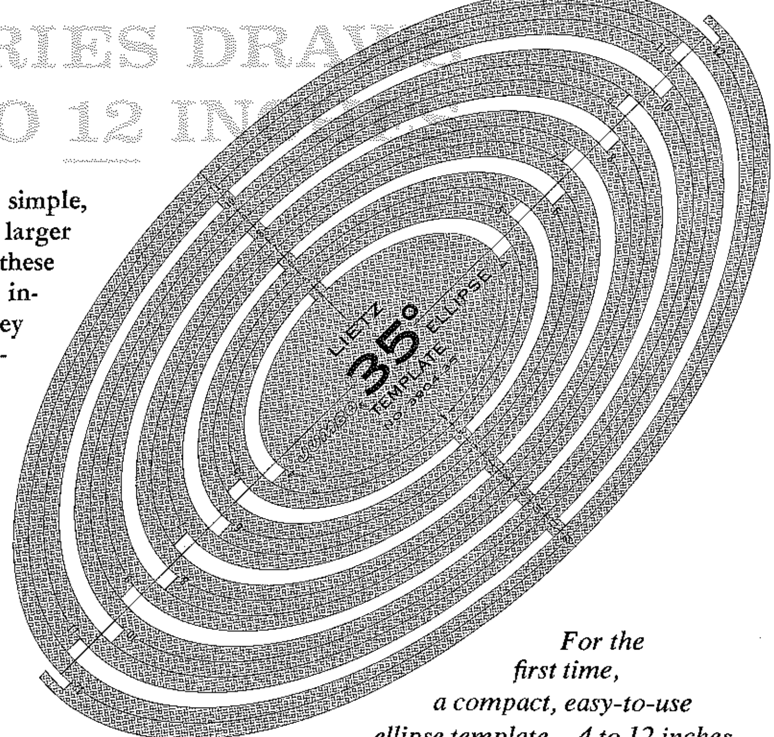

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CONTENTS

EDITORIAL

This issue of the Journal again brings you an article on curriculum. We also print an article on advanced Nomography by Professor Levens which assumes you have studied the basic notions presented by Professor Arnold in the 1963 Winter issue. Also printed is a report of nomographic - electronic computation by Professor Douglas P. Adams who has pioneered in this field. His definition of a graphics process as the correlation of space position with a numerical value is indeed a modern one to your editor who still hankers after a pencilled line and such notions as visualization and conceptualization in the mental processes underlying engineering graphics. Between Doug Adams and Steve Coons at M.I.T. we can glimpse the future of engineering graphics.

All engineering colleges will be visited this year by the national ASEE Committee on "Goals of Engineering Education." One might hypothesize that the primary goal of Engineering Education is still "to teach our students to think". Don't wince at this hackneyed phrase. The engineering style of thinking is different from the scientist or the mathematician. He is characterized by the ability to unify and simplify a vast amount of information into a workable solution of a real problem. The engineering style, because the solution must be simple even though based on deep understanding, requires intuitive invention. Maurice Biot says the engineer's thought is characterized as "cutting through scientific red tape".

The Nat'l ASEE encourages you to take an active part in the study group in your school concerning GOALS. Our engineering graphics courses can be the foundations of design, requiring practice in the engineering style of thinking, exercises in conjecture, insight, synthesis, and invention.

For the Spring (May) 1964 issue we would like to have your articles on "Goals of Engineering Education in Graphics." This Journal has not heard from some of the most vocal members of the graphics engineering educators. Write us an article!

M.F.B.

M.F. Blade

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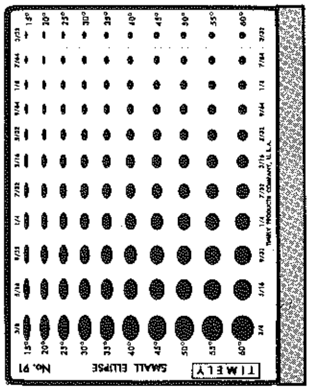

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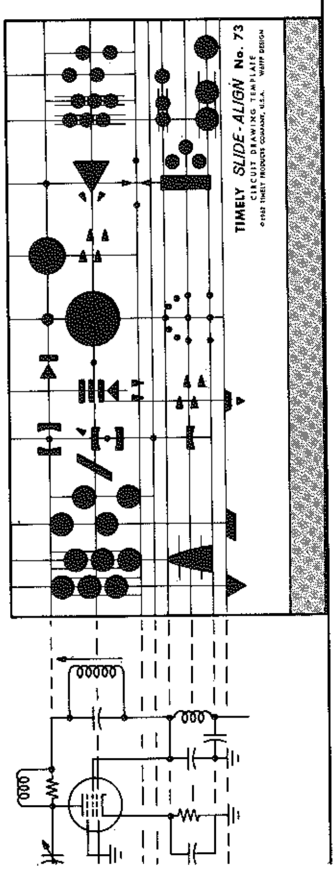

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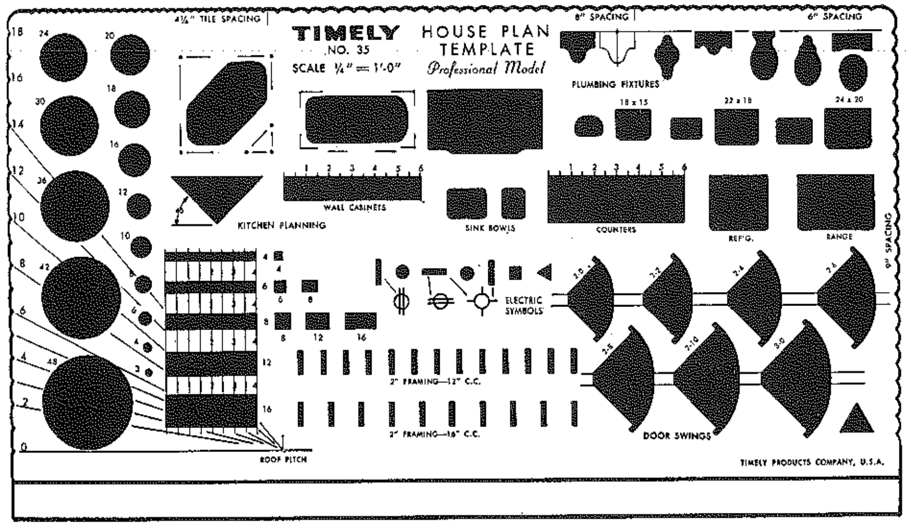

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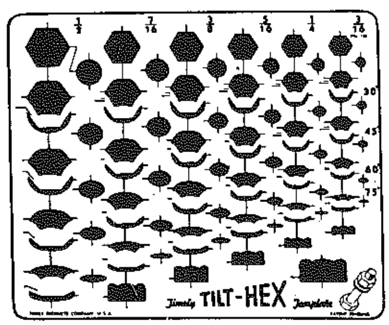

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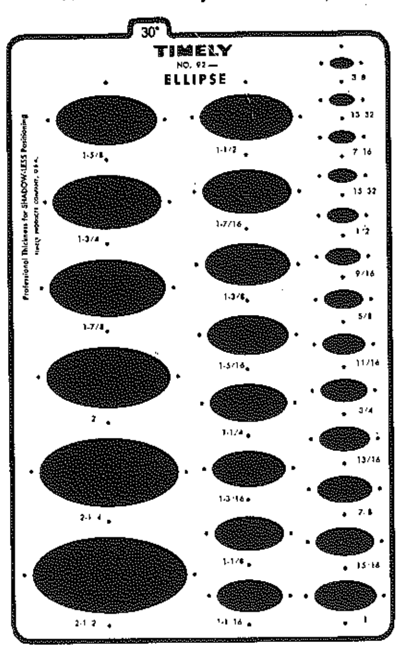

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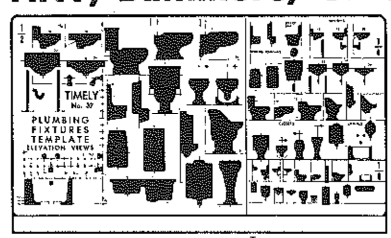

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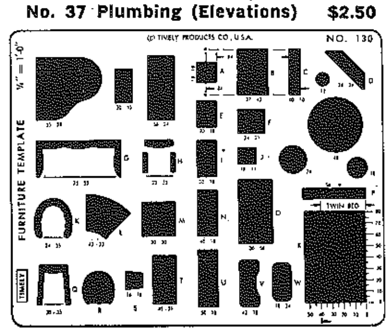

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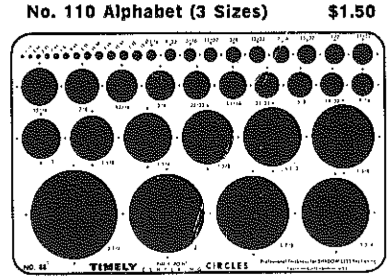

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WORKSHOP ON NOMOGRAPHY - June 15 & 16, 1962*
Conducted by A. S. Levens, Prof. Of Mechanical Engineering, University of California at Berkeley

The following paper was presented as part of an advanced Nomography Workshop, and follows Professor Arnold's paper, printed in the Fall 1963 Issue of the Journal. The following nomograms and methods are discussed: -

Summary

I. Nomograms for equations of the form:

$$f_1(u) + f_2(v)\, f_3(w) = f_4(w)$$

(a) Development of theory.
(b) Application to selected problem.
(c) Points to be stressed in teaching.
(d) Workshop exercises.

II. Nomograms for equations of the form:

$$f_2(u) = \frac{f_3(v)\, f_6(w) - f_4(v)\, f_5(w)}{f_3(v) - f_5(w)}$$

(a) Development of theory.
(b) Application to selected problem.
(c) Points to be stressed in teaching.
(d) Workshop exercises.

III. Nomograms for equations of the form:

$$\frac{f_1(u)}{f_2(v)} = \frac{f_3(w)}{f_4(q)}$$

(a) Development of theory.
(b) Application to selected problem.
(c) Points to be stressed in teaching.
(d) Workshop exercises.

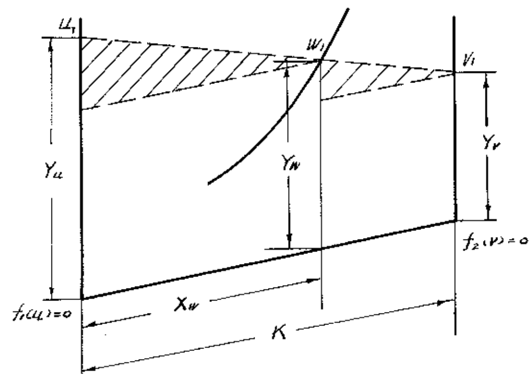
IV. The Method of Determinants in the Design of Nomograms.

(a) The substitution approach.
(b) The matching approach.
(c) Examples related to several type forms.

V. Nomographic Method for Testing the Validity of a Family of Data Curves.** (by slides)

I. Equations of the form: $f_1(u) + f_2(v)\, f_3(w) = f_4(w)$

Fig. 1



From the similar triangles shown shaded in Fig. 1 it follows that:

$$\frac{Y_u - Y_w}{Y_w - Y_v} = \frac{X_w}{K-X_w} \text{ from which}$$

$$Y_u\,(K-X_w) + Y_v\, X_w = KY_w \tag{1}$$

$$Y_u + \frac{Y_v\, X_w}{K-X_w} = \frac{K\, Y_w}{K-X_w} \tag{2}$$

$$m_u\, f_1(u) + m_v\, f_2(v)\, \frac{X_w}{K-X_w} = \frac{KY_w}{K-X_w};$$

$$(\text{since } Y_u = m_u\, f_1(u) \text{ and } Y_v = m_v\, f_2(v)) \tag{3}$$

$$\text{When } \frac{X_w}{K-X_w} = \frac{m_u}{m_v}\, f_3(w), \text{ and,} \tag{4}$$

$$\frac{KY_w}{K-X_w} = m_u\, f_4(w), \tag{5}$$

then $f_1(u) + f_2(v)\, f_3(w) = f_4(w)$

From Eq. (4), $$X_w = \frac{K m_u\, f_3(w)}{m_u\, f_3(w) + m_v} \qquad (6)$$

and from Eq. (5), $$Y_w = \frac{m_u\, m_v\, f_4(w)}{m_u\, f_3(w) + m_v} \qquad (7)$$

<u>EXAMPLE:</u>

$V = 0.5236\ (3A^2 + D^2)\ D$

$V = 1.57\ A^2\ D + 0.5236\ D^3$

D (1 to 10')
A (2 to 10')
V = vol. in c.f.
of a spherical segment

or $V - 1.57\ A^2\ D = 0.5236\ D^3$, which places the equation in type form.

