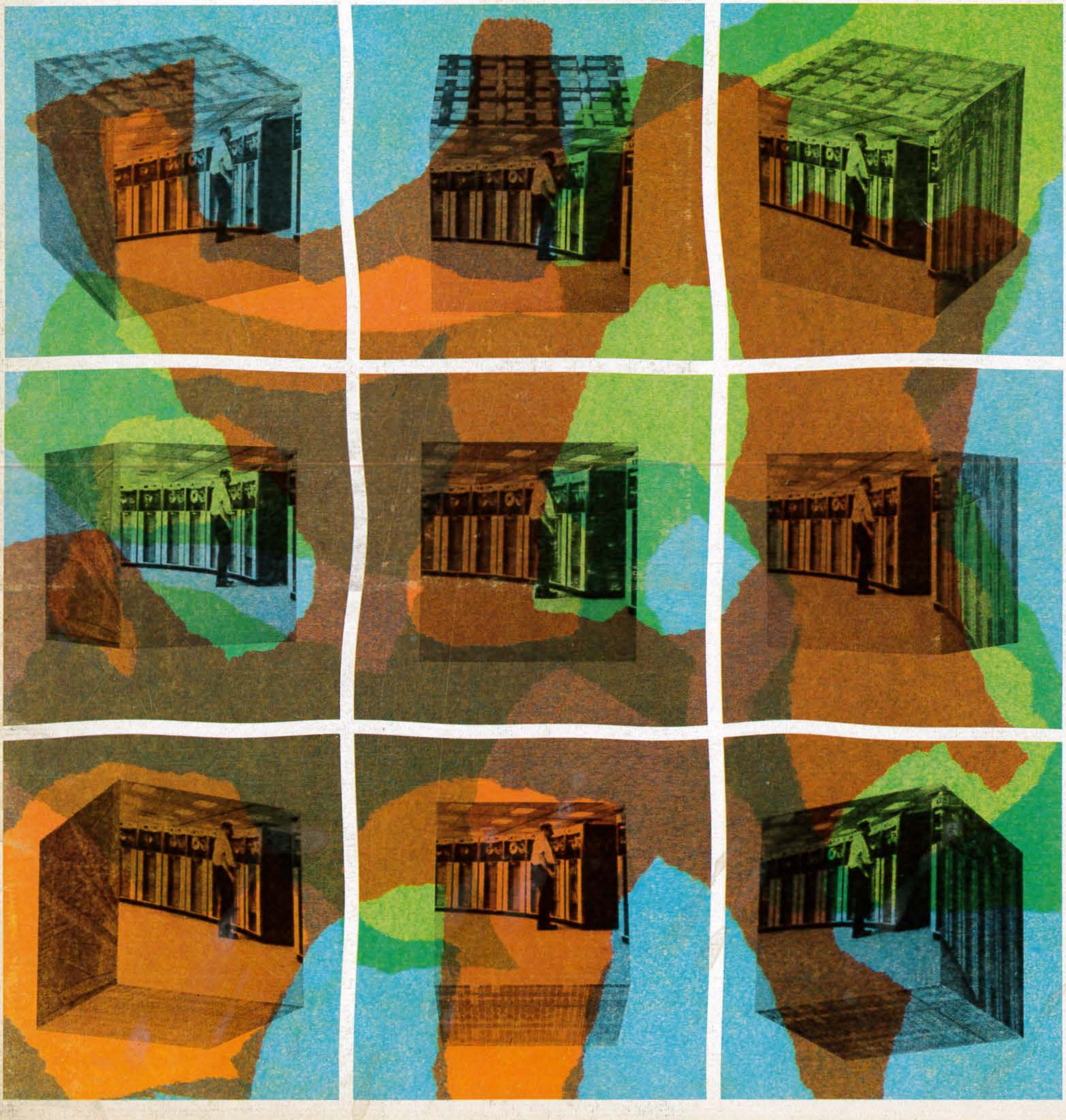
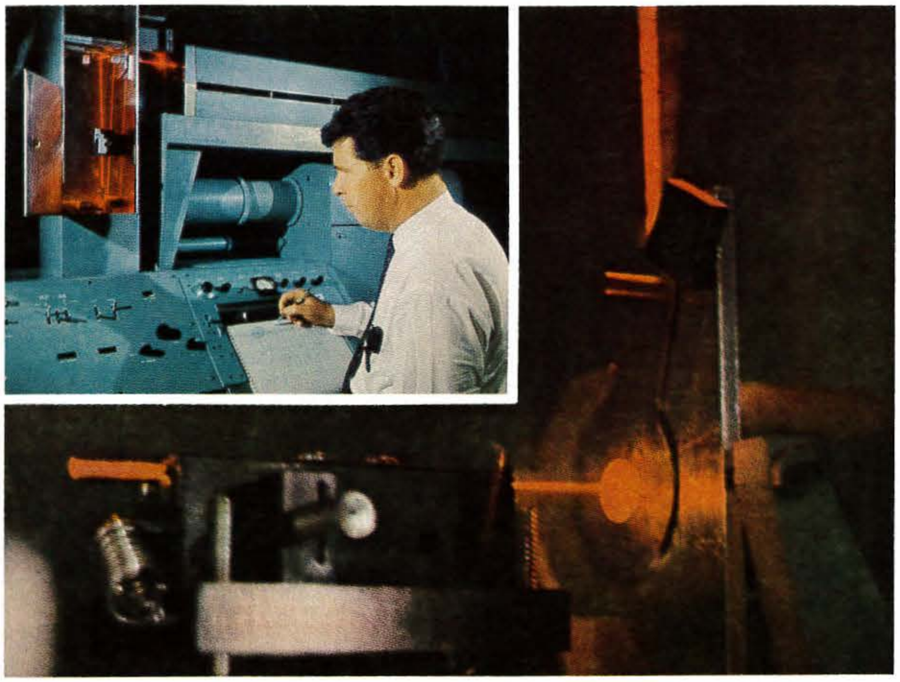
Volume 3 Number 3 May/June 1966

Information Display

Journal of the Society for Information Display



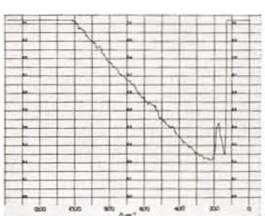


Sample cell, slightly enlarged, showing end of 0.5 mm I.D. tube in which sample is irradiated with laser beam. Inset: Kenyon P. George, Development Engineer, checks Raman Spectra on CARY Model 81 Spectrophotometer made by Applied Physics Corporation, Monrovia, California.

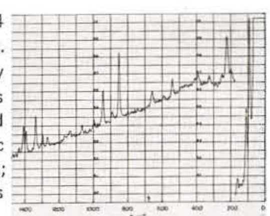
Laser sheds new light on molecular structure

When you want to learn about the architecture of a complex molecule, you can tune in on its vibrations and help determine its structure if you irradiate it with monochromatic light and observe the Raman effect – a form of molecular light-scattering which results in a unique spectral signature for any given molecule.

