COMIC: An analog computer in the colorant industry

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Chemical & Engineering
NEWS

AUGUST 15, 1966

Technology

Color matching

success with instruments, but some problems remain

The problem

Find the proportions of several pigments to mix to match a given sample.

"Industry's number-one color problem" (1963)

Why is it hard?

Colors: A 3-dimensional space

Coordinates: R,G,B or

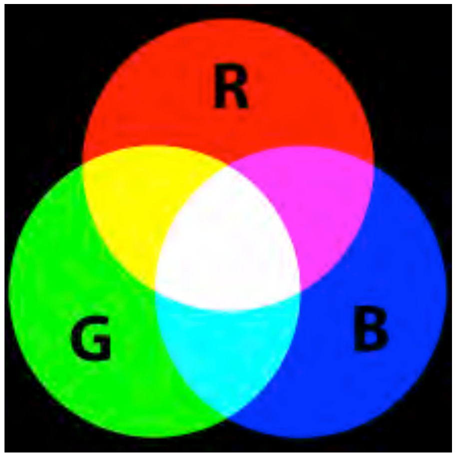
X,Y,Z (CIE* tristimulus values)

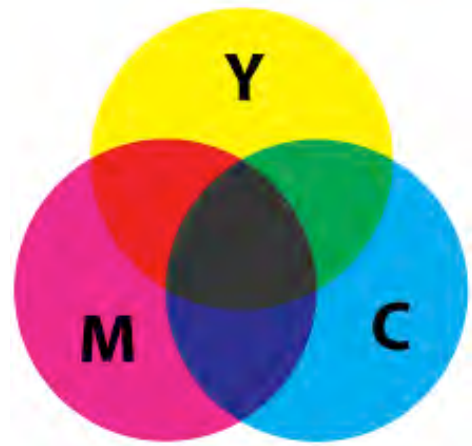
X,Y,Z of mixture of lights:

sum of X,Y,Z values of components

*CIE: Commission Internationale d'Éclairage

Color Mixing





Additive mixing of lights

Subtractive mixing of absorbing filters

sum tristimulus values

spectral transmission data needed

Additive matching

$$X = c_1X_1 + c_2X_2 + c_3X_3$$

$$Y = c_1Y_1 + c_2Y_2 + c_3Y_3$$

$$Z = c_1Z_1 + c_2Z_2 + c_3Z_3$$

Given X,Y,Z of a color, and three lights, solve the equations for the amounts c_i of those lights to match the given color.

Mixed pigments, dyed fabric: harder

Kubelka-Munk theory(1931): uses absorption and scattering by particles and substrate

$$K/S = \frac{(1-R)^2}{2R} \quad \text{for} \quad \begin{array}{r} \text{absorption } K \\ \text{scattering } S \\ \text{reflectance } R \end{array}$$

K, S of a mixture: linear functions of component K, S values

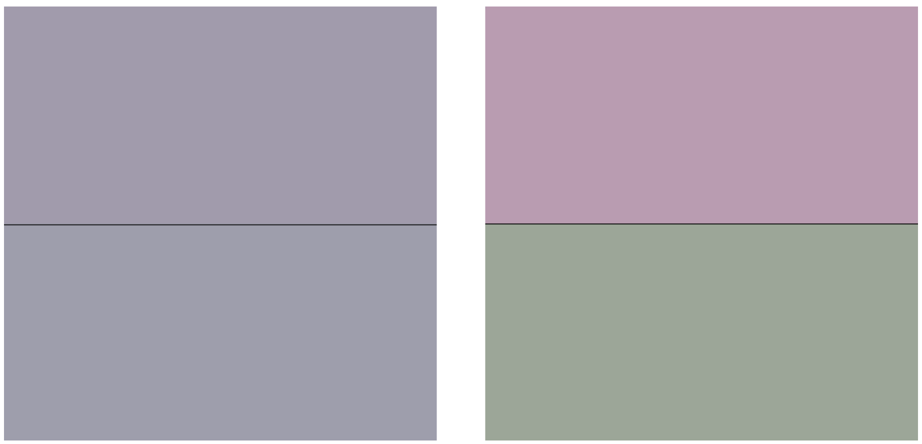
Pastel paints, dyed fabric: assume all scattering due to white pigment or fabric (S_w).

Result: linear equation in c_1, c_2, c_3: quantities of the three colorants

$$\left(\frac{K}{S}\right)_{\text{mixture}} = c_1 \frac{K_1}{S_w} + c_2 \frac{K_2}{S_w} + c_3 \frac{K_3}{S_w} + \frac{K_w}{S_w}$$

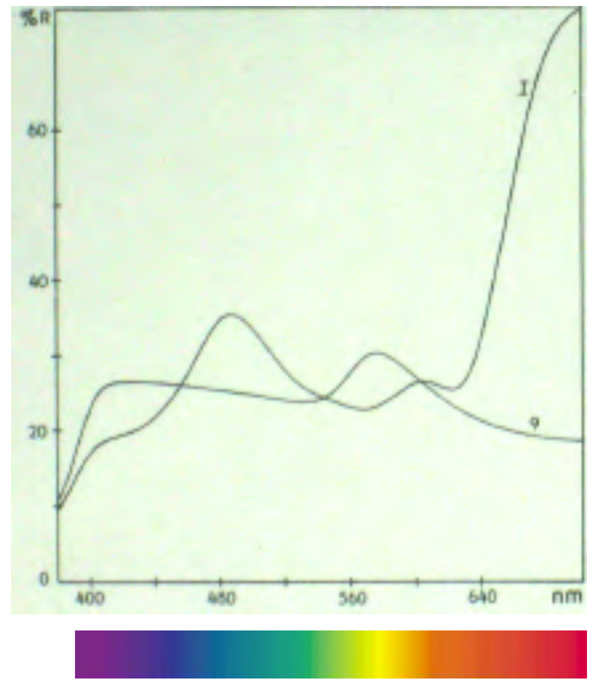
Color also depends on the illuminant.