Now, $$\begin{cases} m_v = \dfrac{10\pm}{2000} = .005 \text{ (where } V_{max} = 2000 +) \\ Y_v = .005\ V \end{cases}$$

$$\begin{cases} m_A = \dfrac{10+}{1.57 \times 10^2} = .06 \\ Y_A = .06 \times 1.57\ A^2 = .0942\ A^2 \text{ (from } A = 0) \end{cases}$$

$$\begin{cases} X_D = \dfrac{(20)\ (.005\ D)}{.005\ D + .06} = \dfrac{0.1\ D}{.005\ D + .06} \\ Y_D = \dfrac{(.005)\ (.06)\ (.5236\ D^3)}{.005\ D + .06} = \dfrac{.000157\ D^3}{.005\ D + .06} \end{cases}$$

The table shows a few values of D and the corresponding values of X_D and Y_D

D	1.	5	...	10
X_D	1.5+	6-	...	9+
Y_D	.003	.23	...	1.4+

.A sketch of the solution is shown in Fig. 2

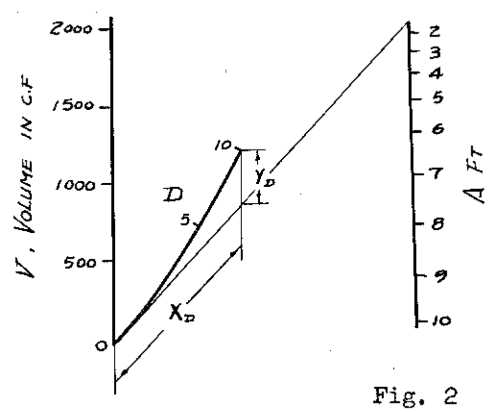


Fig. 2

II. Equations of the form:

$$f_2(u) = \frac{f_3(v)\, f_6(w) - f_4(v)\, f_5(w)}{f_3(v) - f_5(w)}$$

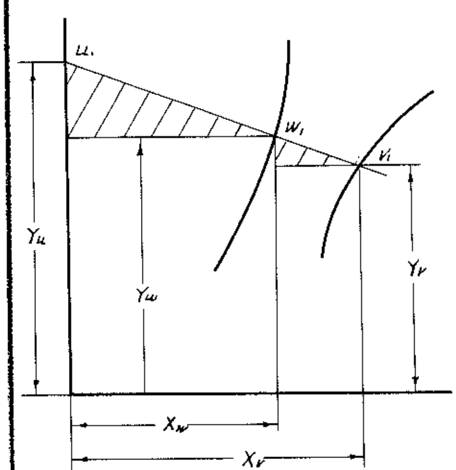


Fig. 3

$$\begin{cases} X_u = m_u\, f_1(u) = 0 \\ Y_u = m_u'\, f_2(u) \end{cases}$$

$$\begin{cases} X_v = m_v\, f_3(v) \\ Y_v = m_v'\, f_4(v) \end{cases}$$

$$\begin{cases} X_w = m_w\, f_5(w) \\ Y_w = m_w'\, f_6(w) \end{cases}$$

*Part of the Summer School program of the Engineering Graphics Division of the American Society for Engineering Education, June 14-16, 1962, at the U.S. Air Force Academy, Colorado Springs, Colorado

**Interested readers can find the material in "Nomography," 2nd Edition, 1959, by A. S. Levens.

$$\frac{Y_u - Y_w}{Y_w - Y_v} = \frac{X_w}{X_v - X_w} \qquad (1)$$

$$Y_u (X_v - X_w) + Y_v X_w = Y_w X_v \qquad (2)$$

$$Y_u = \frac{X_v Y_w - Y_v X_w}{X_v - X_w} \qquad (3) \qquad (4)$$

$$\text{or } m_u' f_2(u) = \frac{m_v f_3(v) m_w' f_6(w) - m_v' f_4(v) m_w f_5(w)}{m_v f_3(v) - m_w f_5(w)}$$

When $m_v = m_w$; and $m_u' = m_v' = m_w'$, then

$$f_2(u) = \frac{f_3(v) f_6(w) - f_4(v) f_5(w)}{f_3(v) - f_5(w)}$$

EXAMPLE: $d = \frac{e^2 + k^2}{e + k}$

$$d = \frac{e(-\frac{1}{k}) - k(\frac{1}{e})}{-\frac{1}{k} - \frac{1}{e}}$$

The parametric equations for each curve are:

$$\begin{cases} X_d = m_d\, d = 0 \\ Y_d = m_d'\, d \end{cases} \quad \begin{cases} X_k = m_k\, (-\frac{1}{k}) \\ Y_k = m_k'\, k \end{cases} \quad \begin{cases} X_e = m_e\, \frac{1}{e} \\ Y_e = m_e'\, e \end{cases}$$

Workshop Problems:

1. $Q = 3.33\ (B - 0.2H)\ H^{\frac{3}{2}}$

   B = width of weir (0 to 5')

   H = head over crest (0 to 5')

   Q = calculated values

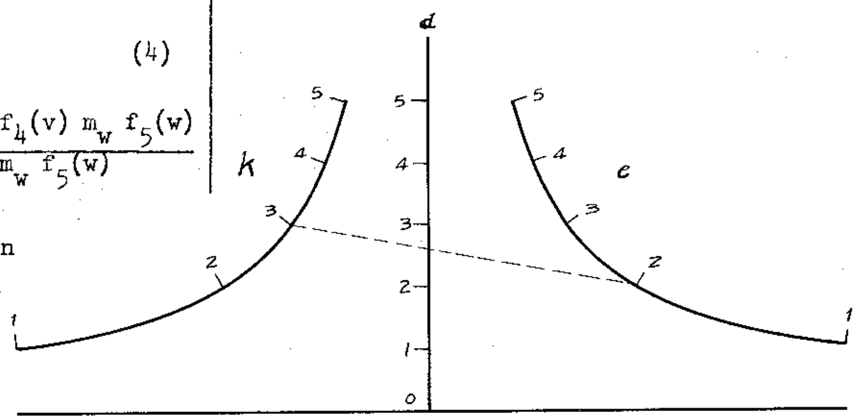
2. $V = 1/2\ \pi r^2 h + 1/6\ \pi h^3$

(vol. of spherical segment with one base)

   h = alt. (0 to 10")

   r = rad. of sphere (0 to 10")

Fig. 4 When k = 3 and e = 2, d = 2.6



Workshop Problems:

1. $\text{Log m t d} = \frac{\Delta T_1 - \Delta T_2}{\log_e \frac{\Delta T_1}{\Delta T_2}}$

ΔT_1 = temperature difference at inlet (5° to 100° F)

ΔT_2 = temperature difference at outlet (5° to 100° F)

Log m t d (5° to 40° F)

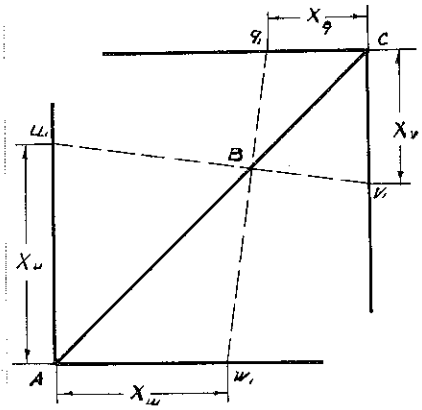
2. $\frac{V}{5.34} = \left(\frac{h_1^{3/2} - h_2^{3/2}}{h_1 - h_2}\right)$

   where h_1 = head to lower edge of orifice (0.5' to 5.0')

   h_2 = head to upper edge of orifice (0.4' to 4.5')

   V = vel. in ft. per sec. (5 to 12)

III. Equations of the form: $\frac{f_1(u)}{f_2(v)} = \frac{f_3(w)}{f_4(q)}$



$$X_u = m_u\, f_1(u)$$

$$X_v = m_v\, f_2(v)$$

$$X_w = m_w\, f_3(w)$$

$$X_q = m_q\, f_4(q)$$

Fig. 5

$$\frac{X_u}{X_v} = \frac{AB}{BC}\ ; \quad \frac{X_w}{X_q} = \frac{AB}{BC}$$

$$\therefore \quad \frac{X_u}{X_v} = \frac{X_w}{X_q} \text{ or } \frac{m_u\, f_1(u)}{m_v\, f_2(v)} = \frac{m_w\, f_3(w)}{m_q\, f_4(q)}$$

When, $\frac{m_u}{m_v} = \frac{m_w}{m_q}$; then, $\frac{f_1(u)}{f_2(v)} = \frac{f_3(w)}{f_4(q)}$

EXAMPLE: $E = 15\ (V - v)\ (1 + \frac{w}{10})$,

Since $v = V \times R.H.$, where

R.H. = monthly mean rel. hum (30 to 90%)

Now, $E = 1.5\ V\ (1\text{-}R.H.)\ (w + 10)$

or $\frac{E}{w + 10} = \frac{1.5\ (1\text{-}R.H.)}{\frac{1}{f(t)}}$

where V is a function of t

where E = evaporation (0 to 10")

V = saturated vapor pressure corresponding to monthly mean temp.,

t = temp (30° to 90° F).

v = actual vapor pressure

w = monthly mean wind vel. (0 to 30 mph)

Now, $m_E = \frac{10}{10} = 1$; $X_E = E$

$$m_w = \frac{10}{10 + 30} = .25\ ;\ X_w = .25\ (w + 10)$$

$$m_t = \frac{6+}{\frac{1}{0.164}} = 1\ ;\ X_t = \frac{1}{f(t)}$$

[f(t) varies from 0.164 to 1.408]

$$\frac{m_E}{m_w} = \frac{m_{R.H.}}{m_t};\ \text{or } \frac{1}{.25} = \frac{m_{R.H.}}{1}\ ;\ \therefore\ m_{R.H.} = 4$$

$$\therefore\ X_{R.H.} = (4)\ (1.5)\ (1 - R.H.) = 6\ (1 - R.H.)$$

The nomographic solution is shown in Fig. 6.

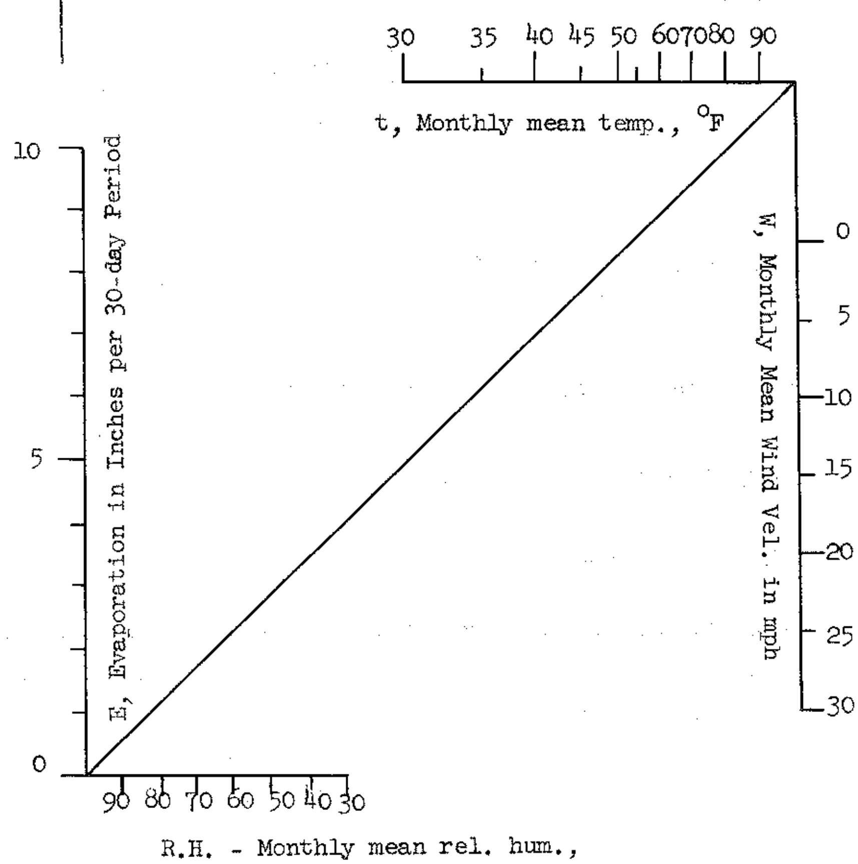


Fig. 6 $\quad E = 15\ (V - v)\ (1 + \frac{w}{10})$

Question: How could we improve the horizontal scales?

Workshop Exercises:

1. $N_s = \frac{NQ}{H^{3/4}}$

N_s = specific speed of a centrifugal pump.

Q = flow rate (1000 to 4000 gpm)

N = speed (100 to 2000 rpm)

H = head (25 to 150 ft.)

2. $X_A = \dfrac{\frac{W_A}{M_A}}{\frac{W_A}{M_A} + \frac{(1-W_A)}{M_B}}$ (Conversion of weight fraction to mole fraction)

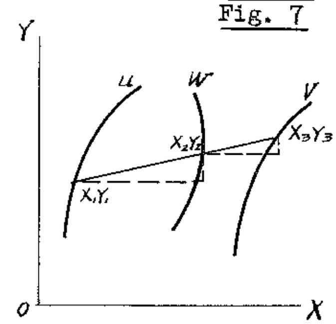
X_A = mole fraction of A (0.01 to 1)

W_A = weight fraction of A (0.01 to 1)

M_A and M_B = molecular weights of A and B (1 to 100)

IV. The Method of Determinants in the Design of Nomograms.

Fig. 7



Let us consider the three colinear points shown in the sketch.

It is easily seen that

$$\frac{Y_3 - Y_2}{X_3 - X_2} = \frac{Y_2 - Y_1}{X_2 - X_1} \quad \text{or } X_1 Y_2 + X_2 Y_3 + X_3 Y_1 - X_1 Y_3 - X_3 Y_2 - X_2 Y_1 = 0$$

or in determinant form

$$\begin{vmatrix} X_1 & Y_1 & 1 \\ X_2 & Y_2 & 1 \\ X_3 & Y_3 & 1 \end{vmatrix} = 0$$

(A) Now suppose $f_1(u) + f_2(v) = f_3(w)$ i.e., $u + v = w$. The determinant $\begin{vmatrix} 0 & u & 1 \\ 1 & v & 1 \\ \frac{1}{2} & \frac{w}{2} & 1 \end{vmatrix} = 0$

expresses the equation in determinant form. How is the determinant obtained?