But many molecules have been difficult to study because of a problem in getting strong Raman signals from small-volume samples. With a new Raman Spectrophotometer[1], however, using a Spectra-Physics Model 125 CW gas laser, you can apply the technique much more broadly – for example, to obtain vibrational spectra of biological samples in less than ten microliters of aqueous solution or a few milligrams of solid material.



Raman spectra from a 2x4 mm crystal of β-alanine. Left, conventional mercury arc light source; right, gas laser. Fluorescence caused by blue light of mercury arc obscures Raman bands; when laser-excited, bands are easily seen.



You'll find Spectra-Physics CW gas lasers used as an integral part of an increasingly wide range of precision analytical, recording, and measuring instruments, wherever a stable, high-intensity source of monochromatic, spatially coherent light is required. Is your application optical data processing, plasma diagnostics, distance determination? We'll help keep you up-to-date on laser application by means of our Laser Technical Bulletins if you'll write us at 1255 Terra Bella Avenue, Mountain View, Calif. 94040. In Europe, Spectra-Physics, S.A., Chemin de Somais 14, Pully, Switzerland.

Spectra-Physics

[1] LASER EXCITATION OF RAMAN SPECTRA IN THE CARY MODEL 81 RAMAN SPECTROPHOTOMETER, PRESENTED BY R.C. HAWES AT THE NATIONAL S.A.S. CONFERENCE, DENVER, COLORADO, SEPTEMBER 2, 1965.

Included in the broad line of Spectra-Physics CW gas lasers is the high-power Model 125, developed to meet the requirements of information display applications. For immediate information on the Model 125 or other Spectra-Physics products, call the nearest sales engineering office listed below:

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(213) 462-7639

Spectra-Physics Inc.
Chicago, Illinois
(312) 386-5104

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Lausanne, Switzerland
Telephone: 28.35.35

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These three NIXIE® tubes will fill 80% of your digital-readout requirements

STANDARD RECTANGULAR — MINIATURE RECTANGULAR — LOW-COST SIDE-VIEWING

The most popular readout ever made—Type 8422. Combines *readability* (maximum viewing distance of 30 feet), *compact* size (0.6″ character in a 1.0″ x 0.8″ end-reading rectangular envelope) and *high reliability* (MTBF of 1 million hours at 90% confidence level). Also available in a decimal-point version, Type B-59956. For high-density packaging (0.7 cu. in.) and minimal instrument height, it's the choice of virtually every important manufacturer of digital instrumentation.

Small wonder this readout (Type B-4998) is chosen when a combination of *compact* size (0.3″ character in a 0.47″ x 0.63″ rectangular envelope), *long life* (200,000 hours dynamic life) and *readability* (maximum viewing distance of 14 feet) are needed. For the smallest electronic readout with BCD decoding and memory, use the B-4998 with the Burroughs BIP-9401A module. Small wonder, indeed!

Our new side-viewing NIXIE tube, Type B-5440. Combines *long-life* (average life of 600,000 hours) with *low cost* ($4.95 in 1000 quantity). Tube has low profile and narrow width for minimum panel-area opening (you can line them up on less than 0.80″ centers), and its new socket is especially designed for pc-board mounting. Independently-operable decimal points are optional at slight extra cost (Type B-5441).

Call or write for full information.

(and we've got the NIXIE tubes for that other 20%, too!)

Only Burroughs manufactures NIXIE Tubes

Burroughs Corporation / ELECTRONIC COMPONENTS DIVISION

PLAINFIELD, NEW JERSEY 07061

Circle Reader Service Card No. 2

Information Display

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BREAK the on-line plotting cost barrier!

Plot 3 million bytes on-line in 75 seconds with System/360

On-line plotting of up to 96 million digital bits of graphical or pictorial data is *now* available. Today's Central Processing Units can now generate inexpensive graphic hardcopy displays. *No additional core buffers or controllers are required.*

Geo Space Corporation's new DP-203 Digital Photographic Plotter uses an advanced electronic CRT camera for data projection. For example, an entire 40 inch by 60 inch image takes 75 seconds to plot, using an IBM System/360 Model 40 computer. One-pass alphameric annotation and pictorial image generation. Data bit resolution is .010 inch with a total plotting accuracy of ± ½ data bit.

DP-203 Plotters are currently available for IBM System/360 and 1130 computer systems. Other computer interfaces available soon. An ALPACA* software plotter program is furnished with the DP-203 Plotter.

Write for Geo Space Product Data Sheet 661.

**Trademark Geo Space Corp.*

GEO SPACE

COMPUTER PRODUCTS

GEO SPACE CORPORATION

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Circle Reader Service Card No. 5

Above: Unretouched photo of detail enlarged six times from High-Speed Digital Printer/Plotter.

(Not unless you're using the new, high-resolution Du Mont Type KC2515 CRT!)

With resolution of 0.0015 inches, our new KC2515 5-inch CRT represents the furthest advance yet made in man/machine interface.

Here's how we obtain it:

- *a deflection angle of only 26°*
  (which virtually eliminates deflection defocusing!)
- *the faceplate is optically finished to within 0.005 in.*
  (which minimizes parallax)
- *a new electron optical design, employing a specially designed electrostatic focus and magnetic deflection gun.*
- *a significant reduction in phosphor grain size.*

Such resolution enables systems designers to employ more sophisticated and more useful techniques of analog and digital presentation. Direct-photography applications are enhanced. So are those of flying-spot scanning.

Such advances in the cathode-ray tube are what you can expect from Du Mont, with our years of experience in design and manufacture. Call in a Du Mont sales engineer for *informed* applications assistance on the new KC2515, or on 4,000 *other* types of tubes in stock, or write for Technical Bulletin KC2515.

WORLD'S LEADING MANUFACTURER OF DISPLAY TUBES

FAIRCHILD

DU MONT ELECTRON TUBES

A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

CLIFTON, N.J.

Circle Reader Service Card No. 6

Volume 3 Number 3 May/June, 1966

Information Display

Journal of the Society for Information Display

ARTICLES

FEATURES

THE COVER

By depicting how fragmented segments retain the entire image of a photographed object, Artist Al Sollway of TRW Systems, Redondo Beach, Calif., illustrates the remarkable phenomenon of a hologram. Segmented image retention offering varied-angle views of the photographed object creates three-dimensional effect.

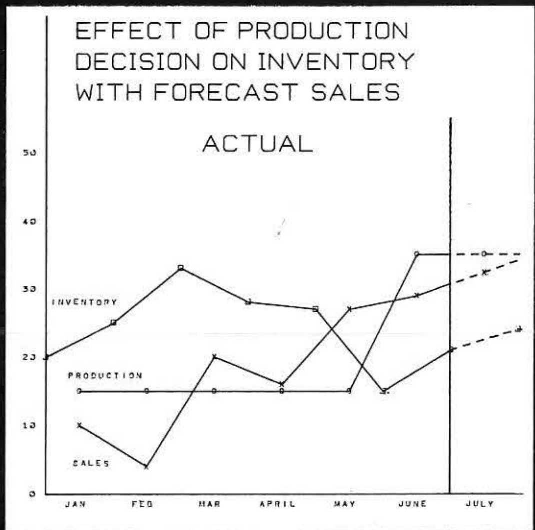
With the new **Milgo Digital Plotting System,** you output only the end points on lines up to 42" long — the plotter does the rest . . . with no deterioration of the plotter's normal dynamic accuracy. There is never a second tier subroutine to compute the length of a line! **Result:** reduced computer programming, reduced computer output time, reduced plotting time.