Colors may match in one light, not in another: *metamerism*.



fluorescent light

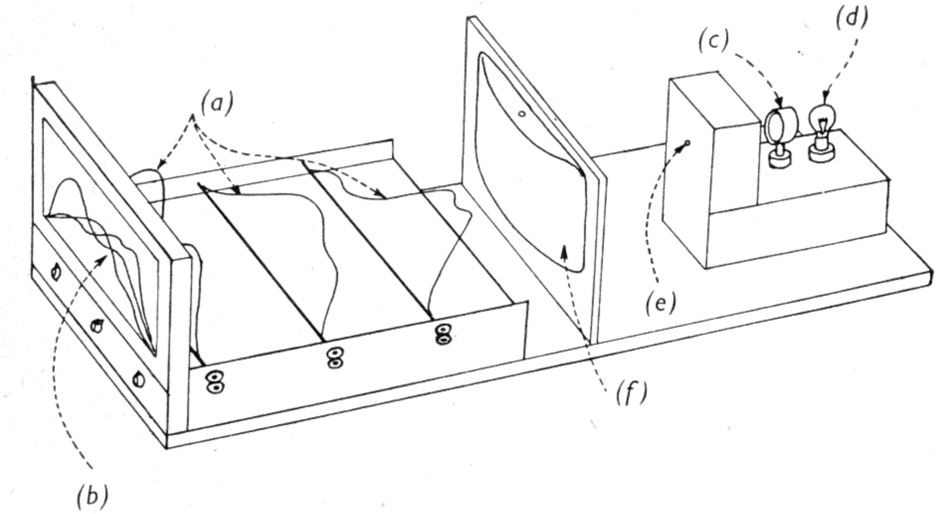
incandescent light



reflectance curves

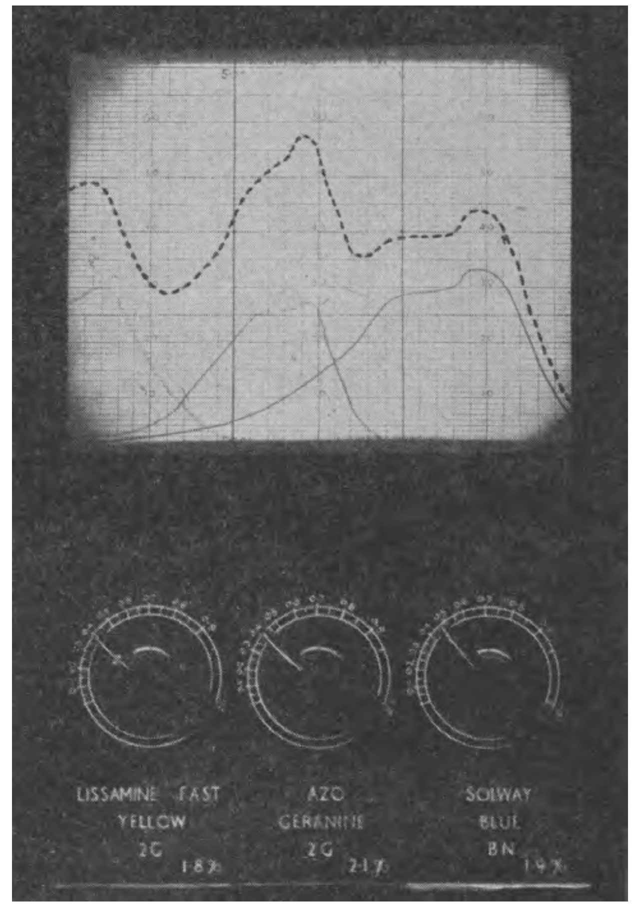
1940s, 1950s: graphical techniques to use the K/S formula: tedious!