Suppose $x = u$ (1)

and $y = v$ (2)

then, $x + y = w$. (3)

When the above equations are consistent, then the determinant made up from the coefficients of x and y and the constant term must vanish. This is shown in the determinant

$$\begin{vmatrix} 1 & 0 & u \\ 0 & 1 & v \\ 1 & 1 & w \end{vmatrix} = 0$$

This determinant can be reduced, quite easily, to the constructional form

$$\begin{vmatrix} 0 & u & 1 \\ 1 & v & 1 \\ \frac{1}{2} & \frac{w}{2} & 1 \end{vmatrix} = 0$$

from which the nomogram can be constructed.

When moduli are included, we can write:

$$x = m_u u \qquad (4)$$

$$y = m_v v \qquad (5)$$

$$\frac{x}{m_u} + \frac{y}{m_v} = w \qquad (6)$$

These equations, considered to be consistant, must satisfy the relation:

$$\begin{vmatrix} 1 & 0 & m_u u \\ 0 & 1 & m_v v \\ \frac{1}{m_u} & \frac{1}{m_v} & w \end{vmatrix} = 0$$

This determinant can be reduced to the constructional form,

$$\begin{vmatrix} 0 & m_u u & 1 \\ 1 & m_v v & 1 \\ \frac{m_u}{m_u + m_v} & \frac{m_u m_v}{m_u + m_v} w & 1 \end{vmatrix} = 0$$

Example 1:

$a^2 + b^2 = c^2$ a and b (0 to 10)

$$m_a = \frac{10}{100} = 0.1 \text{ and } m_b = \frac{10}{100} = 0.1$$

$$\text{Now, } \begin{vmatrix} 0 & 0.1a^2 & 1 \\ 1 & 0.1b^2 & 1 \\ \frac{1}{2} & 0.05c^2 & 1 \end{vmatrix} = 0$$

From which the nomogram can be constructed. See Fig. 8.

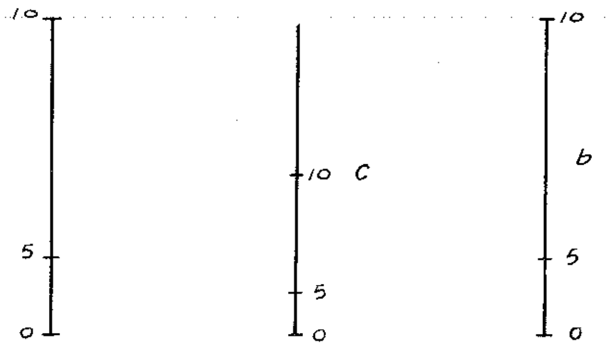


Fig. 8

Now suppose "a" varies from 4 to 10 and "b" from 3 to 10.

$$m_a = \frac{10 \pm}{100 - 16} = .12$$

$$m_b = \frac{10 \pm}{100 - 9} = .11$$

The determinant becomes:

$$\begin{vmatrix} 0 & .12\,(a^2 - 4^2) & 1 \\ 1 & .11\,(b^2 - 3^2) & 1 \\ \frac{.12}{.23} & \frac{(.11)\,(.12)}{.11 + .12}\,(c^2 - 5^2) & 1 \end{vmatrix} = \begin{vmatrix} 0 & .12\,(a^2 - 4^2) & 1 \\ 1 & .11\,(b^2 - 3^2) & 1 \\ \frac{12}{23} & .06\,(c^2 - 5^2) & 1 \end{vmatrix} = 0$$

from which the nomogram is constructed.

(B). Consider the form $f_1(u) = f_2(v)\, f_3(w)$. i.e., $u = vw$

Let $x = m_u u$ (1)

$y = m_v v$ (2) and $\begin{vmatrix} 1 & 0 & m_u u \\ 0 & 1 & m_v v \\ \frac{1}{m_u} & \frac{-w}{m_v} & 0 \end{vmatrix} = 0$

then, $\frac{x}{m_u} - \frac{y}{m_v} w = 0$ (3)

The determinant can be reduced to

$$\begin{vmatrix} 0 & m_u u & 1 \\ 1 & -m_v v & 1 \\ \frac{m_u w}{m_u w + m_v} & 0 & 1 \end{vmatrix} = 0$$

Suppose $m_u = 1$ and $m_v = 2$, then

$$\begin{vmatrix} 0 & u & 1 \\ 1 & -2v & 1 \\ \frac{w}{w+2} & 0 & 1 \end{vmatrix} = 0$$

from which the nomogram is constructed.

(C) Consider the form, $\frac{1}{f_1(u)} + \frac{1}{f_2(v)} = \frac{1}{f_3(w)}$

i.e. $\frac{1}{u} + \frac{1}{v} = \frac{1}{w}$

Let $x = \frac{1}{u}$

and $y = \frac{1}{v}$

then, $x + y = \frac{1}{w}$

$$\rightarrow \begin{vmatrix} 1 & 1 & \frac{1}{u} \\ 0 & 1 & \frac{1}{v} \\ 1 & 1 & \frac{1}{w} \end{vmatrix} = \begin{vmatrix} u & 0 & 1 \\ 0 & v & 1 \\ w & w & 1 \end{vmatrix} = 0$$

When moduli are used,

$X = m_u \left(\frac{1}{u}\right)$

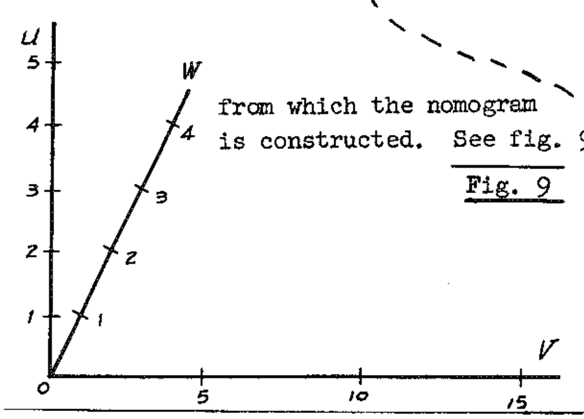
$Y = m_v \left(\frac{1}{v}\right)$

$\frac{X}{m_u} + \frac{Y}{m_v} = \frac{1}{w}$

$$\rightarrow \begin{vmatrix} \frac{u}{m_u} & 0 & 1 \\ 0 & \frac{v}{m_v} & 1 \\ \frac{w}{m_u} & \frac{w}{m_v} & 1 \end{vmatrix} = 0$$

Suppose $m_u = 1$ and $m_v = 2$, then,

$$\begin{vmatrix} 0 & u & 1 \\ \frac{v}{2} & 0 & 1 \\ \frac{w}{2} & w & 1 \end{vmatrix} = 0$$



from which the nomogram is constructed. See fig. 9

Fig. 9

(D) Consider the form: $f_1(u) + f_2(v)\, f_3(w) = f_4(w)$

i.e. $u + vw = w^2$

Let $x = m_u u$ (1)

$y = m_v v$ (2)

$\frac{x}{m_u} + \frac{y}{m_v} w = w^2$ (3)

$$\rightarrow \begin{vmatrix} 1 & 0 & m_u u \\ 0 & 1 & m_v v \\ \frac{1}{m_u} & \frac{w}{m_v} & w^2 \end{vmatrix} = 0$$

$$\begin{vmatrix} 0 & m_u u & 1 \\ 1 & m_v v & 1 \\ \frac{m_u w}{m_u w + m_v} & \frac{m_u m_v w^2}{m_u w + m_v} & 1 \end{vmatrix} = 0$$

Suppose $m_u = 2$ and $m_v = 5$, then,

$$\begin{vmatrix} 0 & 2u & 1 \\ 1 & 5v & 1 \\ \frac{2w}{2w+5} & \frac{10w^2}{2w+5} & 1 \end{vmatrix} = 0$$

This determinant is used to construct the nomogram.

(E) Consider the equation, $a \sin \Theta + b \cos \Theta - 1 = 0$

Let $x = a$

$y = b$

then, $y \sin \Theta + y \cos \Theta = 1$

$$\rightarrow \begin{vmatrix} 1 & 0 & a \\ 0 & 1 & b \\ \sin \Theta & \cos \Theta & 1 \end{vmatrix} = \begin{vmatrix} \frac{1}{a} & 0 & 1 \\ 0 & \frac{1}{b} & 1 \\ \sin \Theta & \cos \Theta & 1 \end{vmatrix} = 0$$

from which the nomogram is constructed.

(F) Two Related Equations. i.e. $E = IR$ and $P = I^2R$

$\text{Log } I + \log R = \log E$;

Let $x = \log I$

and $y = \log R$

then $x + y = \log E$

(1)

$$\rightarrow \begin{vmatrix} 0 & \log I & 1 \\ 1 & \log R & 1 \\ \frac{1}{2} & \frac{\log E}{2} & 1 \end{vmatrix} = 0$$

From the relation $P = I^2 R$

$$2 \log I + \log R = \log P$$

$$\left.\begin{aligned} \text{Let } x &= \log I \\ y &= \log R \\ 2x + y &= \log P \end{aligned}\right\} \rightarrow \begin{vmatrix} 0 & \log I & 1 \\ 1 & \log R & 1 \\ \frac{1}{3} & \frac{\log P}{3} & 1 \end{vmatrix} = 0 \qquad (2)$$

The nomogram is constructed from determinants (1) and (2)

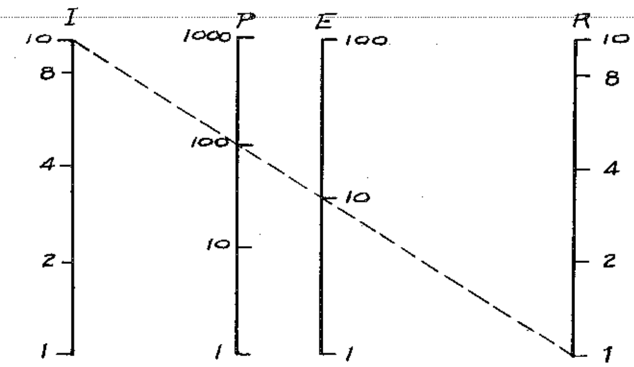


Fig. 10. $E = IR$ and $P = I^2R$.

Example: When I = 10 and R = 1; P = 100 and E = 10

(G) The Matching Method

We know that

$$\begin{vmatrix} X_1 & Y_1 & 1 \\ X_2 & Y_2 & 1 \\ X_3 & Y_3 & 1 \end{vmatrix} = X_1 Y_2 + X_2 Y_3 + X_3 Y_1 - X_3 Y_2 - X_1 Y_3 - X_2 Y_1 = 0$$

1. Consider the equation $L = \dfrac{a^2 - b^2}{a - b}$

Now, $La - Lb - a^2 + b^2 = 0$

$$\left.\begin{aligned} \text{Let } X_1 Y_2 &= L\,a \\ X_1 Y_3 &= L\,b \\ X_3 Y_2 &= a\,a \\ X_2 Y_3 &= b\,b \end{aligned}\right\} \rightarrow \begin{vmatrix} L & 0 & 1 \\ b & a & 1 \\ a & b & 1 \end{vmatrix} = 0$$

(Note this determinant is not in constructional form)

$$\text{However, } \begin{vmatrix} L & 0 & 1 \\ b & a & 1 \\ a & b & 1 \end{vmatrix} = \begin{vmatrix} L & 0 & 1 \\ b & \frac{1}{b} & 1 \\ a & \frac{1}{a} & 1 \end{vmatrix} = 0$$

(Which is in constructional form)

This nomographic solution is shown in Fig. 11

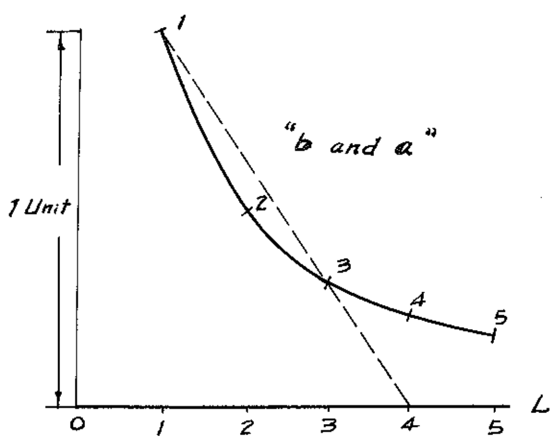


Fig. 11

Ex: a = 3; b = 1; then L = 4

Note: This is an interesting solution to the given equation, $L = \dfrac{a^2 - b^2}{a - b}$ Another solution, perhaps more practical, could be designed since $L = a + b$.