The **Milgo DPS-6** includes a choice of off-line readers, plus either a vertical or horizontal plotter. And the system provides for all standard digital inputs plus straight analog. It accepts magnetic tapes recorded in either gapped, gapless or long record format. An optional core storage buffer allows up to 10,800 bits between gaps.

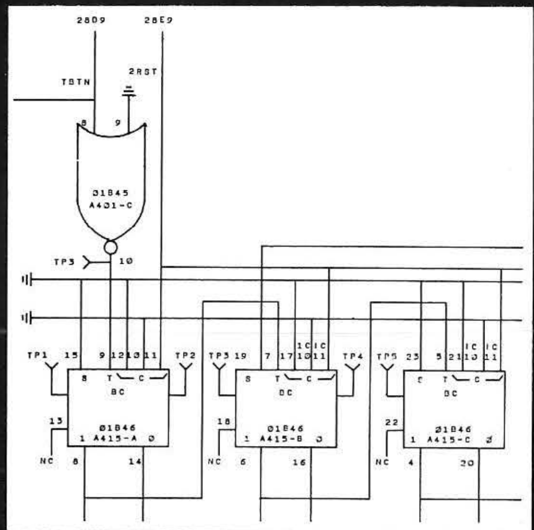
Send for a brochure-full of additional features on the Milgo DPS-6. Write or call **Milgo Electronic Corporation** 7620 N.W. 36th Avenue, Miami, Florida 33147. Phone 305-691-1220. TWX 305-696-4489.

milgo

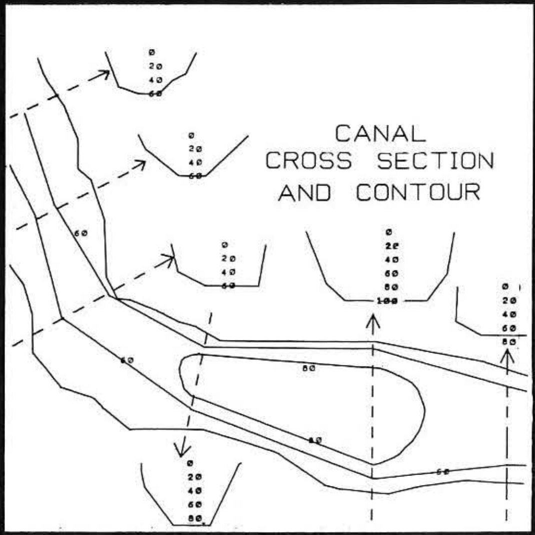
Now... save programming steps on every plot



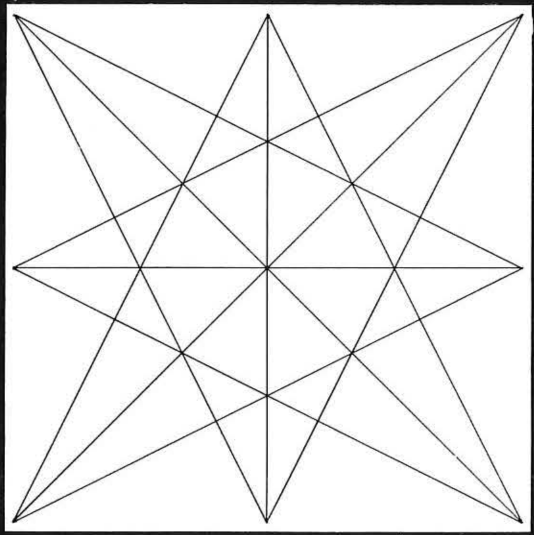
Before: 450 program steps. **Now:** 300



Before: 1000 program steps. **Now:** 700



Before: 600 program steps. **Now:** 500



Before: 54 program steps. **Now:** 14

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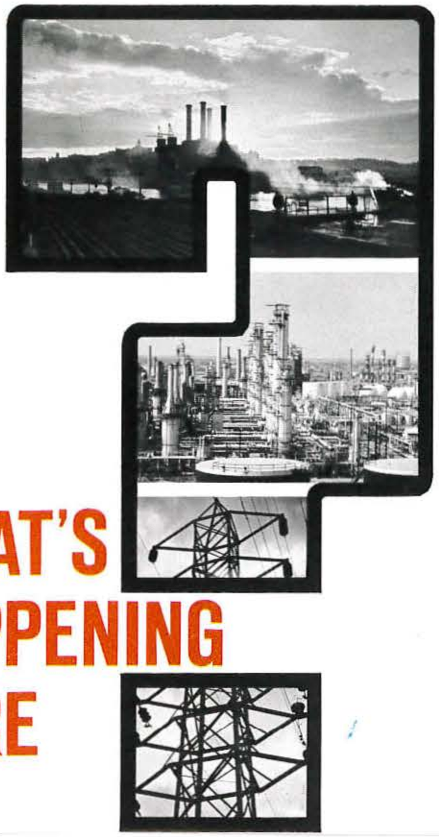


WHAT'S HAPPENING HERE

Northern States Power Company

The Mitre Corporation

Louisiana Power & Light Company

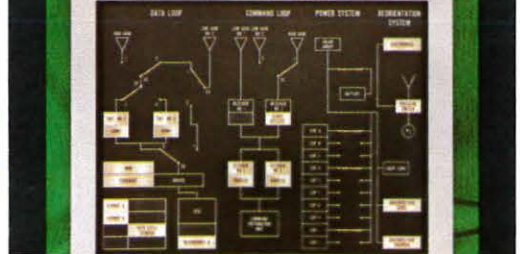
ASI Computer Division, Electro-Mechanical Research, Inc.

Univac Division, Sperry Rand Corporation

SEE THE ANSWERS DISPLAYED CLEARLY, CONCISELY, COLORFULLY WITH TEC-LITE

DATA • PANEL

DISPLAY SYSTEMS



SEE WHAT'S HAPPENING...