1955 analog device:



(a) Wire profiles
(b) Shadows of profiles
(c) Condenser
(d) Car bulb
(e) Pinhole
(f) Converging lens

FIG. 9



Davidson & Hemmendinger, Inc

- Formed 1952 by electrical engineer and physicist
- color measurement and specification
- produced *Munsell Color Atlas*, 1956
- standards and measurements:

  blood tests

  peach grading

  false teeth

  tropical bird colors

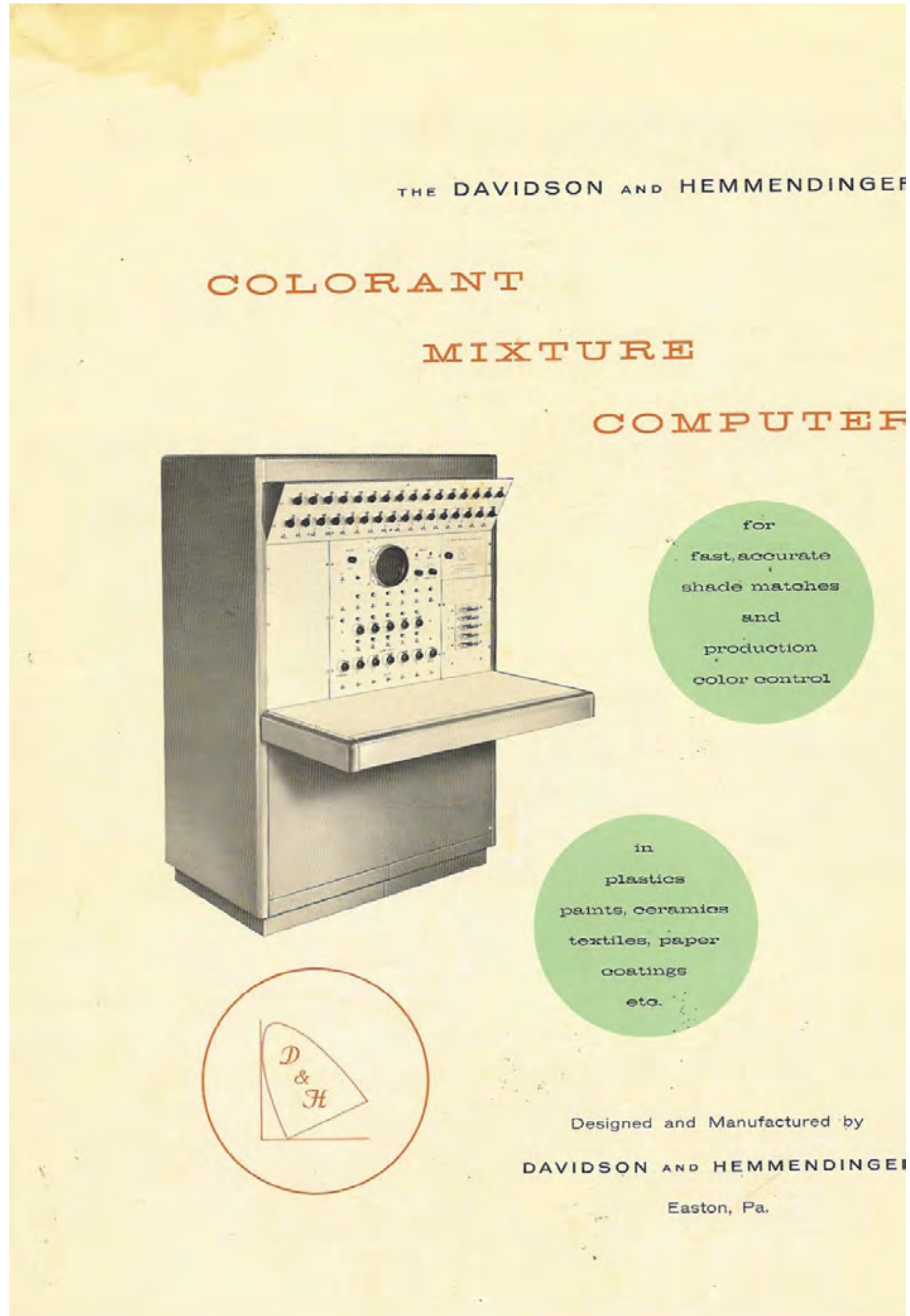
COMIC, 1958

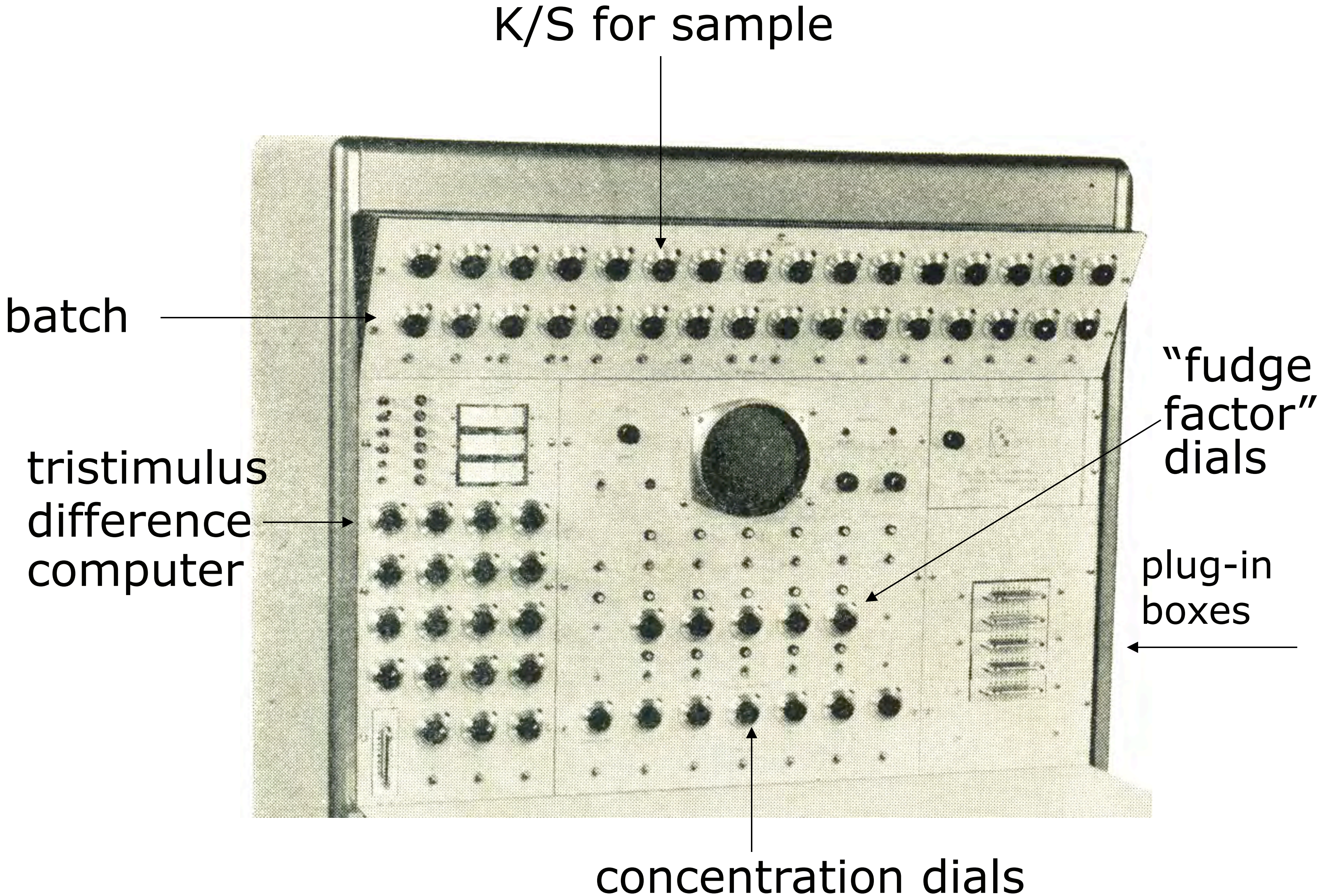
Analog computer

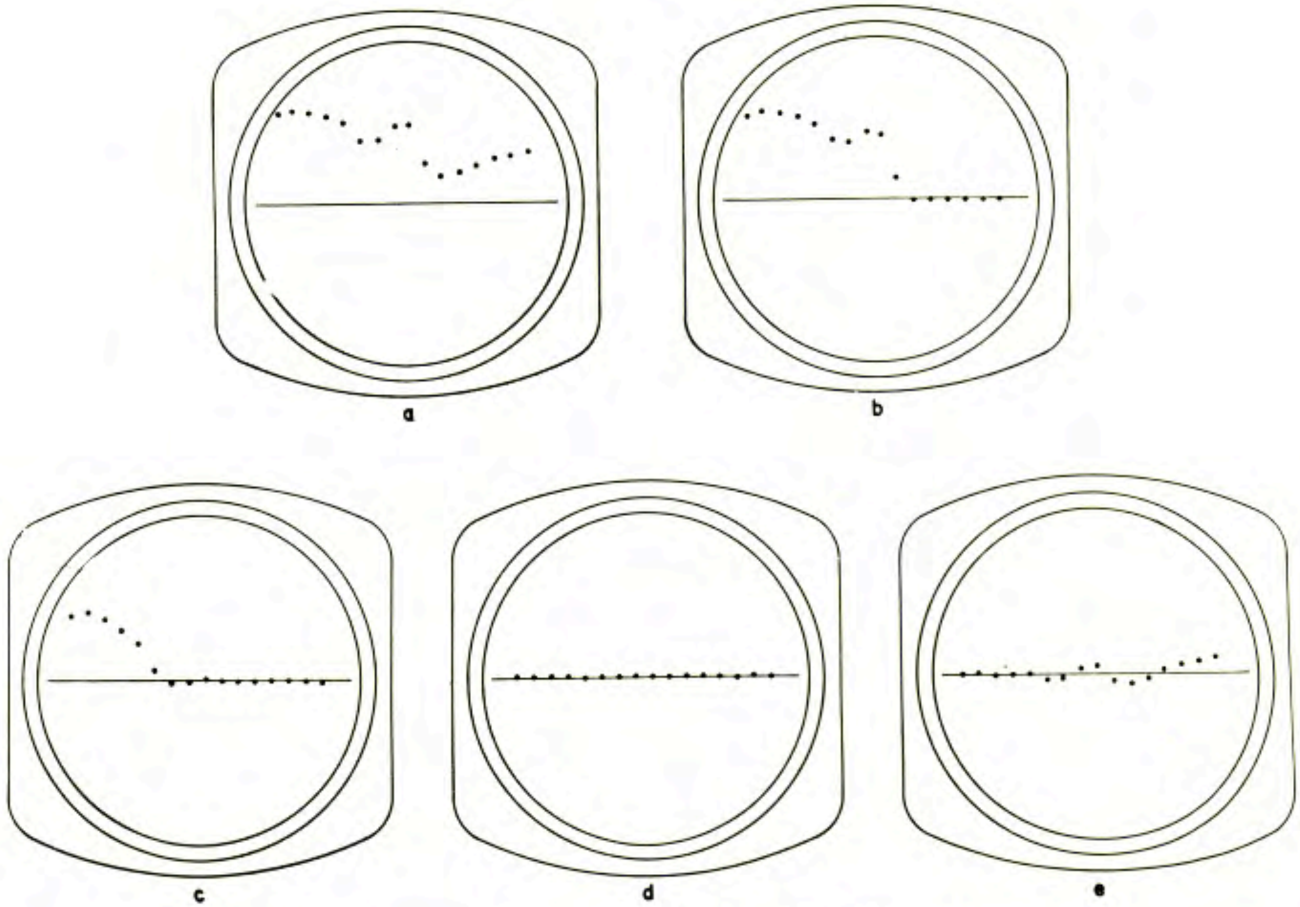
16 simultaneous equations, 3-5 unknowns (c_i):