2. Consider the form: $f_1(u) + f_2(v)\, f_3(w) = f_4(w)$

i.e. $u + vw = w^2$

$$\left.\begin{array}{l} \text{Let } X_1\ Y_2 = 1\ u \\ X_3\ Y_1 = v\ w \\ X_2\ Y_1 = w\ w \end{array}\right\} \longrightarrow \begin{vmatrix} 1 & w & ? \\ w & u & ? \\ v & ? & ? \end{vmatrix} = \begin{vmatrix} 1 & w & 0 \\ w & u & 1 \\ v & 0 & 1 \end{vmatrix} = 0$$

$$\begin{vmatrix} 1 & w & 0 \\ w & u & 1 \\ v & 0 & 1 \end{vmatrix} = \begin{vmatrix} 1 & \frac{1}{u} & 0 \\ w & \frac{1}{w} & 1 \\ v & 0 & 1 \end{vmatrix} = \begin{vmatrix} u & 1 & 0 \\ w^2 & 1 & w \\ v & 0 & 1 \end{vmatrix} = \begin{vmatrix} 0 & u & 1 \\ w & w^2 & 1 \\ 1 & v & 0 \end{vmatrix} =$$

$$\begin{vmatrix} 1 & u & 1 \\ (w+1) & w^2 & 1 \\ 1 & v & 0 \end{vmatrix} = \begin{vmatrix} 1 & u & 1 \\ 1 & \frac{w^2}{w+1} & \frac{1}{w+1} \\ 1 & v & 0 \end{vmatrix} = \begin{vmatrix} u & 1 & 1 \\ \frac{w^2}{w+1} & \frac{1}{w+1} & 1 \\ v & 0 & 1 \end{vmatrix} = 0$$

from which the nomogram can be constructed.

Workshop exercises

Write the following equations in constructional determinant form:

(a) $SS_1 + SS_2 = 2S_1\, S_2$

(b) $\sin \theta = \dfrac{\sin(\alpha + \beta)}{\sin \alpha + \sin \beta}$

(c) $W = \dfrac{M - m}{100 - M}$

(d) $\tan \alpha = \sin \beta \tan \theta$

Suggestion: Try the substitution method first.

V. The Validation of a Family of Data Curves for Which There Is An Implicit Relation.

(a) Test for Bilineality

(b) Graphical Anamorphosis

(c) Application of the Law of Duality.

(d) Examples shown by slides.

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Dear Editor:

I am writing you concerning a new development in our state. As you may have noticed by the letterhead, we are in the process of forming a state association of Engineering Graphics. Our primary purpose in this endeavor is to see if we can do some grass roots consideration of mutual problems that have been plaguing the national division for quite some time.

Hollie Shupe of Ohio State, has arranged for a meeting of the group in their Faculty Club, April 18, 1964. At this meeting we hope to get under way with the organization of the group if need is believed to exist. The only formal program at the meeting will be; introduction of sponsors, registration, introduction of industrial representatives, luncheon, and business meeting. We have found that there are approximately 100 people at the college level who teach Engineering Graphics in Ohio. We are therefore looking forward to a most interesting session.

If you can use this information in any effective manner feel free to do so. You of course realize that we hope this group will affiliate in some manner with the division of Engineering Graphics.

Sincerely yours,
Charles W. Keith
Co-ordinator
Industrial Technology
Kent State University

A NEW GRAPHICS FOR TOMORROW'S PROBLEMS

Douglas P. Adams
Department of Mechanical Engineering
Massachusetts Institute of Technology

It is possible to bring together graphical work and modern electronic techniques so as to present time-honored graphical procedures within a modern technical framework. We describe a graphical computing technique which is fast, efficient and not subject to the conventional limitations on accuracy of the old-fashioned graphical method. To do this, we use a definition of "graphics" which states that wherever numerical value is correlated with space position, a graphical process has occurred. For this computing technique, it has been figured that before long for many relationships 10,000 solutions per second could be obtained with three figure accuracy--a goal far below a theoretical limit of 50,000 solutions per second. Such rates would be useful, for instance, in solving systems of partial differential equations. For oppositely moving satellites travelling about 100 miles above the earth's surface, a ten thousandth of a second can represent a relative displacement of a few feet so as to be useful in proximity problems. Present investigating rates are at about 500 solutions per second. Both graphical and nomographic techniques are used in conjunction with electronics.

The notion at the heart of the NOEL (NOmographic-ELectronic) computer is a simple one, first, that an equation or relationship hard to solve in its original variables (let us call them the blue variables) can be changed into one (in what we may call the red variables) which is easy to solve. When the red answer is known, the blue one can be found by an inverse correlation. A second and vital part of the technique is that there are many equations in blue variables which can all become changed under this technique into one and the same equation in red variables (namely, a linear equation).

It is the simplifying change from the blue variables to the red variables and how to set up this correlation graphically that first concerns us. Imagine a scale in U, a curved line on the page graduated and calibrated in values of U, so that for each value of U it is easy to read off the X and Y coordinates U_x and U_y for each value and conversely easy to ascertain the value of U that corresponds to every U_x, U_y defining a point on the scale. This is clearly a graphical device within the definition we set up earlier. Now the potentialities of the alignment diagram suddenly become clear. An equation or relationship $F(U,V,W) = 0$ in the blue values U, V, and W is placed in such a form, Figure 1, as to define a pair of coordinates (red values) U_x, U_y for U (similarly for V and W) so that the original blue equation $F(U,V,W) = 0$ is replaced by a red linear equation in $U_x, U_y, V_x, V_y, W_x, W_y$. If U and V are specified in blue, the corresponding red pairs U_x, U_y, V_x, V_y, are now known. We could now run through a table of red W_x, W_y, pairs and find one such that it satisfied with the former a linear relationship.

$$\frac{U_y - V_y}{U_x - V_x} = \frac{W_y - V_y}{W_x - V_x} \qquad (1)$$

The blue W-value corresponding inversely to that red W-pair just found (Figure 1 (b)) is the W-value corresponding to the given U, V values in the equation $F(U,V,W) = 0$. For our pains, we have a system where the red equation has been easy to solve and it has led back to the blue answer value.

In the old-fashioned nomogram, the correlation between a blue U value and a red U-position pair U_x, U_y is shown by drawing a blue scale in U defined by red coordinates, Figure 1 (d). We now show this same correlation correspondence between blue value and red position pair - but in a different way.

We set up the same correlation, Figure 1 (e), of the value of U with U_x, U_y, V with V_x, V_y, W with $W_x W_y$ by representing each of the nine quantities by a column of countable bits--a vertical column of bits for each of the quantities we have mentioned. We physically place the vertical columns U, U_x, U_y, V, V_x, V_y together with a clock tract on a memory film so that an optical image of the columns of bits is passed across six photoelectric cells as the memory is moved. At any instant the cumulative count of the bits in a given column is taken to be the value of that variable in the respective column at that instant If we know the value of the independent variable U and the independent variable V, we can cause counting to stop when the prearranged known va-

Figure 1 (a)
The equation has been placed in nomographic determinant form.

$$\frac{U^2 + V^2}{U + V} = W \text{ ; can be written}$$

$$F(U,V,W) \equiv W - \frac{U^2 + V^2}{U + V} \equiv \begin{vmatrix} \frac{1}{U} & U & 1 \\ -\frac{1}{V} & V & 1 \\ 0 & W & 1 \end{vmatrix} \equiv 0$$

Blue Variables

lue is this cumulative count. At the same time we then know U_x and U_y values through their simultaneous cumulative counts. If we now, in a "second pass", treat three W columns W, W_y and W_x (plus a clock track) to the same counting process, trying out cumulative counts of W_x and W_y for a linear relationship 1) with the known U_x, U_y, V_x, V_y counts, there will come an instant when they will satisfy this linear relation. If we arrange to shut off the W counting at that instant, we will then have trapped in the cumulative W-count the value of W satisfying $F(U,V,W) = 0$ for the specified values of U and V introduced at the outset.

The functional behavior $F(U,V,W) = 0$ is thus brought about solely by the use of funny little black marks called countable bits together with the relative placement of these in their respective columns. This is the purest form of graphical process, fortunately amenable to speedy electronic counting devices and achieved today at the rate of 1 million bits per second using comparatively inexpensive equipment.

Example:

A simple case will bring together most of these ideas, which later can be extended. In Figure 2, the equation $F(U,V,W) = 0$ appears at the lower left. It is assumed that an alignment diagram of the form shown there can be drawn to represent this equation. The alignment diagram is shown embedded in an XY axis system and the equation of the straight line of colineation appears below the diagram. The blue variables are U, V, W and the red variables are X_1, Y_1 ($X_1 \equiv 0$); X_2, Y_2 ($X_2 \equiv G$); and X_3, Y_3. In the lower center of the diagram there is a typical example of a piece of film with "first pass" columns $V: V_x \equiv G$, $V_y \equiv Y_2$ and V; U: $U_x \equiv 0$, $U_y \equiv Y_1$ and U; and "second pass" columns $W: W_x \equiv X_3$ and $W_y \equiv Y_3$ and W. The constancy of V_x and U_x ends the need of their being present in this representation.

We now carry out the above mentioned scheme in the following way. Values of V come from the tape (upper left), are cumulatively stored in the binary pulse counter (1) until their negative sum equals the present input positive sum in V, leaving a zero count in this counter and causing two things to happen, 1. The S_2 gate opens, interrupting the flow of the Y_2 count to the binary pulse counter (2) in the upper right. 2. The switch O is activated causing the assimilated Y_2 count in the pulse counter (1) to be deposited in the Accumulator (5). Corresponding events in the lower left counter (3) have happened to input U and Y_1, causing a $-Y_1$ count to be terminated by switch S_1 when the U cumulative count reached 0. This count was taken from the reversible counter (4) and placed in the Accumulator (5).

Figure 1 (b)

The nomographic interpretation of the determinant form on the left is the diagram on the right.

$$\begin{vmatrix} U_x & U_y & 1 \\ V_x & V_y & 1 \\ W_x & W_y & 1 \end{vmatrix} = 0$$

Red Variables

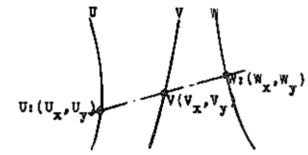


Figure 1 (c)

Here we correlate the two determinant forms

(c) 1.

$U_x = \frac{1}{U}$; $U_y = U$

$V_x = -\frac{1}{V}$; $V_y = V$;

$W_x = 0$; $W_y = W$

Red Blue; Red Blue

(c) 2. obeying the relations

$$\frac{U_y - V_y}{U_x - V_x} = \frac{W_y - V_y}{W_x - V_x}$$

Red Variables

or

$$\frac{U - V}{\frac{1}{U} - (\frac{-1}{V})} = \frac{W - V}{0 - (\frac{1}{V})}$$

or

$$\frac{U^2 + V^2}{U + V} = W$$

Blue Variables

Figure 1 (d)

Interpreting (a), (b) and (c) we then have this diagram

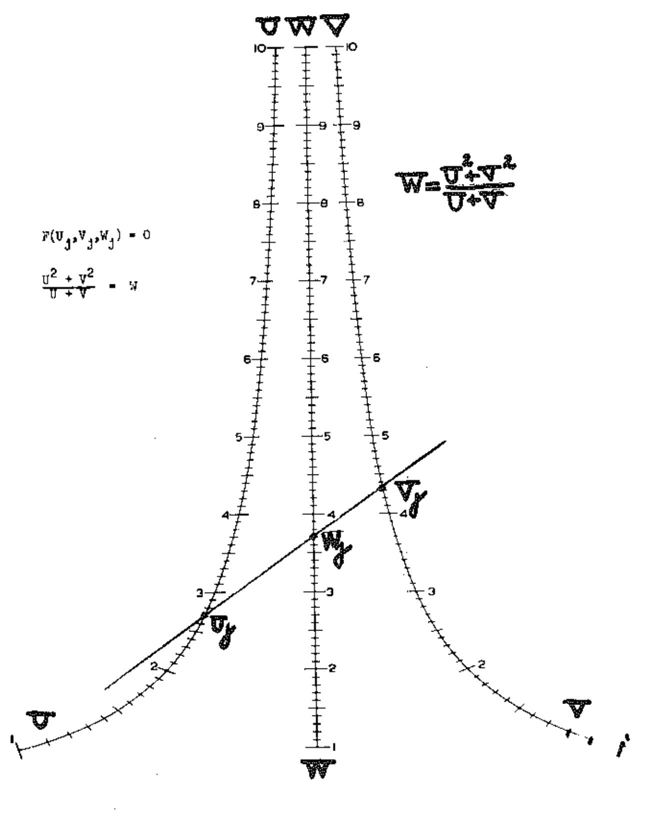
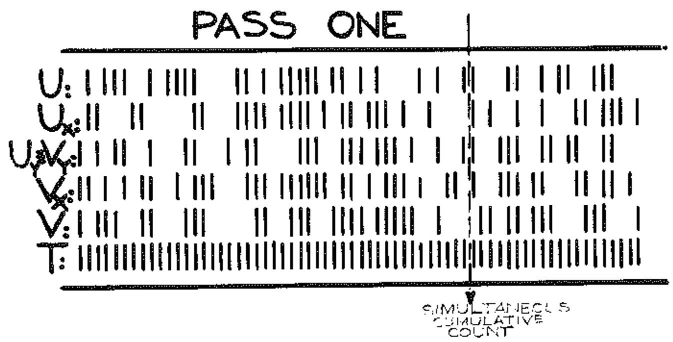


Figure 1 (e)

Here simultaneous cumulative counts of bits in the columns express the relations (c) 1. and an electronic circuit effectuates (c) 2.



As the film moves upward, by the time the reading gets to the dotted line separating pass 1 from pass 2, the final result in the Accumulator (5) reads $Y_2 - Y_1$ and the reversible counter (4) reads $-Y_1$. Pass 2 is now ready to begin. On the first X_3 pulse (and not again) the upper right binary pulse counter (2) is cleared and the Accumulator (5) is placed in that counter leaving there the count $Y_2 - Y_1$. On every subsequent X_3 pulse acting through gate 0 the value of the binary pulse counter $Y_2 - Y_1$ is dumped into the Accumulator (5) creating the product $X_3(Y_2 - Y_1)$. Each Y_3 pulse enters the reversible counter (4) after a short delay establishing there the sum $Y_3 - Y_1$. At the same time the lower right binary pulse counter (7) is collecting the cumulative pulse value of the W count. Meanwhile there is a steady comparison going on through the coincidence circuit (6) of the values existing 1) in the Accumulator (5) and 2) in the Reversible counter (4). Assuming for simplicity that G = 1, the red equation shown in Figure 2 will be satisfied when the coincidence circuit (6) detects identity in the magnitude of the Accumulator (5) and the Reversible Counter (4). When this occurs, the Accumulator (4) opens the switch S_3 and the answer value, the cumulative blue W-value, appears trapped in the lower right binary pulse counter (7).