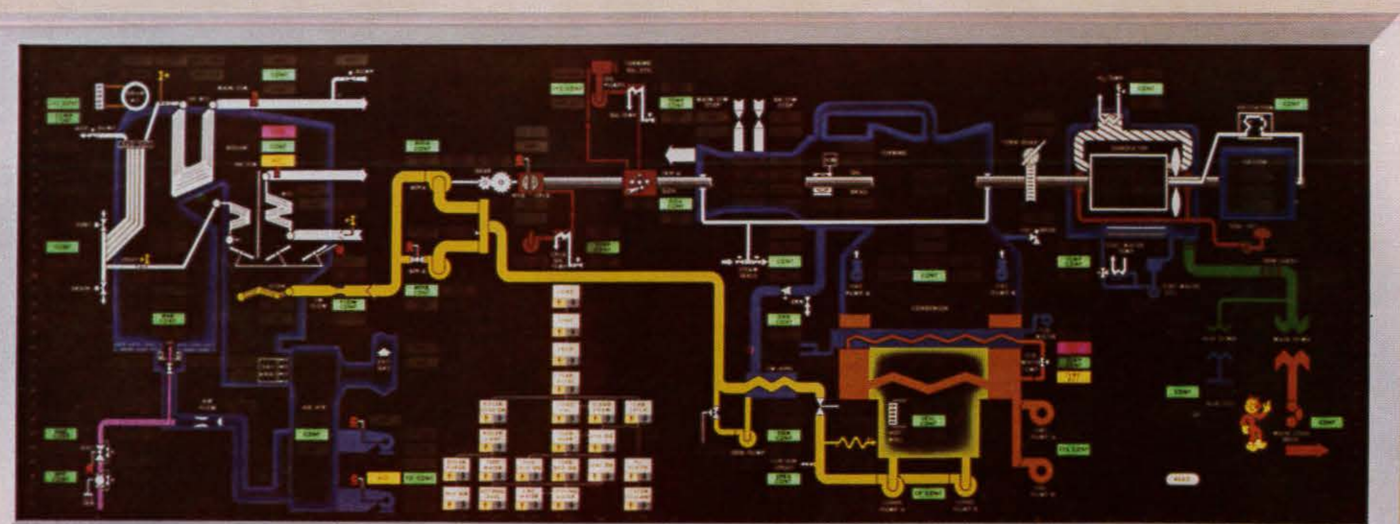
SOLVE MAN-MACHINE COMMUNICATION PROBLEMS

VERSATILITY

DATA • PANEL Display Systems convey information clearly and concisely with graphic versatility never before available. You get a new world of freedom in styling and panel layout . . . information on display with an entirely new look. Alpha-numeric messages and symbols are brilliantly visible behind planes of glare-free graphic gray glass. Only illuminated indications are visible. Operators are not confused by the visual presence of non-indicating indicators—they suffer less visual fatigue, make fewer errors.

Only the DATA • PANEL Display System concept can give you such latitude in selecting the size, shape, color and location of messages . . . and of overall dimensions. DATA • PANEL Display Systems can be custom designed as a complete electronic assembly ready to operate (via multi-pin connectors) from the signal voltages of any analog, digital or hybrid system. Switches, in a wide variety of types and actions can be mounted in the panels as an integral part of the DATA • PANEL Display System. Write for new, full story brochure, specifications and ordering information.

Here's proof of visual clarity: Designed for the GP-4 Digital Computer of General Precision Inc's. Link Group, this DATA • PANEL Display System has 469 separate message displays. But, the operator sees only the important illuminated messages. Permanently visible legends (lower half of panel) can be provided as desired. This panel also includes readouts and pushbuttons for alternate, momentary and interlock switches.



Here's proof of visual versatility: At Little Gypsy Power Plant of Louisiana Power & Light Company, all phases of a steam generating plant monitoring system are pictorially displayed on one large panel . . . from gas input, left, to main load breaker, right. Status reports, invisible when off, appear in color in boxes located at appropriate points on the panel. Pictorial displays and symbols are permanently visible.

TEC-LITE DATA • PANEL

DISPLAY SYSTEMS

TEC LITE
INDICATING DEVICES

Transistor Electronics Corporation

Box 6191 Minneapolis, Minnesota 55424

Circle 4 On Reader Service Card

More to it than meets the eye because it meets all your requirements!

The Sanders 720 COMMUNICATOR was designed by our engineers with primary emphasis on the users' needs. That's why the 720 COMMUNICATOR offers, at low cost, more standard working features than any comparable equipment.

Format, for example . . . with Sanders unique page concept, 30% more usable information is presented on the screen. You can position 1000 different characters anywhere on the exclusive 2000 space screen. When you call out reports, records or any data at all, you read the information just like typewritten copy on a page.

Versatility, for another . . . the 720 provides, as standard, full editing capabilities. You can add, delete, correct information anywhere on the screen — insert new letters, words, even sentences in the middle of a line or paragraph. The data already on the screen simply moves over making room for additions or closing the gap caused by deletions. There is no special training or programming required.

Superior techniques in microcircuitry make the Sanders 720 COMMUNICATOR Information Display a compact video/keyboard system that fits perfectly on a desk, table or counter-top. Clear, bright, solid letters, numerals and symbols, properly spaced, make every message easy to read under any lighting conditions.

The Sanders 720 COMMUNICATOR works directly with all modern high speed computers. You can install it in your present system or plan it into a future set-up and never worry about obsolescence.

There's more to it than meets the eye. For detailed information on Sanders 720 COMMUNICATOR and discussion of your requirements, call or write Sanders Associates, Inc., Commercial Display Marketing, Nashua, New Hampshire 03060, Area Code 603 883-3321, Extension 1545.

Sanders Associates, Inc. *

CREATING NEW DIRECTIONS IN ELECTRONICS

*T. M., Sanders Associates, Inc.

Circle Reader Service Card No. 11

Data Display Devices from Raytheon

New Raytheon Recording Storage Tubes extend your system capabilities

Two new miniature types, new high resolution tube added to Raytheon's broad line.

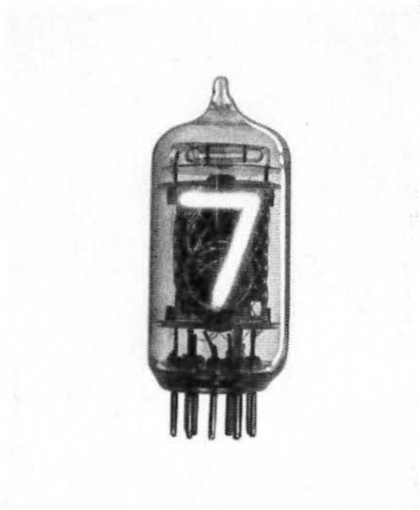
Raytheon's wide range of Recording Storage Tubes enable you to design additional capability into any system which stores and transfers electronic information. Applications include: scan conversion, stop motion, integration for signal-to-noise improvement, time delay or phase shift, correlation and slow-down video.

The new miniature types—Raytheon's CK1516 and CK1519—are designed for compact packaging, such as in airborne and space satellite applications. Both tubes provide high resolution and erase capability in a fraction of a second. The CK1521 is a new standard type featuring ultra-high resolution of 2500 TV lines and fast erasure in milliseconds.

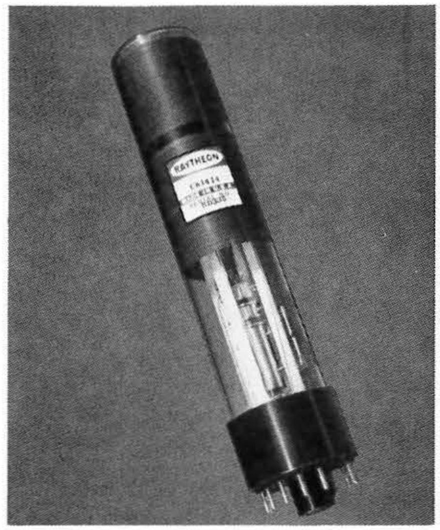
Raytheon Recording Storage Tubes are electronic input-output devices which feature: fast write, immediate and nondestructive read, long storage, high resolution, and fast erase. Information can be written and stored using sequential scan techniques or by random access writing. Erasure can be complete or selective. Dual and single gun types are available.