$$\left(\frac{K}{S}\right)_{mix} = c_1 \frac{K_1}{S_w} + c_2 \frac{K_2}{S_w} + c_3 \frac{K_3}{S_w} + \frac{K_w}{S_w}$$

K/S evaluated at 16 wavelengths across spectrum




K/S for sample
batch
tristimulus difference computer
"fudge factor" dials
plug-in boxes
concentration dials



Photograph courtesy of *Journal of Society of Dyers and Colourists*

a: beige sample. Try yellow, red, green dyes.

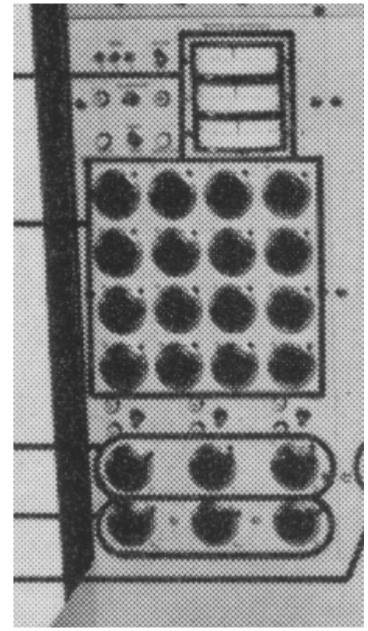
b: add green; c: add red; d: add yellow: match

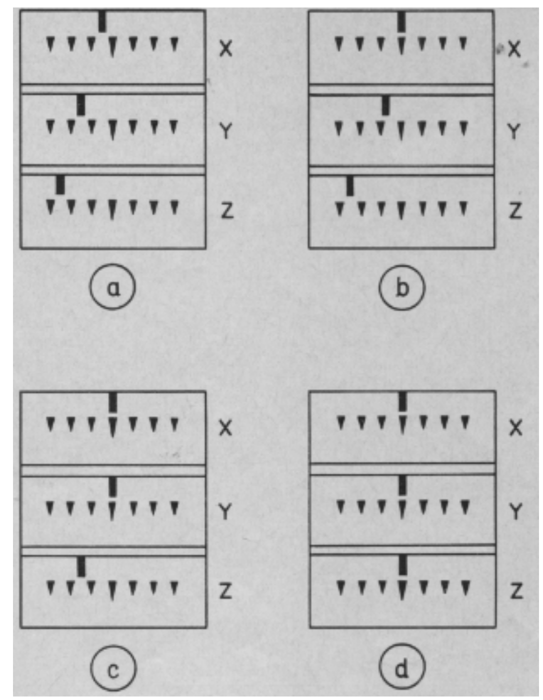
e: try black, not green: imperfect spectral match

If imperfect match

- use TDC
  zero meters for tristimulus (XYZ) match
- may be metameric
- can switch TDC to another illuminant to assess degree

Tristimulus Difference Computer (TDC)





batch settings

2nd trial: set K/S of first trial.

adjust colorant concentration dials: add or subtract to get match

-- or use TDC

Industrial use

~200 sold, 1959-1967

$10,000, later $18,000

plug-in boxes: $40 each

typical results: reduce trials by 35-40%

(Monsanto, Coats & Clark)