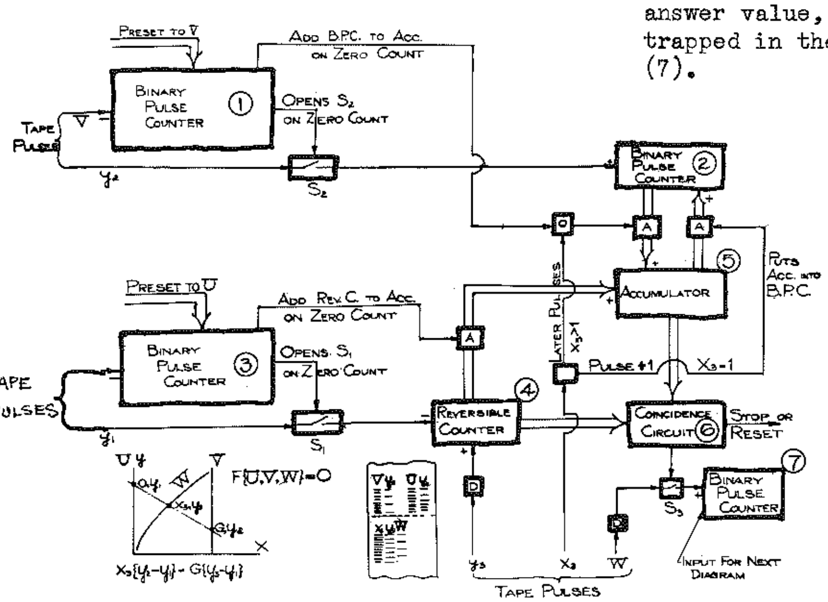
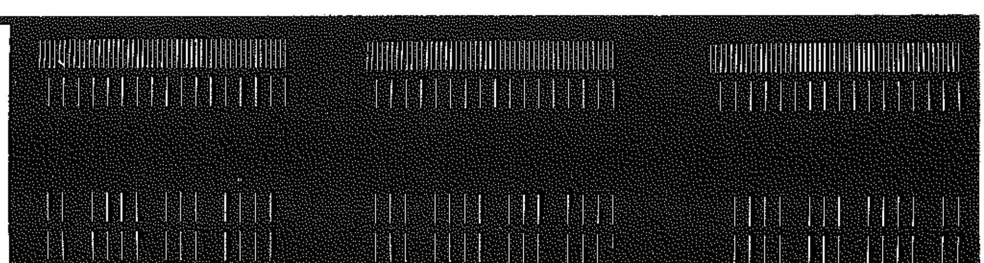


Figure 2 (a)

A simple circuit to carry thru computation by countable bit.

Figure 2 (b).

A portion of a nomogram prepared for nomographic-electronic (NOEL) countable-bit computation.



It will be seen right away that many problems arise in implementingthe above scheme. We have referred glibly to the transformation of film memory of countable bits into a pulse pattern receivable by the arithmetic element. This requires a form of scanning or reading, introducing a wide variety of mechanical and electronic problems.

For this pattern to be "read", the bit pattern has to be transformed into a pattern of pulses as described above on which the arithmetic element can work. For this purpose various types of reading devices can easily be imagined and some have been developed. In Figures 3 - 6 it will be easy to see that in some cases the memory is fixed and a system of mechanical-optical scanning is employed. In others, optical elements remain fixed and the memory moves so as to bring raster after raster of bits into contact with the optical elements which, in turn, bring their images to the photoelectric cells. It is even possible to conceive of reading devices in which there are no mechanical optical moving parts, for instance, that a cathode-ray-tube moving electron beam could read this memory pattern and register it on photoelectric tubes to yield the desired pulse pattern used by the arithmetic element.

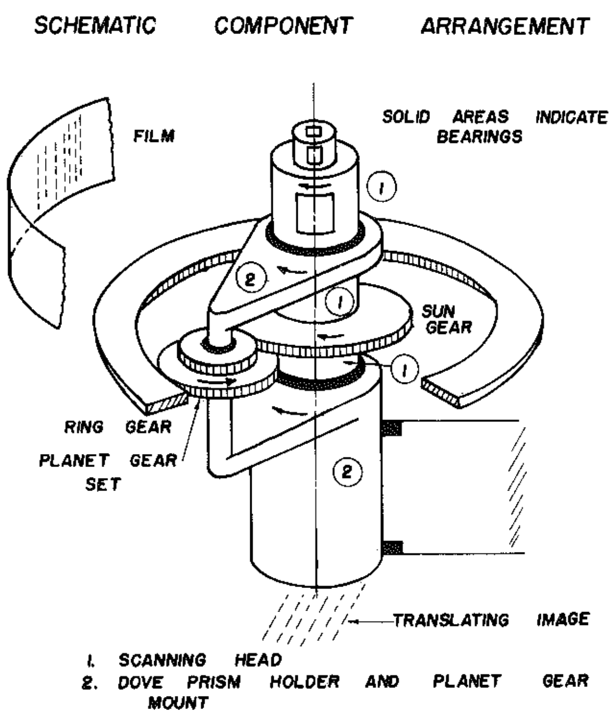
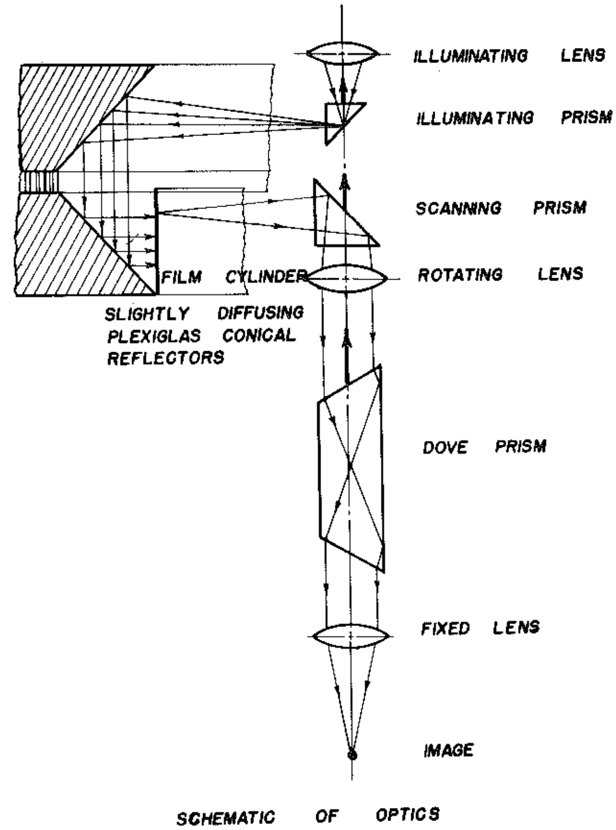


Figure 3 (a).

This shows a fixed-memory, moving-optics type of bit-memory reader. Details of the light path appear in Figure 3 (b).

Figure 3 (b).

Rough schematics of optical path of light in the fixed-memory, moving-optics reader shown in Figure 3 (a).



Still other helpful simplifications can be broadly envisaged. Let us imagine the bit pattern replaced by an identical pattern of tiny charged ferrite cells, one for every bit. Imagine that each column of cells can be unloaded in sequence to a "delay" column, which changes each electric pulse to a mechanical disturbance passing down the column, then reverting in turn to an electric pulse at the end of the column. The latter is conveyed to the top of the column by a closed circuit, so that the pattern runs repeatedly thru the cycle--a device in recent extensive use. If we conceive that all the columns can be made to do this at a uniform rate, we have the picture of the memory pattern moving repeatedly down the delay lines, instead of around on a film. Counting and arithmetic can be done as before, and here we have achieved the desired end of "no moving parts" for reading the bit memory.

Figure 4.

Film is held in film-holder 3 in this fixed-optics, moving-memory type of reader.

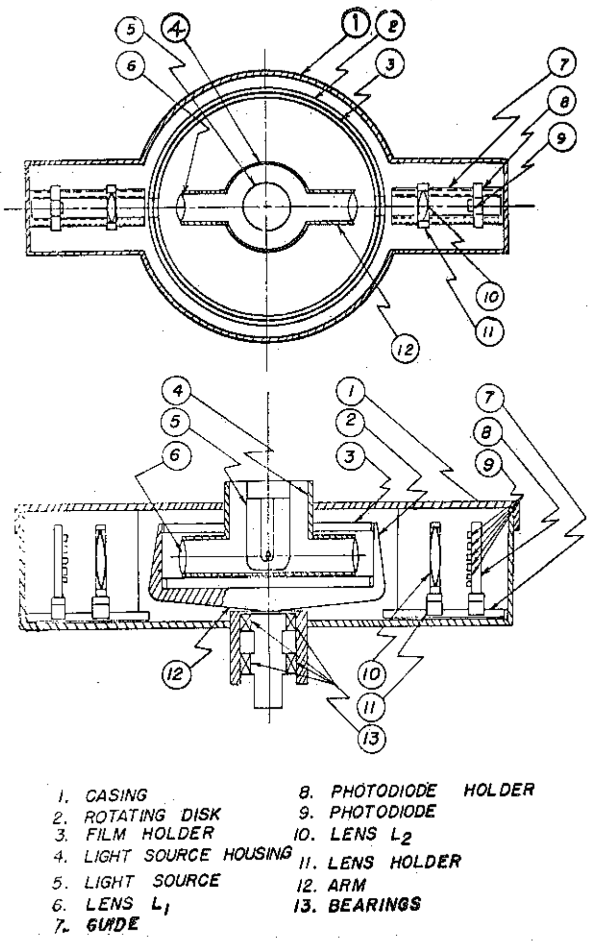
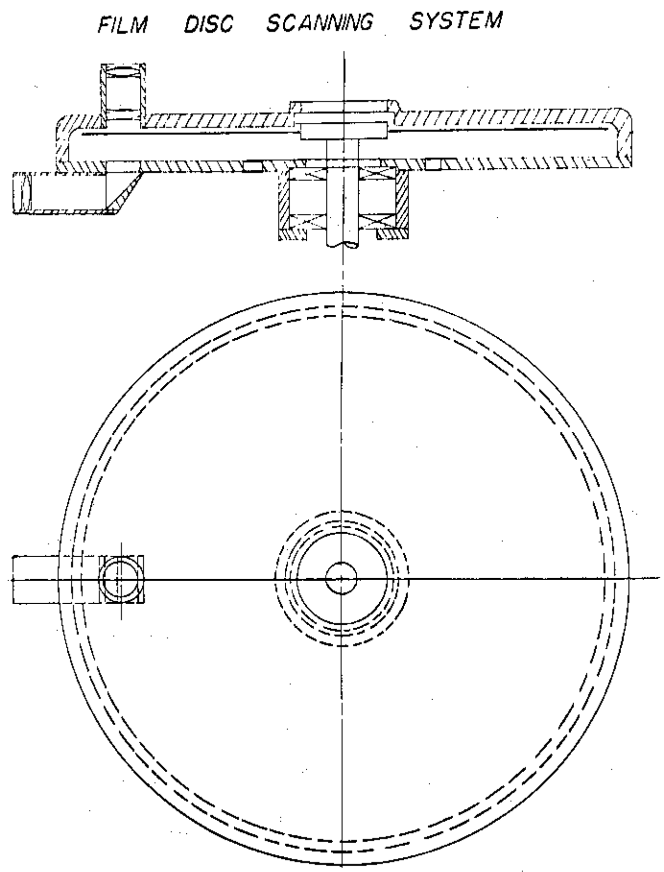


Figure 5.

Schematic of the elements of a disc-memory reading system. The optics are fixed and the disc turns, carrying the bit-pattern of the memory.



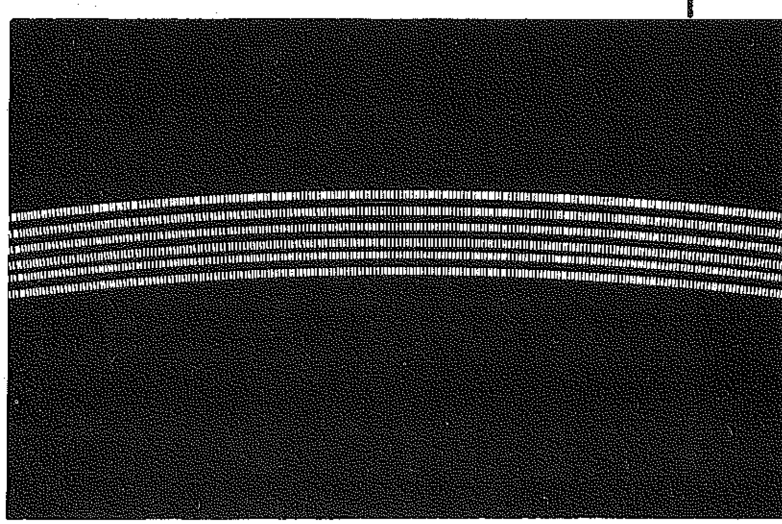


Figure 6.