For more information or demonstrations, contact your Raytheon Regional Sales Office.

Raytheon Decade Counter Tubes are gas-filled, cold-cathode, glow discharge, bi-directional stepping devices, capable of operation at frequencies up to 100 kilocycles/sec. They provide both electrical and visual readout and are characterized by very long life, low current requirements, relatively few external components necessary for proper operation, and low operating temperature. These characteristics make them very useful as counters in such applications as radiation measuring equipment, timers, programmable counters and scalers, sorting apparatus, and many others. In these applications they can be used as scale-of-ten counters or as devices capable of operation at any desired preset scale.



Datavue* Side-View Tubes. New type CK8650, with numerals close to front, permits wide-angle viewing. These side-view, in-line visual readout tubes display singly numerals 0 through 9 or preselected symbols such as + and − signs. Their 5/8″ high characters are easily read from a distance of 30 feet. Less than $5 in 500 lots, they also cost less to use because the bezel and filter assembly can be eliminated and because their mating sockets are inexpensive.



New Symbolray* CRT. This new tube provides alphanumeric inputs for computer readout devices. The tube's 2″ target can be scanned electronically to select symbols, characters, and punctuation marks in sequence to form readout on a display tube. Designated type CK1414, this tube provides an economical method of generating characters for hard copy print-out or for cathode-ray display. Designs with 64 or 100 characters are available.

Datavue* End-View Tubes. These tubes are easily read in high ambient light—do **not** wash out like other displays. Erroneous readings due to segment failure do **not** occur because the characters are fully formed. Raytheon Datavue End-View Tubes fit existing sockets and conform to EIA ratings. Models include round (CK8421) and rectangular (CK8422). All are designed for ultra-long life—an expectancy of 200,000 hours or more in dynamic operation.

Send the reader service card for literature kit containing data sheets and catalogs on these products:

- Recording Storage Tubes
- Datastrobe Digital Readout Subsystem
- Datavue Numerical Indicator Tubes
- Cathode Ray Tubes
- Decade Counter Tubes

Or call your nearest Raytheon regional sales office, or write to *Raytheon Company, Components Division, 141 Spring Street, Lexington, Massachusetts 02173.*

*Trademark of Raytheon Company

RAYTHEON

Raytheon Components Division—A single source for Transistors/Diodes/Integrated Circuits/Industrial Tubes/Control Knobs/Panel Hardware/Circuit Modules/Display Devices.

Circle Reader Service Card No. 14

WANT A CHANCE TO DISPLAY YOUR TALENTS?

THE DATA SYSTEMS DIVISION OF LITTON INDUSTRIES IS CURRENTLY OFFERING UNIQUE OPPORTUNITIES FOR INFORMATION AND SYSTEMS DISPLAY ENGINEERS

WHAT YOU'LL BE DOING

You will be involved in the design and development of advanced microelectronic display systems utilizing multiple gun CRT techniques. Your assignments will include systems design, development of overall specifications, and advanced circuitry and electronics to meet the system requirements. For these projects we need graduate engineers with experience in high resolution cathode ray techniques, storage tube display equipment, scan convertor techniques and circuitry and application of microelectronic techniques to display equipment.

WHAT WE'VE DONE

The Data Systems Division is notable for the design and development of the highly mobile MTDS (Marine Tactical Data System) and the ATDS (Navy Airborne Tactical Data System) for the E2A aircraft. We are engaged in the following systems work: air defense, air traffic control, command and control, data processing and display, reconnaissance, space information and surveillance.

WHAT WE'RE DONING NOW

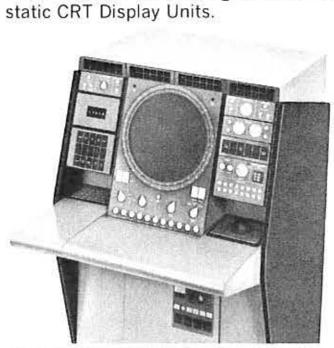
Typical of current DSD projects are these advancements:

LC-25, 25 Megacycle Radar Sweep Convertor

This unit accepts radar sweep data from a Radar Azimuth Convertor, symbol position data from a computer, and converts these for application to a display console. The high speed capability of the unit, utilizing primarily integrated circuits, permits display of high resolution sweeps at lower ranges than previously possible, with no switching disturbances. Current mode integrated circuits and Digital-to-Analog convertors are used.

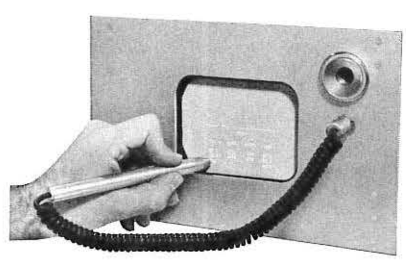
Advanced Display Console

The Advanced Display Console is a product of Litton's continuing program to develop a line of display modules, with which displays to suit the varied applications can be constructed. Emphasis has been placed on standardization of components, reduction in weight and power, and advanced display techniques. Modules designed and constructed include Radar Azimuth Convertor, Symbol Generators, Data Entry and Readout Units, and both electromagnetic and electrostatic CRT Display Units.



Litton's Entry Query Control Console

Designed as an interface unit for Litton's L-300 line of Microelectronic Computers, the EQCC replaces the keyboards and push-buttons usually found on Computer-control consoles. With the advantage of being programmable, it can be tailored to any type of operation or level of operator skill. It is completely self contained, with microelectron symbol generator and microelectron power supplies.



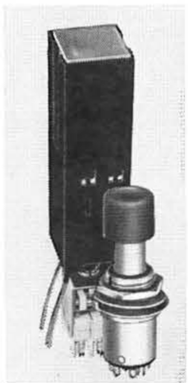
Information Display and Systems Display Engineers are invited to apply for immediate openings. Send your resume to P.O. Box 7601, Van Nuys, California or call L. D. Harrold at 781-8211, Ext. 2726.

LITTON INDUSTRIES DATA SYSTEMS DIVISION

— An Equal Opportunity Employer —

HOW CAN YOU BEAT ODDS LIKE THESE IN FINDING THE DISPLAY LIGHT YOU WANT?

You're looking for one very special display light or switchlite. Control Switch makes over 2,900...the broadest line you can tap at any one manufacturer. Check the items below for an idea of our diversification. Then . . . get a real reference file by sending for all the literature listed.



Goof-proof Switchlites

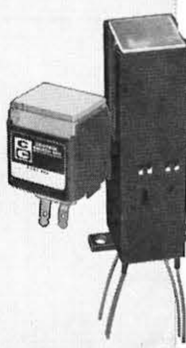
One to four lamps and colors. Four-lamp Quadlite* monitors up to nine conditions by combining flashing and steady lights. All re-lamping from front. Extra compact designs. Round lenses from ⅝" diam.; square units from ⅞". Over 1,800 styles in all.