best for fabric dyeing, pastel paints

plug-in colorant boxes

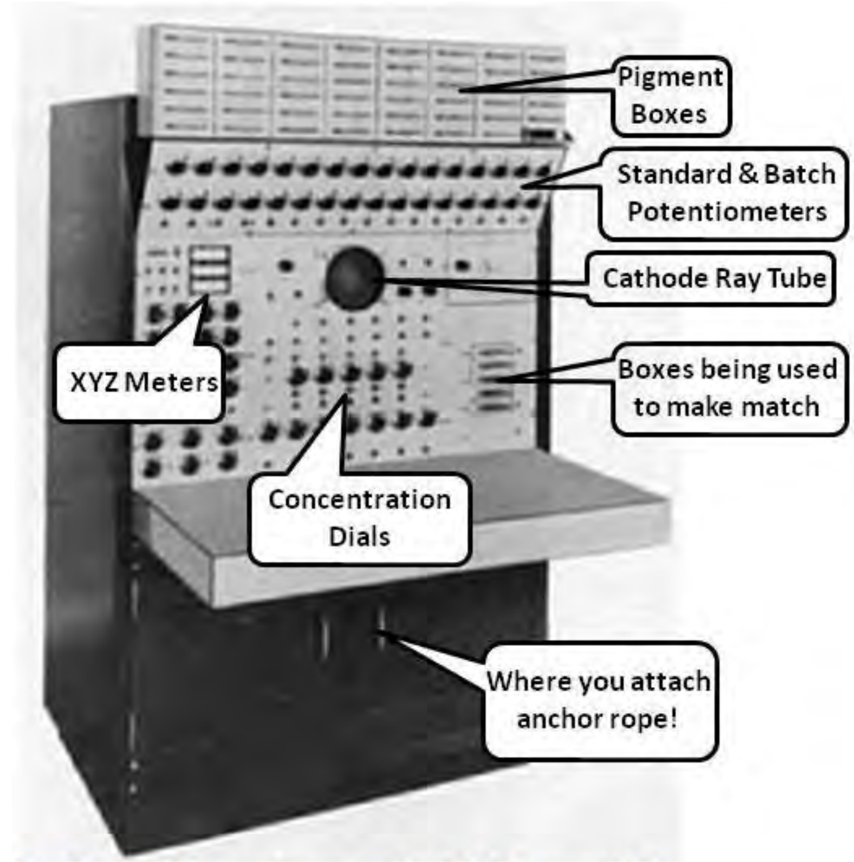
Merits:

- match in 5-20 min, not hour or more
- operator used expert knowledge
- emphasized reflectance curves, not just perceived color

Limitations:

- manual data entry
- colorant boxes: single concentration
- needed “fudge factors” for deep colors
- K/S equation: not quite linear

One opinion:

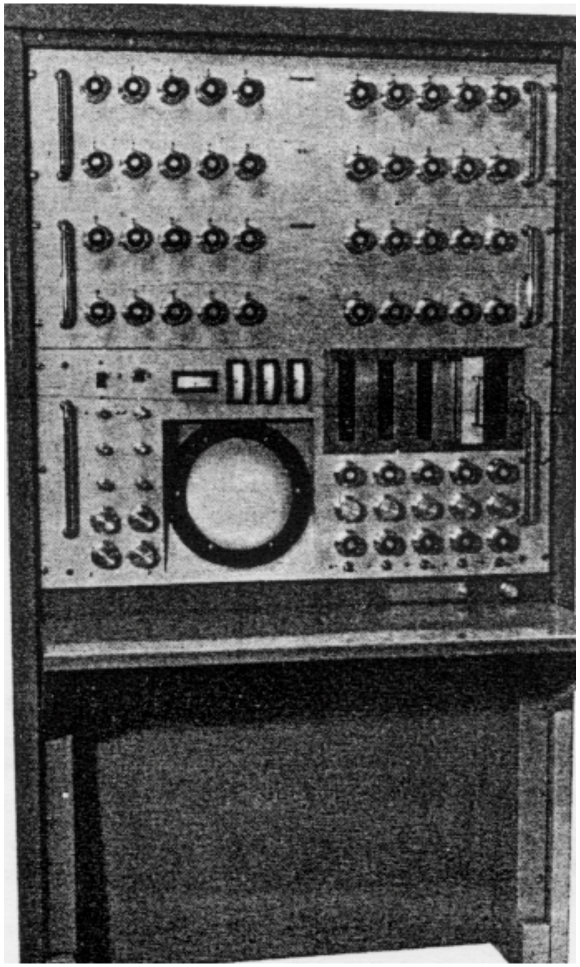


Davidson & Hemmendinger analog COMIC circa 1960

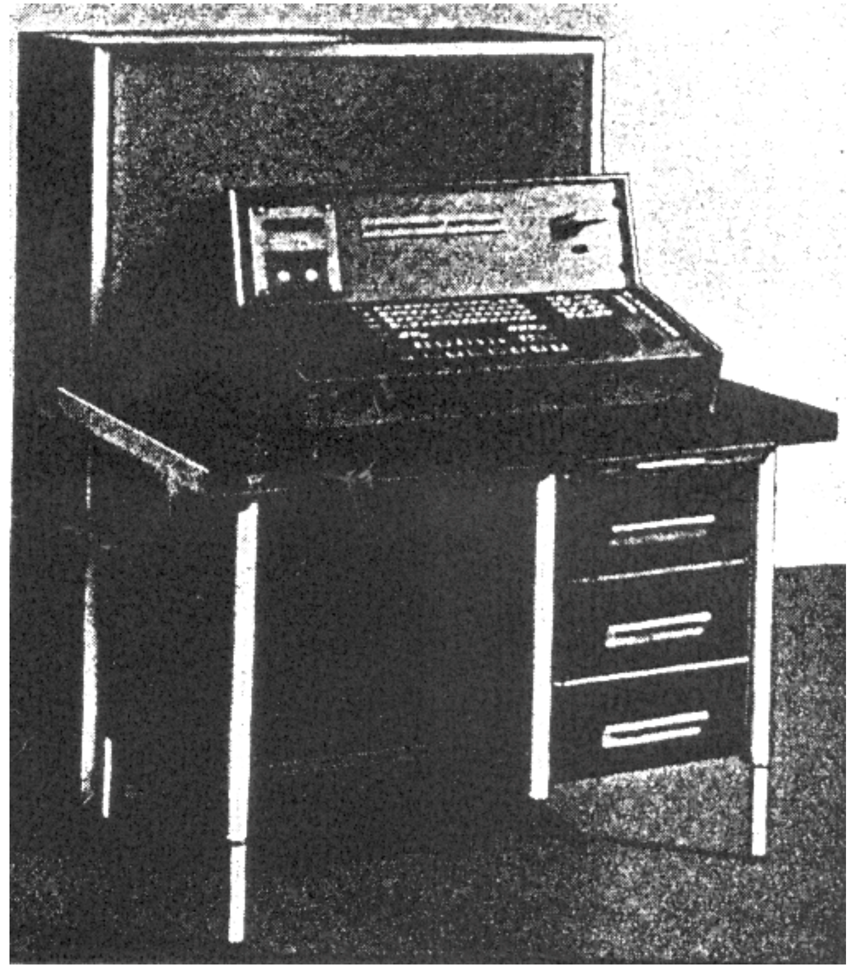
www.rpdms.com/wineyrpt.html

-- author preferred a digital program

Other special-purpose computers

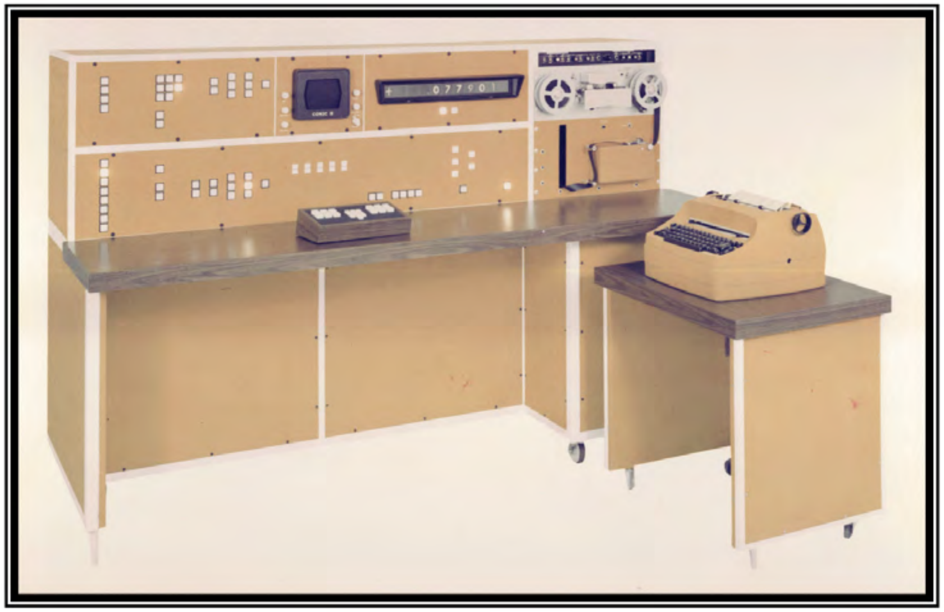


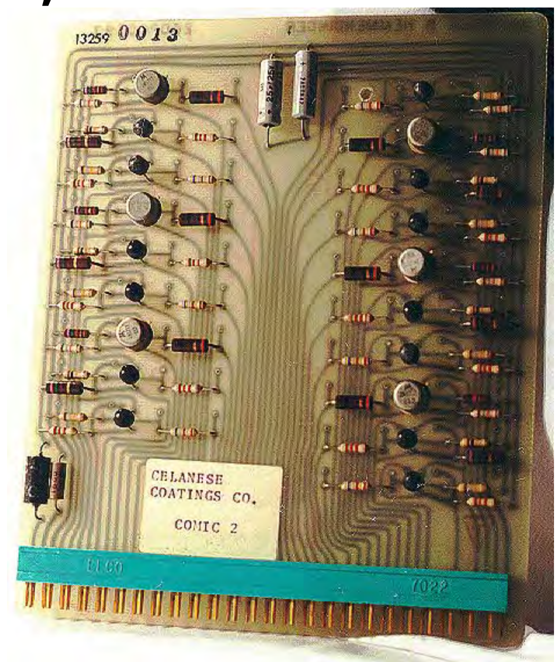
Redifon, 1965
analog/digital



Pretema FR-1, 1966
digital

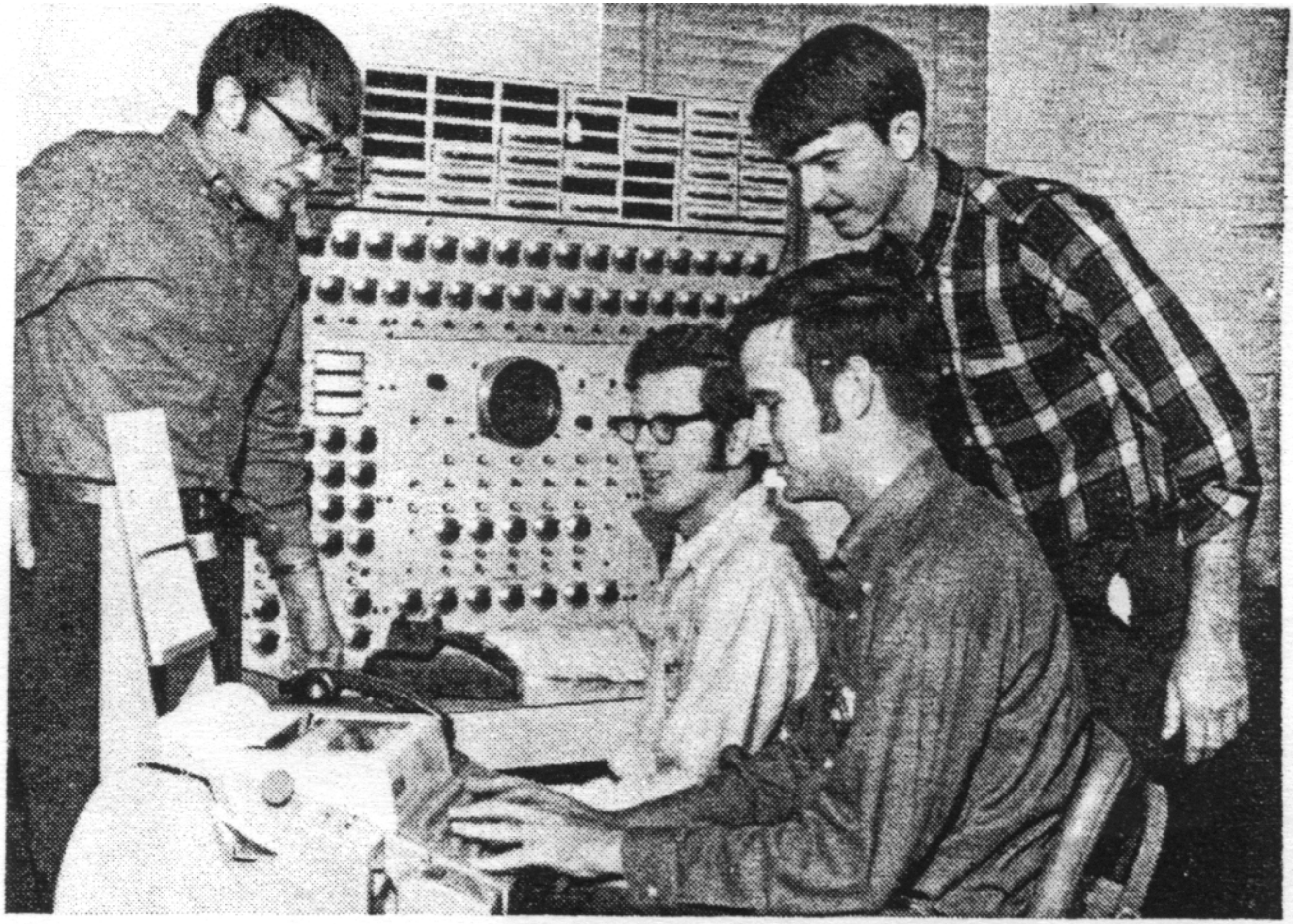
D&H Digital COMIC II, 1967





- 400 boards, magnetic drum, paper tape
- solved more general equations
- few sold. “Obsolete the day it came out.”

  -- Ralph Stanziola, D&H salesman



Seniors are learning to do it themselves in an experimental color program at North Carolina State University's Department of Textile Chemistry. They have access to the sophisticated colorant mixture computer (background) and a computer terminal

Outdated, the COMIC had educational value -- Dec, 1969 Am. Dyestuff Reporter

Digital computing

1959, IBM: Am. Cyanamid computer not enough to solve color equations

1961: Imperial Color, UK: *Instrumental Match Pgm*: colorimetric (XYZ) matches -- couldn’t handle metamerism

1963: Am. Cyanamid, *Computer Color Match* (CCM) found all recipes for 3 out of 10 dyes, with costs, metameric index

-- IBM 1620, later 1130

Clients sent sample measurements, got results within a day

1967: IBM library program for 1130, later 360 systems

CCM, IBM programs solved matrix equation by approximation and iterative refinement

Later versions handled deep colors well, as the COMIC did not

Minicomputers: well-suited to color-matching computations

1970, Applied Color Systems (ACS), co-founded by Mr. Stanziola (from D&H), ran programs on time-sharing DEC 10

Later, used PDP-11s extensively

Merged with Swiss Pretema, UK Instrumental Colour Systems to form Datacolor, 1990

Comparison

COMIC operator: “in the loop”. Adjusted concentration dials to zero the dots: inverting a matrix

With metameric matches, iteratively modified dial settings to get colorimetric (XYZ) match

Analog computing: less highly-mediated experience

Conclusion

The COMIC: right degree of automation for the time

Drew on dyer's experience

Educational role: taught importance of spectral reflectance curves

Digital programs provided more information, had fewer limitations

Risks of automation:

Conclusion, II

Charles Mertz (Minolta, former ACS VP), 2000

Put these tools in the hands of an experienced colorist who understands the plant's processes and you have a powerful team. These same tools placed in the hands of someone who does not understand the science of color and the processes of their plant's operation can lead to frustration and unfulfilled expectations.