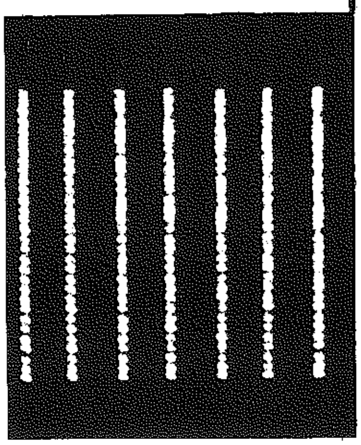
Bit pattern generated on a rotating disc, 400 bit/inch density, on a 3" radius, enlarged 16 times.

Limiting ourselves to photographic memory, before such pulses can be read they must have been written into the memory, that is, they must have been inscribed by the thousands and with complete accuracy. The solution developed at the Engineering Projects Laboratory at M.I.T. required that bits should never appear in the memory except upon certain evenly spaced rulings called rasters. In a given column of bits it then becomes the question whether or not, on the cumulative counting of these bits, one should or should not be inserted in order that the cumulative count of that variable should be in sufficiently close step with the cumulative count of the other variables in their respective columns. There can also be no escape from the conclusion that the value or intrinsic worth of a bit may well have to change from time to time as progress occurs up a column of bits representing a non-uniform function. The signalling required to do this is fairly extensive but does not pose any problems beyond those of basic electronic circuitry.

A law, or algorithm, for determing whether or not a bit should be written in for a given raster for proper representation of the function is now assumed to have been worked out, leaving the question of how a bit is "written" once the command is given to draw it. One way is to use the oscilloscope output of the IBM 7094 which computed the yes-or-no decision for the bit in the first place. A subroutine can be prepared and called into play for each bit to be written. This subroutine scintillates a dot pattern, Figure 7, over the desired bit area.

Figure 7.

Bit-patterns generated by scintillation techniques as a CRT output of the 7094. A subroutine of the scintillations establishes the bit whenever the bit-or-no-bit 7094 program calls for one. X-20



A second type of writing technique employs an enlarged raster pattern of bits, (that is, a line of bits perpendicular to the column direction). Each bit "window" is the end of a chamber containing a well diffused strobotac flash tube of one microsecond duration. These are then "fired" from the same IBM 7094 tape output that would have been used to "write" the bits by oscilloscope scintillation. The large raster is then photographed into a small raster in a radial position on a steadily rotating disc. Figure 6 shows an enlarged pattern of these at 400 bits per inch on a three inch radius.

Changing the memory is all that is required to adapt the computer to any other equation for which a memory has been prepared--a matter of microseconds. The same arithmetic element will be used in all cases, expressing each time the linear relationship in terms of the "red" variables as previously described. The hoped-for solution-times previously referred to indicate that fast or slow cheap control can be had by this device. One imagines that all of the processes in a given plant could perhaps be controlled by a single central unit of this nature.

Use in connection with differential equations has been mentioned and can perhaps best be illustrated by showing first how nomography can be used in the normal way to help solve such a problem: We employ a technique by Professors Morita and Simokawa, Kanazawa University, Japan which utilizes a well-known Runge-Kutta series development of fourth order accuracy in such a way that nomographic techniques are effective. Briefly, a solution is developed for an ordinary differential equation

$$g(x,y,y') = 0 \qquad (1)$$

from point (x_n, y_n) to point (x_{n+1}, y_{n+1}), in which

$$x_{n+1} = x_n + h \qquad (2)$$

$$y_{n+1} = y_n + (1/6)(k_1 + 2K_2 + 2k_3 + k_4) \qquad (3)$$

where

$$k_1 = h \cdot f(x_n, y_n)$$

$$k_2 = h \cdot f(x_n + (1/2)h, y_n + (1/2)k_1)$$

$$k_3 = h \cdot f(x_n + (1/2)h, y_n + (1/2)k_2) \qquad (4)$$

$$k_4 = h \cdot f(x_n + h, y_n + k_3)$$

and where the original relationship $g(x,y,y')$ is also soluble in the form

$$y' = f(x,y)$$

The latter restriction upon form will be found not to be binding in the nomographic case we use. Equation (1) must be able to be put into canonical nomographic form or else a series of such forms. As a matter of practice, differential equations tend to have a relatively simple aspect, which, while they may be very hard to wring formal solutions from, nevertheless frequently indeed can be put into the required nomographic form.

Example: Figure 8

$$50e^{-y'} + (x - y)e^{y'} = 10x \quad \leftarrow (5)$$

A nomographic form of this equation is:

$$g(x,y,y') \equiv \begin{vmatrix} x/50 & y/50 & e^{-y'}/10 \\ 0 & G & G \cdot e^{y'}/10 \\ 1 & 1 & 1 \end{vmatrix} = 0 \quad \leftarrow (6)$$

Where G is the width of the chart and yielding parametric equations

$X = x/50$; $Y = 0$ for the x-scale $\leftarrow$ (7)

$X = y/50$; $Y = G$ for the y-scale

$X = e^{-y'}/10$; $Y = G\,e^{y'}/10$ for the y'-scale

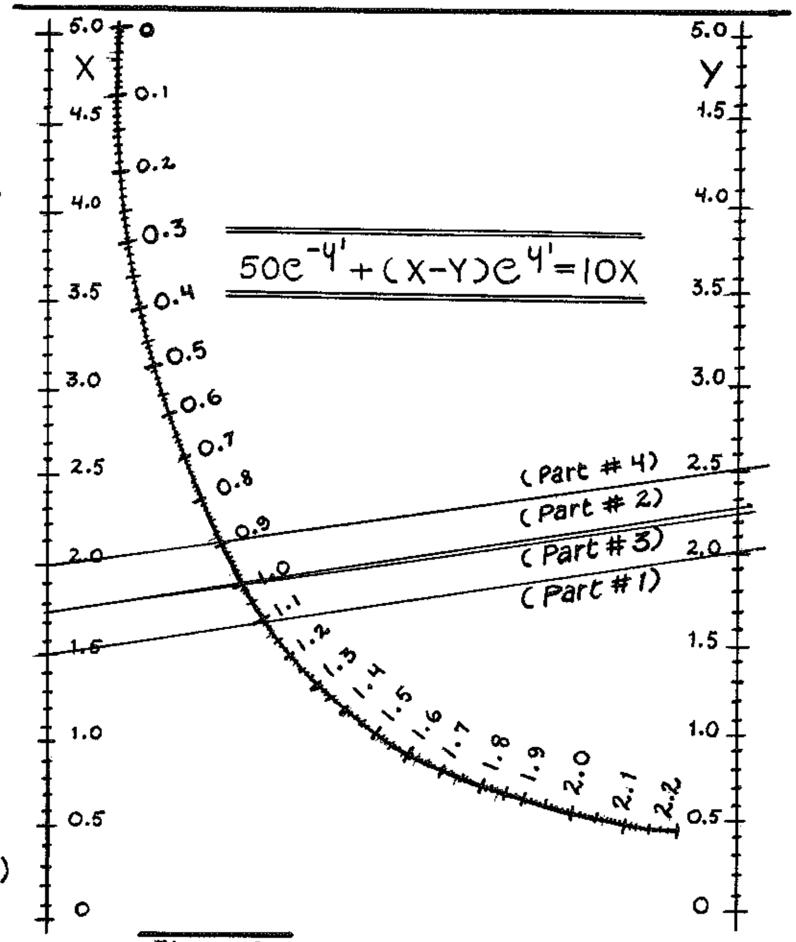


Figure 8.

Home-made nomogram for the solution of the differential equation shown, using Runge-Kutta developments.

Figure 8 shows the old-fashioned use of the chart for the following values, with answers, as required by the formulas (4), in extending a solution from x = 1.5, y = 2.0 by steps of h = 0.5.

$x = 1.5$;	$y = 2.0$; $y' = f = 2K_1 = 1.11$;	$k_1 = 0.55$
$x = 1.5 + 0.25 - 1.75$;	$y = 2. + 0.2775 = 2.278$	$2K_2 = 0.98$; $k_2 = 0.49$
$x = 1.75$;	$y = 2.245$;	$k_3 = 0.490$
$x = 2.0$;	$y = 2.490$;	$k_4 = 0.430$

$$y_{n+1} = y_n + 1/6\,(0.55 + 0.98 + 0.98 + 0.430) = 2.49$$

The nomogram of Figure 8 is, of course, never reproduced in the form shown but is presented only in permanent memory form as columns of countable bits.

Example 2.

A second ordinary differential equation $y' + y \cdot e^x - e^x = 0$ is shown in Figure 9, together with its canonical form and the nomogram expressing this equation. A solution also appears, practically identical with a classical solution, though separated in the drawing.

Example 3.

Figures 10a and 10b. A non-linear differential equation $y' + xy^2 = x$ with its nomogram and solution shown. The nomographic, Runge-Kutta solution cannot be distinguished from the classical solution even though an increment as large as $x = 0.1$ was used. Under an Euler method, modified Euler method, or Runge-Kutta techniques, the nomographic solution differs from the classical by about 10^{-3}.

It is worth mentioning that many problems of the required circuitry can be simplified by using the projective geometry or central projection (a modern graphical subject,) since this gives a nomogram great flexibility in shape and hence flexibility in the nature and needs of the various columns of countable bits.

The examples have shown non-linear ordinary differential equations of the first degree and order, but those of higher degree or order can be represented by systems of equations whose members are all of first order.

The case of partial differential equations, as well as systems of them, is much more difficult but shows promise. Here is the point where the teaming of such a fast, special-purpose computer with a fast general-purpose computer of relatively small memory could be especially helpful. Many forms of attack on this problem along nomographic lines are currently under investigation because of its importance in modern technology.

DIFFERENTIAL EQUATION: $y' + y\, e^x - e^x = 0$

INITIAL CONDITIONS: $x = 0 \quad y = 2$

ANALYTICAL SOLUTION: $y = 1 + e^{(1 - e^x)}$

X	Y (NOMO)	Y (ANALYT)	ERROR
0.00	2.0000	2.0000	0.0000
0.10	1.900	1.9001	0.0000
0.20	1.8009	1.8013	0.0004
0.30	1.7037	1.7047	0.0010
0.40	1.6109	1.6115	0.0006
0.50	1.5221	1.5227	0.0006
0.60	1.4376	1.4395	0.0019
0.70	1.3607	1.3628	0.0021
0.80	1.2915	1.2936	0.0021
0.90	1.2302	1.2323	0.0021
1.00	1.1773	1.1794	0.0021
1.10	1.1327	1.1348	0.0021
1.20	1.0960	1.0982	0.0022
1.30	1.0666	1.0693	0.0027
1.40	1.0450	1.0471	0.0021
1.50	1.0296	1.0308	0.0012

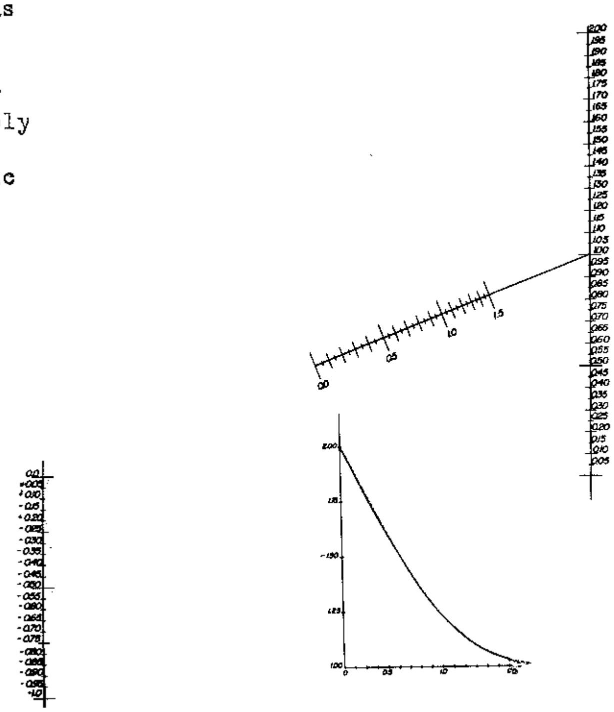


Figure 9.

An ordinary differential equation and its solution by nomographic techniques based upon Runge-Kutta developments.

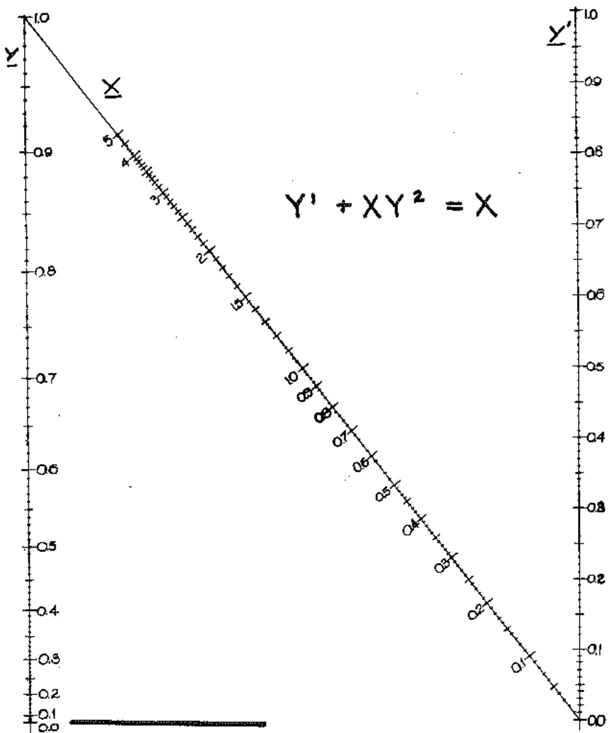


Figure 10 (a)

A home-made nomogram for the non-linear ordinary differential equation shown.