See literature offer—Bulletin 54-A, 55-C, 63.

World's tiniest indicator lights

Type L10,500 (top), only .200" diam. L10,600 (center), only .383" diam. and L10,400 (bottom) only .219" diam. Operating life, 16,000 hours at 28 v; 60,000 hours at 5 v. All with 100% moisture-proof integral lamp and lens assembly molded to stainless steel assembly. Available with RFI radiation shielding. (See RFI item at right).

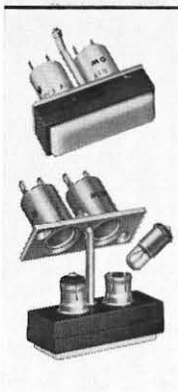
See literature offer—Bulletin 60



Multi-color indicator lights

From two to four lamps and colors. Four-lamp Quadlite* monitors up to nine conditions by combining flashing and steady lights. Twinlite* monitors two conditions simultaneously in different colors. All re-lamp from front. Choice of five colors, plus clear. Compact for tight, symmetrical stacking.

See literature offer—Catalog 120



See-able billboards

Over-sized. Two lamps for extra clarity. Operators get the message for sure. Captive lens housing can't be reversed or interchanged. Single or split lens. Split lens can be any of six colors, lighted independently. Choice of 6, 14, or 28 v incandescent or 115 v neon. Press-to-test types included.

See literature offer—Catalog 120

* Trademarks

Single lamp/color indicator lights

Virtually every size and type you could want. Subminiatures with lenses as small as 0.200" diam. and cases to fit holes as small as 13/32" diam. Types include edge-lit, water-tight, moisture-proof, back or front panel mounting, press-to-test and others . . . even lighted legends and numerical read-outs!

See literature offer—Catalog 120

RFI-shielded indicator lights

New! Especially designed to reduce RFI and EMI emission from filaments of lamps in otherwise well-shielded panels. Metal mesh in lens attenuates emissions in the important 0.15 to 1,000 mc range. Special conductive gasket provides electrical conductivity between shield and case in removable lens types. Standard sizes with 115 v neon lamps, subminiatures with long life 5 or 28 v incandescent lamps.

See literature offer—Bulletin 62

Human engineering advances for extra safety

Control Switch designers are deep into human engineering for the development of switch and light features that take the guesswork out of panel equipment operation. Advances include a broad range of toggle, pushbutton and special-actuator switches as well as switchlites and indicator lights. Write us about your specific needs.

Get this complete literature packet

You are welcome to any or all of the literature listed here. If you get the complete set, you'll have the handiest, most comprehensive light reference file available from any single source. Just check numbers on the Reader Service Card as shown for each item at the right.

Reader Service Card #	
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95	Twinlite Bulletin 55-C
96	Indicator Light Catalog 120
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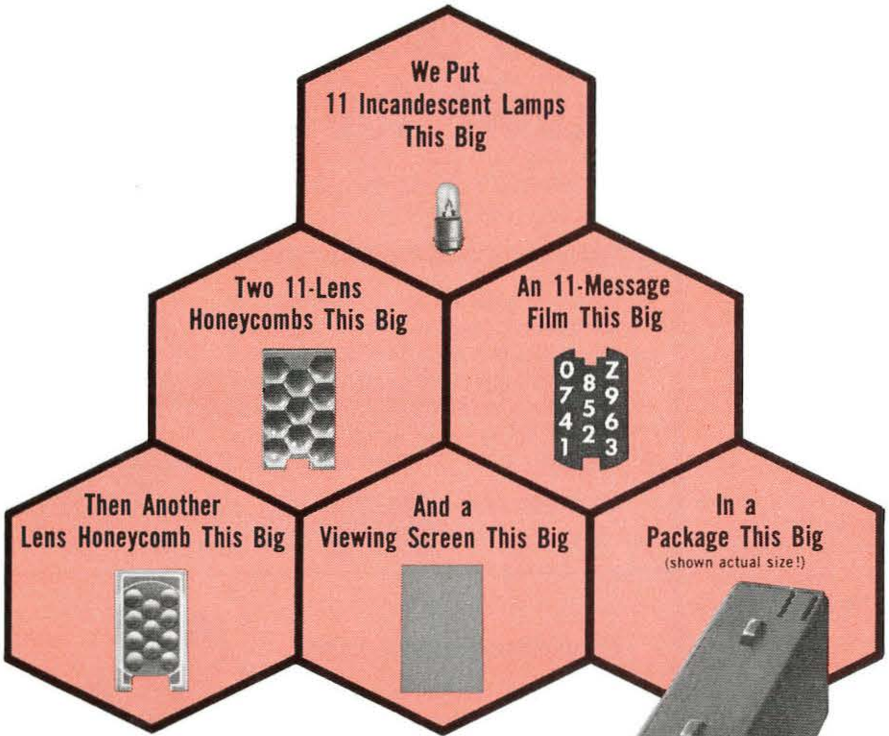

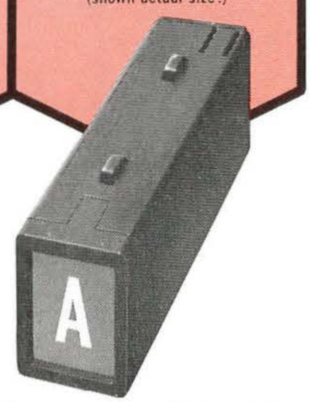

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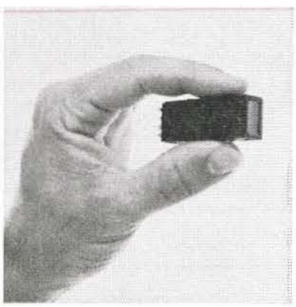

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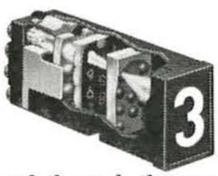

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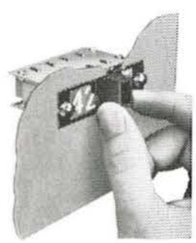

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EDITORIAL

COMING OF AGE

There comes a time in the development of any organism, entity or group, when it becomes "mature". This is the culmination of a number of successive developmental stages. During these various stages there is an accumulation of experience, knowledge and reasoning. Until the point of maturity is reached, there are the usual "growing pains," the search for identity, etc. Once maturity is reached, these aspects become submerged; a goal emerges.

As organizations go, the *Society for Information Display* has reached, if you will, "the age of reason". As an embryo organization, its main purpose was the exchange of ideas and information in the Display area. As any other newly organized group, its aims were somewhat subordinated to the social aspects. And, as with any organization, its destiny was one of two things: extinction or growth. *SID* grew.

With this growth there has emerged maturity. And with maturity, there must be a materialization of goals. *SID* comprises a number of professional individuals interested in the professional growth and integrity of the organization. We are *active* members of a recognized professional society which has achieved a measure of status. Our organizational behavior should reflect this status. The question arises: how?