In resume, we view the nomographic technique as an organization of a computation conducive to a correlation of the old variables with new ones. The new variables satisfy a linear relation.

This can be done for a large class of equations, making it worthwhile to put the correlation in a countable bit form and have the linear relation worked out by circuitry.

Computation and writing of the thousands of bits in memory can be done very quickly by IBM 7094 with oscilloscope output, and other methods.

Reading can be done in a variety of optical-mechanical and other ways.

Speed and cheapness are the reward.

This article draws in part from portions of material presented in such sources as Engineering Graphics Seminar, Princeton University, Department of Graphics and Engineering Drawing, "Countable-Bit, Nomographic Electronic Computation", February 11, 1963 and "Workshop on Computer Organization", Edited by Alan A. Barnum and Morris A. Knapp, Spartan Books, Inc., Washington, D.C., 1963, pgs. 1-65.

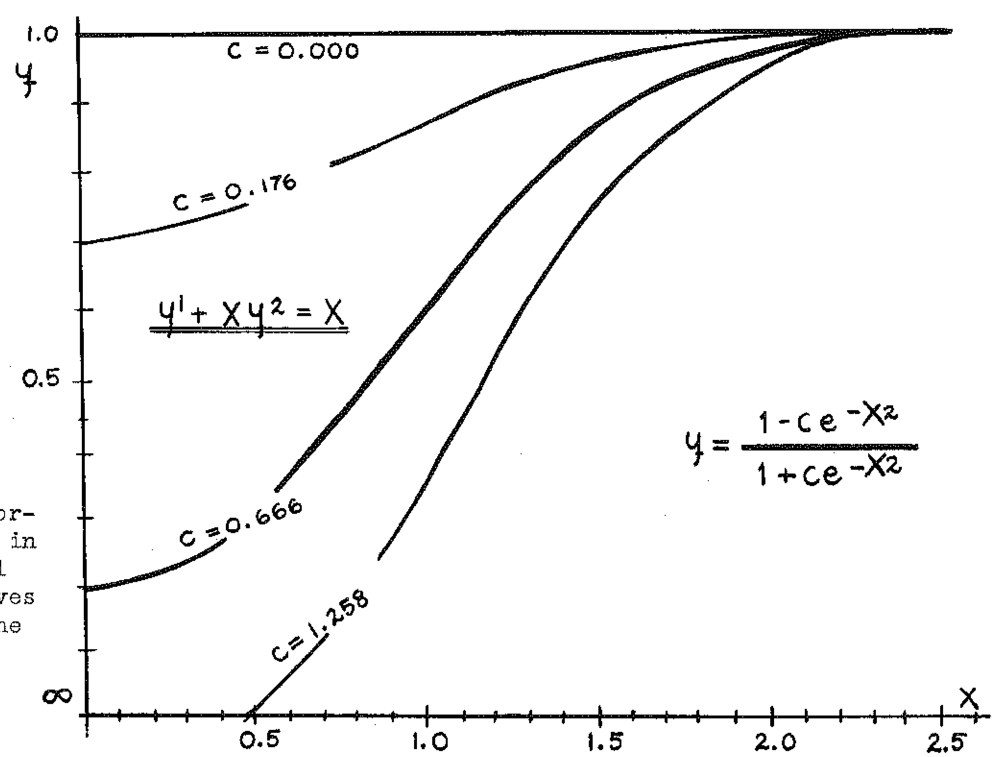
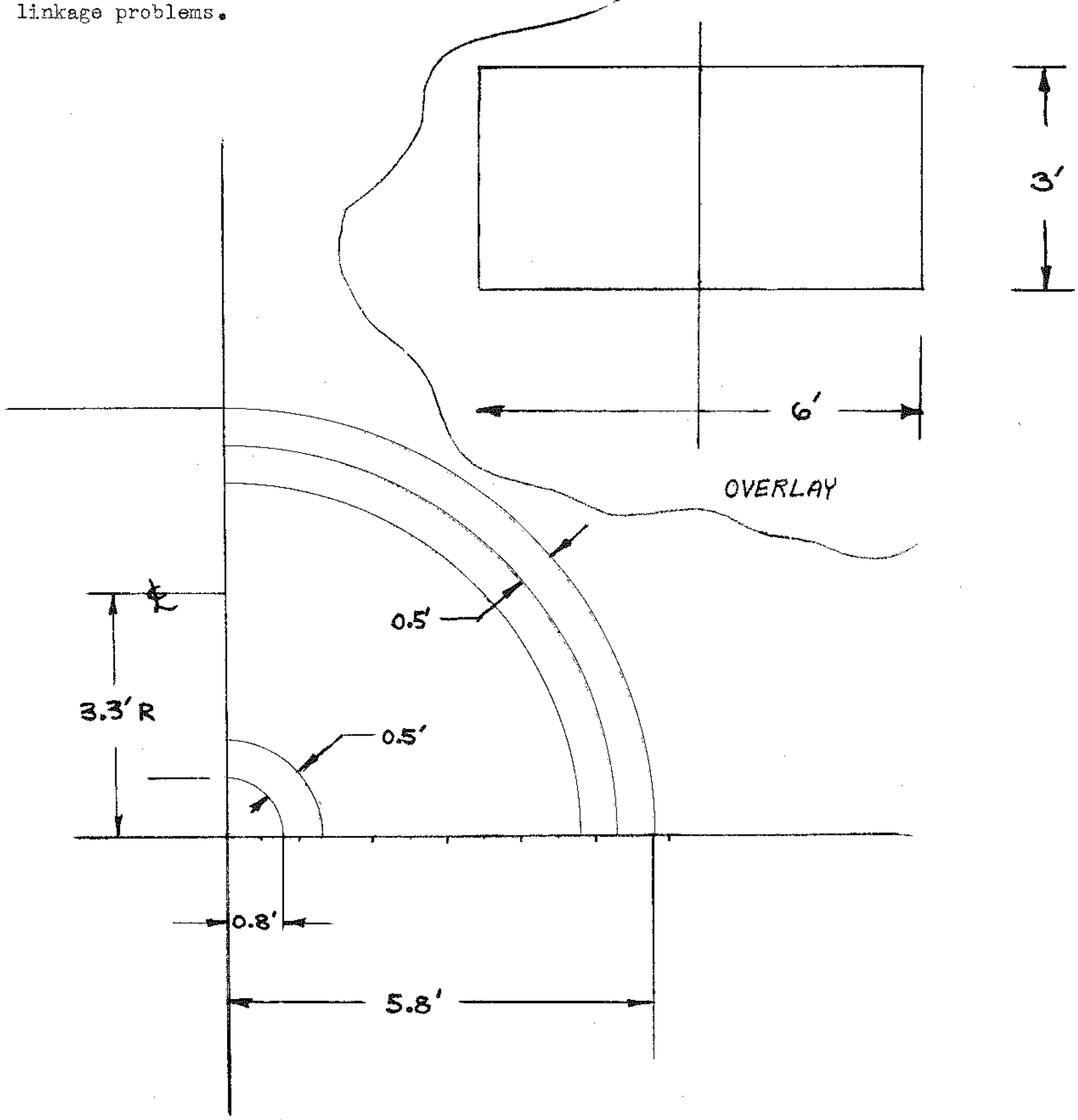


Figure 10 (b).

Solutions to the non-linear ordinary differential equation in Figure 10 (a). The classical and nomographic solution curves cannot be distinguished in the region shown.

Solution to the Winter '63 Tantalizer

Professor Wm. Chalk of the University of Washington gives the following solution; he says he used an overlay technique which he uses in solving linkage problems.



COURSE		DWG NO. 1/2

UNIVERSITY of WASHINGTON–SEATTLE, WASH.

DR BY WS CHALK	CK BY	SCALE 1" = 2'	DATE 2-13-64

HIGHLIGHTS OF THE MID-WINTER MEETING

Texas A & M University, January 1964

Edsel J. Burkhart in his talk on "Graphics as Viewed by a Consulting Engineer":

Inspire the student to visualize the problems in a manner that will convey the solution to others in a form which will require no further explanation.

Bob LaRue, Professor of Mechanical Engineering at Colorado State University, in his paper "Simulate to Stimulate", said that: -

Graphical simulation of a system enables an individual to more easily recognize basic principles that are involved in the system and to react so as to properly apply his knowledge of these fundamentals to problems which arise during the design or operation of the system.

J. H. Venema of the Ford Motor Co. in his talk on "Engineering Communications":

"Engineering Communications constitute a large part of engineering effort in terms of manpower and money, without contributing to the technical excellence of the engineering job. Still, the most brilliant engineering is followed by confusion, high cost and erratic product performance if the engineering message is not accurately conveyed to those who must manufacture the product. These two opposing conditions create, concurrently, a desire to reduce the communications cost burden and a reluctance to take action which could impair the dissemination of information. This dilemma is most severe in large, diverse industries where recipients of the information have varied technical background and thus, diverse bases for interpretation - and there is always interpretation."

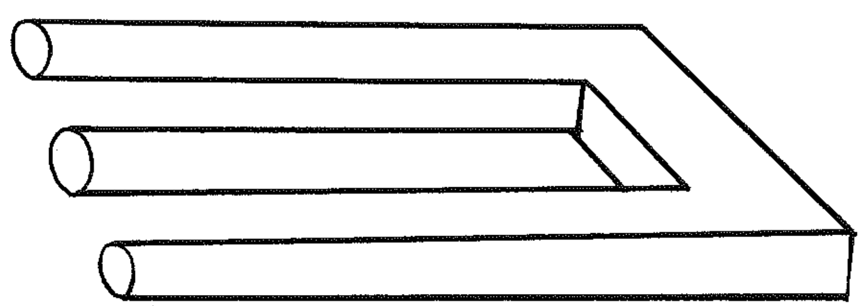
Ernest C. Schamehorn, Professor of Mechanical Engineering, West Virginia Institute of Technology, presented a 32 page report on Engineering Graphics Course Content.

Clarence E. Hall and William E. Lambert did some graphic and mental gymnastics in their demonstrations in **duplicating** a cube and **bisecting** an angle.

Error - Page 27, Fall Issue, 1963
Professor Arnold's reference in the footnote should read "Graphic Aids in Engineering Computation" by Hoelscher, Arnold and Pierce; published by Balt Publishers, 308 State Street, West Lafayette, Indiana. (This was formerly published by McGraw-Hill.)

Figure this out!

Submitted By:
Robert Meir
The Cooper Union



Report of the Nominating Committee
ENGINEERING GRAPHICS DIVISION - ASEE
(Revised January 16, 1964)

The Nominating Committee of the Division of Engineering Graphics of ASEE has selected the following slate of nominations for the offices indicated for 1964-65: (listed alphabetically)

Vice-Chairman
- J. S. Dobrovolny - University of Illinois
- J. Howard Porsch - Purdue University

Secretary
- Mary F. Blade - The Cooper Union
- Frank M. Hrachovsky - Illinois Institute of Technology

Director - Executive Committee (4 years, to fill the unexpired term of A. J. Philby, elected in 1963)
- R. A. Kliphardt - Northwestern University
- R. R. Worsencroft - University of Wisconsin

Director - Executive Committee (5 years)
- M. W. Almfeldt - Iowa State University
- C. C. Perryman - Texas Technological College

Division Editor (ASEE Journal)
- A. S. Palmerlee - University of Kansas
- S. M. Slaby - Princeton University

Editor of Journal of Engineering Graphics
- E. D. Black - General Motors Institute
- K. E. Botkin - Purdue University

Respectfully submitted
Nominating Committee:
J. S. Blackman
E. M. Griswold
R. E. Lewis
I. Wladaver
J. S. Rising, Chairman

INTERESTING READING

For your spring vacation reading adventures, here are three titles which will lead you to new ideas and pleasures:

"Love and Joy About Letters" by Ben Shahn
Grossman Publications, 1963 (about letters and lettering).

"Logic Machines and Diagrams" by Martin Gardner
McGraw-Hill, 1958.

"The Inventor and His World" by H. Stafford Hatfield,
Pelican Press - First published 1933, and reprined continuously.

Graphics Tantalizer

A problem from Polya:
Find the triangle, given the lengths of three altitudes.

CURRICULUM IN TECHNICAL DESIGN

At Arizona State University, in the Division of Industrial Design and Technology, there is a Technical Design - four year college curriculum. At present there are 50 students majoring in this program and about 200 students are taking at least one Technical Design course. Professor Lucile B. Kaufman, who has fostered this program since its inception 14 years ago is presently in charge of it. She reports that one of the most important features is that students now have the experience of designing a product and then having it manufactured and put to use. (This is the TD 450 and 451 sequence.) The curriculum outline is presented here for Engineering Graphics readers.

GENERAL EDUCATION REQUIREMENTS (40 Sem. Hrs.)	Hrs. Cr.	In Prog	Grade
COMMUNICATIONS 6 Sem. Hrs.			
1-EN 101 English	3		
1 1-EN 102 English	3		
HUMANITIES 8 Sem. Hrs. (Upper Division)			
SOCIAL SCIENCES 8 Sem. Hrs.			
GB 101 Intro. to Business	3		
SCIENCES 8 Sem. Hrs.			
Group 1 (Physical Science)			
*1-CH 111 or 113 Elem. Chem.	4		
*1-CH 114 General Chemistry	4		
Group 3 (Mathematics)			
*MA 116 or 117 Algebra	3		
HEALTH AND ADJUSTMENT 1 Sem. Hr.			
PE 101	0.5		
PE 102	0.5		
GENERAL EDUCATION ELECTIVES			
*1-PH 111 General Physics	4		
*MA 118 Trigonometry	3		
*ES 400 Tech. Communications	3		
GRAND TOTAL GENERAL EDUCATION ____			
AIR OR MILITARY SCIENCE (6 Sem. Hrs.)			
*ME 102 Eng. Problems	2		

Minimum of 120 hrs. for graduation (exclusive of Military)

*Denotes required in Technological Core (ME 102 replaced IA 109 for Technical Design).

TECHNICAL DESIGN (REQUIRED)	Hrs. Cr.	In Prog	Grad
*TD 111 Tech. Drawing	2		
TD 112 Descrip. Geom.	2		
TD 121 Prod. Language	2		
TD 200 Machine Drafting	2		
TD 302 Tech. Drawing	3		
TD 303 Descrip. Geom.	3		
TD 305 Precision Design	2		
TD 310 Product Design	3		
TD 315 Materials	3		
TD 330 Electro-Mech. Design	2		
TD 340 Fluids	3		
TD 350 Design Lab	3		
TD 402 Structural Detail	2		
TD 406 Mech. Design	4		
TD 407 Mech. Design	4		
TD 408 Nomographics	2		
TD 450 Experimental Tech.	1		
TD 451 Experimental Tech.	1		
REQUIRED SUPPORTING FIELD			
*ME 102 Eng. Prob. Analysis	2		
ME 230 Mats. & Ind. Proc.	2		
1-MA 120 Analyt. Geom. & Cal.	4		
1-MA 121 Analyt. Geom. & Cal.	4		
TE 200 Elec. & Electronics	3		
TE 330 Transistors	3		
KE 320 Metallurgy	3		
TM 366 Ind. Inspection	3		
SUGGESTED ELECTIVES			
TD 160 Tech. Illustration	2		
TD 260 Tech. Illustration	2		
TD 370 Tool Design	2		
TD 371 Tool Design	2		
TD 380 Aero. Draw. & Design	2		
TE 340 Elect. Measurements	3		
ME 280 Appl. Thermodynamics	3		
GL 311 Engineering Geology	3		
CE 241 Surveying	3		
GE 211 Elem. Cartography & Graphics	2		
GB 301 Mech. Data Proc.	3		
GB 302 Electronic Data Proc.	3		
GB 305 Business Law	3		
AC 332 Acct. for Engr.	4		
MG 301 Prin. of Management	3		
IE 439g Supervis. & Labor	2		
IE 322 Work Anal. & Design	3		
Other Industrial Design & Tech. courses			

DIVISION OF INDUSTRIAL DESIGN AND TECHNOLOGY

Arizona State University 1963-65 Catalog

TECHNICAL DESIGN

Suggested Pattern

FRESHMAN

First Semester		Hrs.	Second Semester		Hrs.
1-EN 101	First Year English	3	1-EN 102	First Year English	3
1-MA 117	College Algebra	3	1-MA 118	Trigonometry	3
1-CH 113	General Chemistry	4	1-CH 114	General Chemistry	4
TD 111	Technical Drawing	2	TD 112	Descriptive Geometry	2
3-GB 101	Intro. to Business	3	TD 121	Production Language	2
1-PE 101	Freshman Physical Educ.	0.5	1-PE 102	Freshman Physical Educ.	0.5
1-AS/MS 101	Basic Air/Mil. Science	0.5	1-AS/MS 102	Basic Air/Mil. Science	1.5
	or	1.5		or	0.5
	16 or	17		15 or	16

SOPHOMORE

1-MA 120	Analytic Geom. & Calculus	4	1-MA 121	Analytic Geom. & Calculus	4
1-PH 111	General Physics	4	ME 230	Materials and Ind. Proc.	2
ME 102	Engineering Prob. Analysis	2	TD 303	Descriptive Geometry	3
TD 200	Machine Drafting	2	TE 200	Elect. & Electronics	3
TD 302	Technical Drawing	3		Approved Elective	3
1-AS/MS	Air/Mil. Science	1.5	1-AS/MS	Air/Mil. Science	0.5
		16.5		or	1.5
				15.5 or	16.5

JUNIOR

TD 310	Product Design	3	TD 315	Materials	3
TD 305	Precision Design	2	KE 320	Metallurgy	3
TE 330	Transistors	3	TD 340	Fluids	3
TD 330	Electro-Mech. Design	2	TM 366	Industrial Inspection	3
1-PY 100	Psychology	3	ME 300	Man and Machine	2
	Approved Elective	3	TD 350	Design Laboratory	3
		16			17

SENIOR

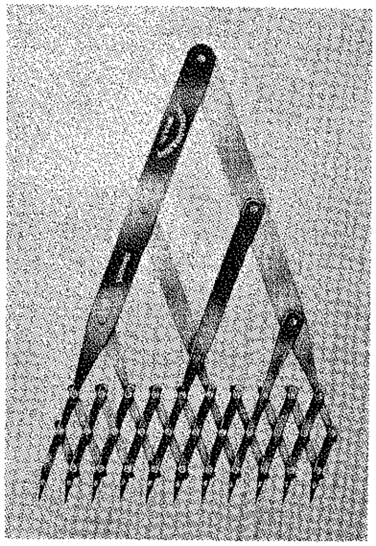
TD 406	Mechanical Design	4	TD 407	Mechanical Design	4
TD 408	Nomographics	2	ES 400	Technical Communications	3
TD 450	Experimental Techniques	1	TD 402	Structural Detailing	2
1-HU	Humanities (Upper Division)	4	TD 451	Experimental Technique	1
	Approved Electives	5	1-HU	Humanities (Upper Division)	4
		16		Approved Elective	2
					16

SUGGESTED ELECTIVES

TD 160	Technical Illustration	2	GE 211	Elem. Cart.& Graphics	2
TD 260	Technical Illustration	2	GB 301	Mech. Data Processing	3
TD 370	Tool Design	2	GB 302	Electronic Data Processing	3
TD 371	Tool Design	2	GB 305	Business Law	3
TD 380	Aero. Drawing & Design	2	AC 322	Accounting for Engr.	4
TE 340	Elect. Measurements	3	MG 301	Principles of Management	3
ME 280	Applied Thermodynamics	3	IE 439g	Supervision and Labor	2
GL 311	Engineering Geology	3	IE 322	Work Analysis and Design	3
CE 241	Surveying	3			

Other Industrial Design & Technology courses.

THE SPACING DIVIDER



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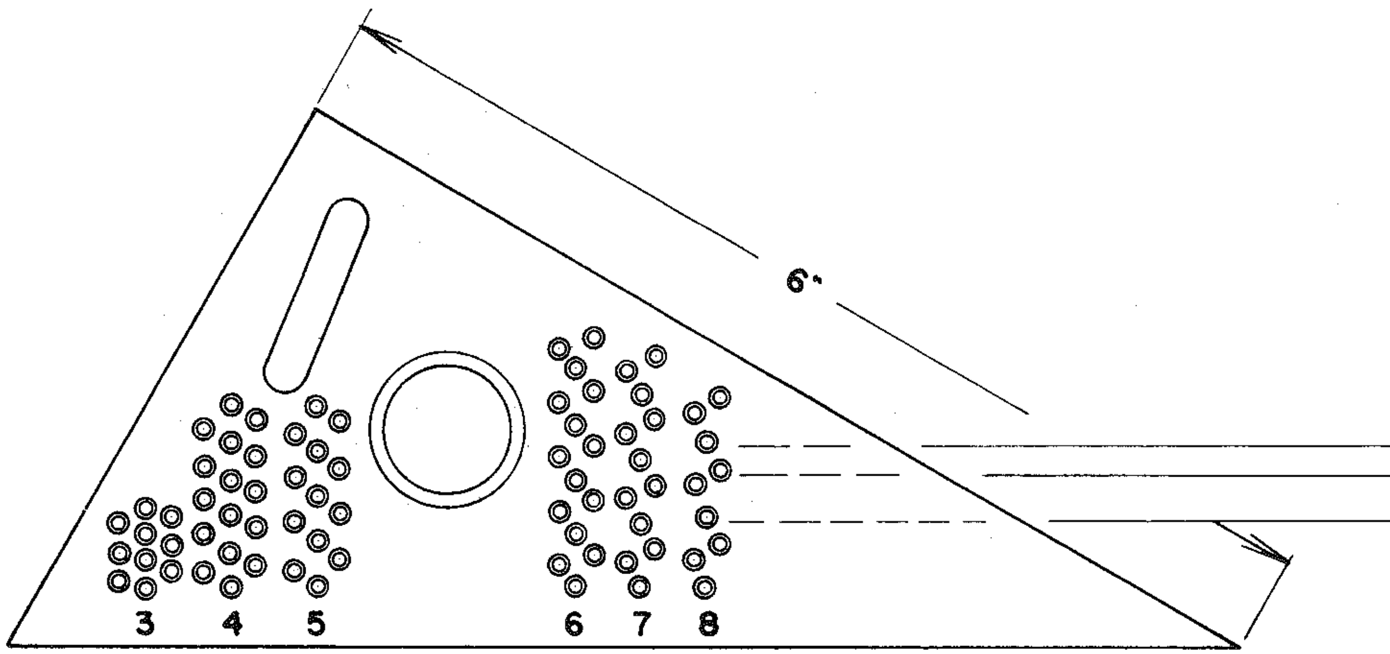

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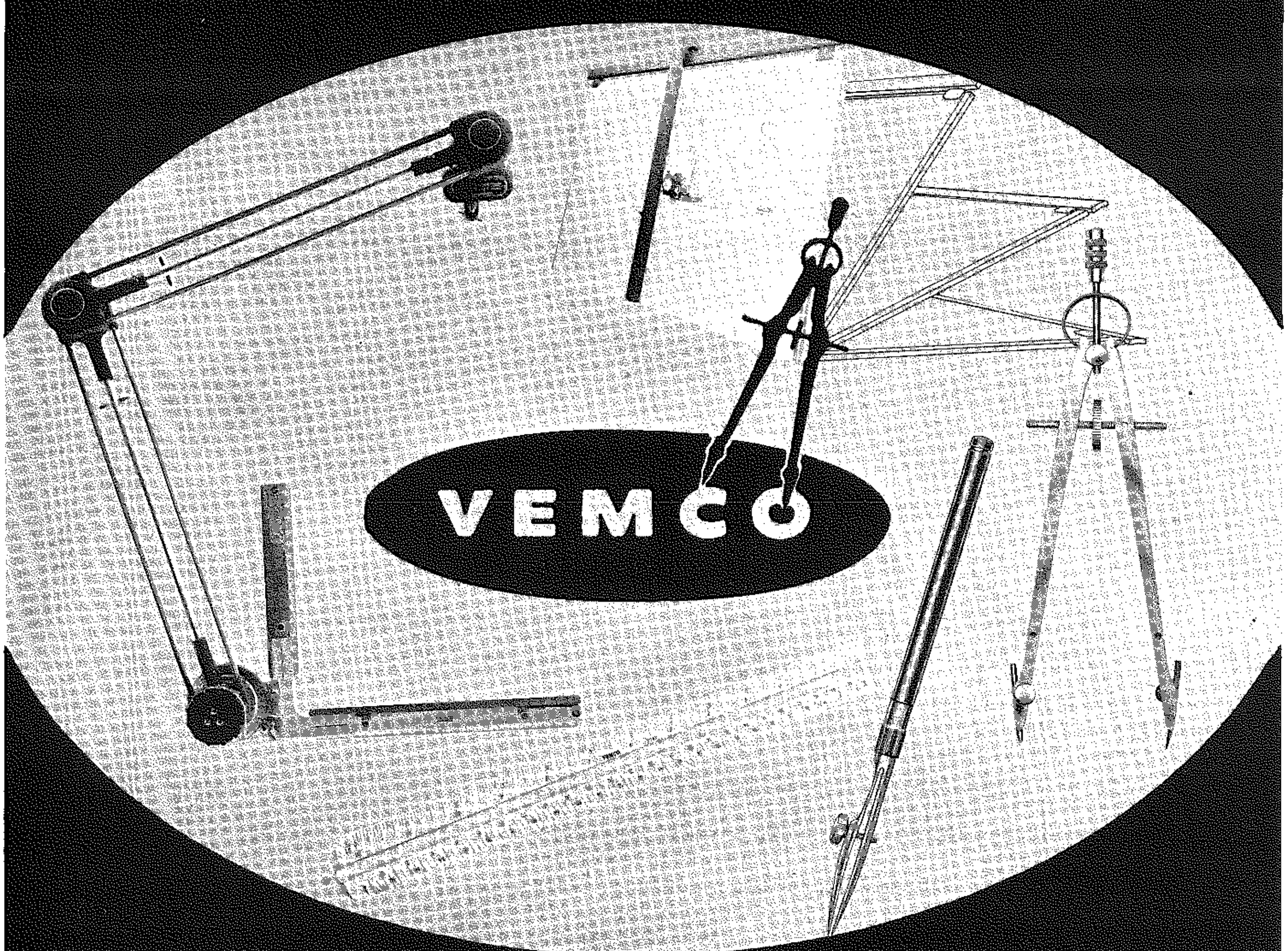

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