In his editorial last month, Dr. Raymond E. Bernberg, *SID*'s Los Angeles Chapter Chairman, made several suggestions. He proposed, for instance, that there be no local chapter organization, but a strong national officer and committee organization. As an alternative, he suggested a strong local chapter organization with no national officers. Within these premises, he pointed out certain ramifications.

Whether or not we agree with Dr. Bernberg is, after all, of little import. What is important is that someone is thinking about *SID* constructively. More recently other groups have made additional suggestions. These are welcomed. A working group has been established and is already at work sifting out various recommendations.

Since we are currently comprised of both national and local groups, I feel there should be a greater effort toward establishing better communication between national headquarters and local and regional chapters. As an organization grows, the physical proximity to its various constituents becomes less than ideal. The national officers are widely dispersed; the need for effective communication assumes an increasing importance.

Communication must not only be established, but must be practiced in a timely manner. To this end it will be necessary to exploit further the concept of a National Executive Office and an Executive Secretary. Communication with "National" has been poor. We should consider the solution to this problem of paramount importance.

As I see it, "coming of age" means that the Society must operate independently of individuals. Continuity must be established through the use of well thought-out administrative procedures (our "formative" years taught us these) for handling routine business matters. Active participation of all the executive officers and board members is imperative for establishing these procedures.

I'm firmly convinced we can do it.

WILLIAM BETHKE
President
Society for Information Display

William P. Bethke is President of the Society for Information Display and a charter member of the ID Editorial Advisory Board. He has held posts of Northeast Regional Director of SID, and Chairman, SID Definitions and Standards Committee. For the past five years, he has been Director of Engineering at the Rome Air Development Center, Griffiss AFB, Rome, N.Y., where he has been employed since 1952. He joined RADC as Staff Engineer, Plans and Operations Office, following an affiliation as Project Engineer, Watson Laboratories, Eatontown, N.J.

Mr. Bethke is a native of Milwaukee, Wis., born April 22, 1920. He was awarded his BSEE from Marquette University in 1942 and did postgraduate work at Illinois Institute of Technology, then served with the U.S. Army from 1942 to 1946. He has authored several reports on ground navigational aids and displays techniques. In addition to his posts in SID, he is chairman of the RADC Scientific and Professional Committee; Chairman of the Vocational Advisory Board for the Rome, N.Y., Board of Education; and Chairman of the IEEE's Mohawk Valley Section.

Holography and Display

Summary

The development of "holography" or coherent optical recording is probably as revolutionary a development as that of the optical lens. It represents a refinement in the techniques for manipulating light waves equivalent to the advance the laser represents in the generation of light. Ultimately, the importance of holography to the field of information display depends, however, not upon its revolutionary character but upon whether it can provide solutions to the important problems in display systems. Only further development will determine the value of holography in solving these problems, but there can be no doubt that it represents, at least, a powerful new tool.

As with any new tool, the usefulness of holography to the designer of information display systems depends upon his knowledge of how it works, how to use it and what its limitations are. It is hoped that this article will help to answer these basic questions about the subject of holography and its potential uses in display applications. The background provided will help the reader to appreciate the significance of future developments and will provide a foundation for further study of the literature. In the interests of brevity no attempt has been made to discuss the rapidly expanding field of holographic applications to scientific measurement.

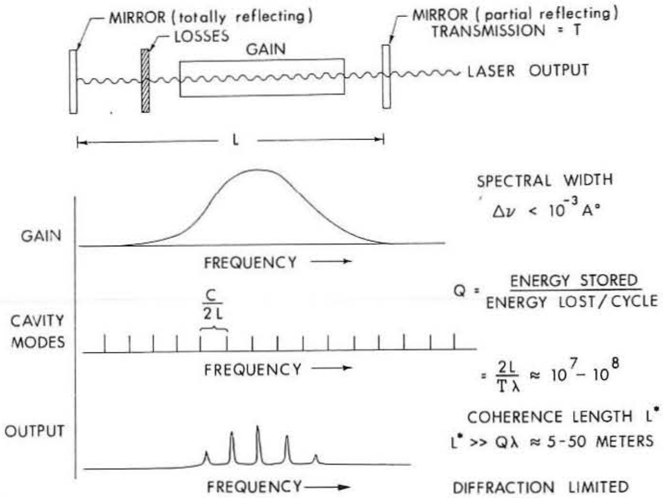


FIGURE 1: Schematic of a laser light source.

by Jerald V. Parker

Electro-Optical Systems, Inc.

Introduction

The pioneering work in holography was done by Gabor,[1,2] and Rodgers[3] in the early 1950's. Following their work very little progress toward practical application was made until the work of Leith and Upatnieks[5] in 1961. The single most important stimulus to holography was the discovery of the laser in 1961. Although the laser is not theoretically necessary to accomplish holography it is the only light source adequate for practical applications.

The importance of laser generated light is its amenability to precise manipulation and detection. Light which originates from conventional sources such as heated filaments and gaseous arcs is composed of many photons which were emitted at random times by atoms in the source. Each photon is emitted independently and the phases and frequencies are randomly distributed.

A process analoguous to this which occurs at much lower frequencies is the random radio energy emitted by lightning strokes. In this analogy the laser is equivalent to a modern radio transmitter which emits a continuous wave of energy at a very constant frequency. The utility of radio transmitters, as opposed to man made lightning bolts, for communications, ranging, detection and tracking is readily apparent. This is precisely the advantage which laser light enjoys over conventional light sources.

This characteristic of single frequency, stable emission is known as coherence in the optical domain. Since no source is perfectly coherent some small change in frequency always occurs as a function of time. If t_c is the average time for which the frequency is constant then a convenient measure of coherence is the "coherence length" or simply the coherence time multiplied by the speed of light:

$$l_c = c\, t_c.$$

How then is this desirable coherence obtained in the laser? Once again the analogy with radio is very close. A tuned circuit of very high quality is coupled to an amplifier with feedback in such a way that a very stable oscillation is ob-

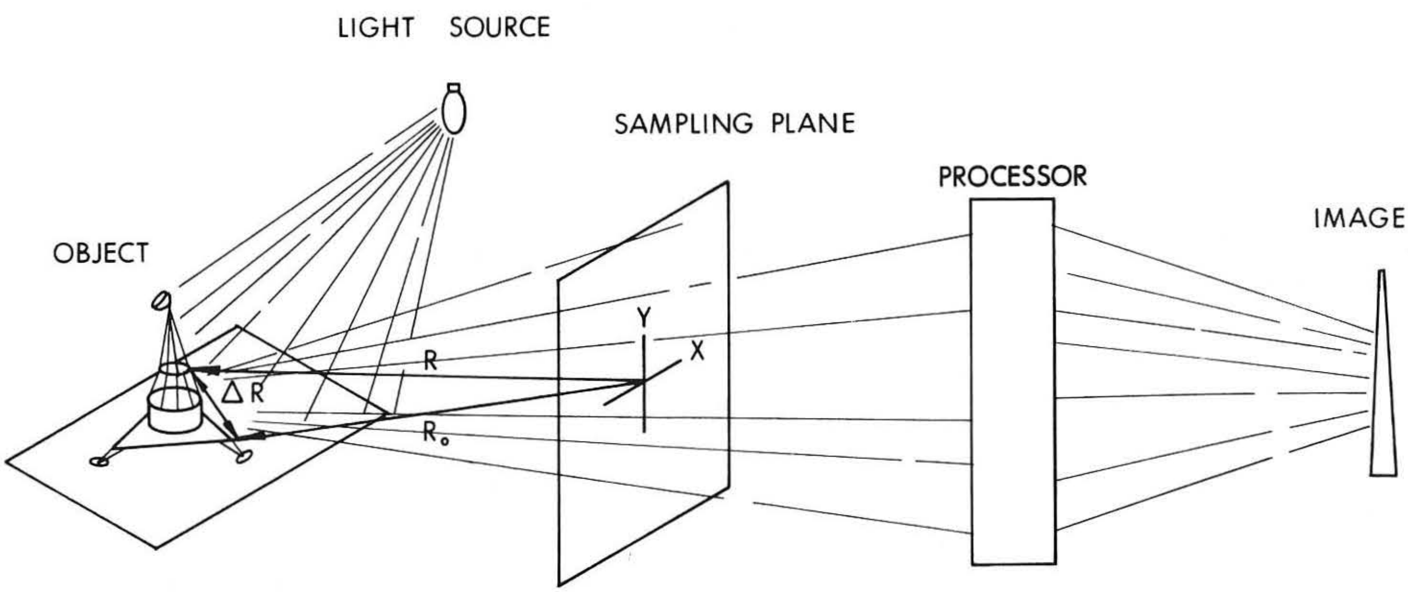


FIGURE 2: General imaging system for photographic recording.

tained in the tuned circuits. The realization of this process is illustrated in Figure 1.

Two mirrors of very high reflectance are carefully aligned so that a light wave which travels along their common axis is reflected repeatedly between between them without escaping from the cavity between mirrors. Assuming a reflectance of 99% the light wave will reflect many hundreds of times before it dies out. This constitutes the optical tuned circuit. The laser is then formed by placing within the cavity a medium which amplifies the light wave as it passes between the mirrors. If the gain of this amplifying medium is greater than the losses at the mirrors (1% in the preceed-

TABLE 1

	Watts	Watts/ Steradian	Coherence Length	Spectral Width
HeNe Laser	10^{-2}	2.50 X 10^{3}	10-100 Meters	10^{-3} Å
Mercury Lamp	10	1	10^{-2} - 10^{-3} Meters	.2 Å

ing example) then the wave will grow in amplitude rather than dying out. The output of the laser is the small amount of light which leaks through the partially reflecting mirror. The typical performance characteristics of a laser are compared with those of a mercury arc lamp in Table 1.

Coherent Imaging

The role which coherence plays in the holographic process is easily seen by contrasting coherent light imaging with ordinary optical imaging. Figure 2 shows a general imaging system for storing images on photographic film. The source of light may have any degree of coherence. The processor "black box" is any device needed to ensure recording of a usable image of the object. In this connection *usable image* means any pattern from which the form of the object can be made visible to the eye at a later time.

Consider first the case of incoherent light. The light which is scattered by the object onto the photographic plate must all pass through the sampling plane (See Figure 2). It is apparent, therefore, that a knowledge of the amplitude, $E(S_x, S_y, t)$, of the light wave on S is sufficient to completely specify the object. However, if the photographic film is placed in the plane S it will record no information other than gross reflectivity of the object. The reason for this is that the information is not contained in the time average intensity

$$I(S_x, S_y) = \frac{I}{T} \int_o^T E(S_x, S_y, t) \; E^*(S_x, S_y, t)dt \qquad (1)$$

but rather in the correlation function

$$I_2 (S_x, s_y, S_x', S_y', \tau) = \frac{I}{T} \int_o^T E(S_x, S_y, t) \, E^*(S_x', S_y', \tau\text{-}t)dt \qquad (2)$$

Since the film records only the intensity function it fails to preserve the information concerning the object. Conventional imaging solves this problem by using for the processor, a lens. A lens is a special type of correlator which performs a simple subclass of the general correlation described by Eq. 2. This special correlation produces a point of light in the image plane for every point of light which is emitting in the object plane. The photographic film is able to record this intensity pattern once the correlation has been done. Note, however, that the lens only performs a special type of correlation correctly, that is, between points lying in the image and object plane. Hence the full three-dimensional nature of the object is not recorded.

Consider now the use of a coherent light source for illumination. If the coherence length l_c of the laser is longer than the difference in path length travelled by photons reflected from different points on the object then all of the light waves arriving at point (S_x, S_y) will have the same frequency and a stationary interference pattern will be formed. The electric vector is thus independent of time.

$$E_c(S_x, S_y, t) = E_c(S_x, S_y) \qquad (3)$$

Once again the film records the intensity pattern given by equation 1.

$$I(S_x, S_y) = E_c(S_x, S_y) \; E_c^*(S_x, S_y) \qquad (4)$$

The correlation function is now greatly simplified however,

$$I_2(S_x, S_y, S_x', S_y', \tau) = E(S_x, S_y)E^*(S_x', S_y') \qquad (5)$$

and is independent of τ. A moment's consideration of equations 4 and 5 will show that it is still not possible to obtain the function I_2 from the function I because the phase information contained in the complex E's has been lost. Once again a processor is needed to make recording feasible. Various schemes of differing complexity have been suggested (Ref. 4) for recording or replacing the missing phase information. It was the suggestion and subsequent demonstration of the principle of the reference wave for recording phase by Leith and Upatnieks,[5] which resulted directly in the current resurgence of interest in holography.

A mathematical exposition of the holographic process will make the operation of the reference wave clear. It is sufficient to say here that this reference wave allows the phase of the electric vectors E_c to be recorded. With this information, in addition to the intensity I, it is apparent that the information represented by the function I_2 has been recorded. This recording is a hologram. Note that this hologram preserves the entire function I_2 and not a special part of I_2. Note also that the hologram is not a conventional point by point image of the object so that the record information cannot be seen by examining the photographic plate in ordinary light. The technique for obtaining a visually observable image of the object is discussed in the next section.

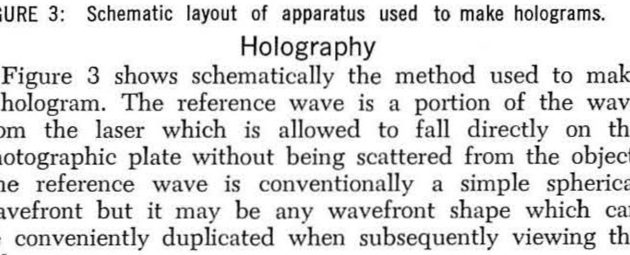


FIGURE 3: Schematic layout of apparatus used to make holograms.

Holography

Figure 3 shows schematically the method used to make a hologram. The reference wave is a portion of the wave from the laser which is allowed to fall directly on the photographic plate without being scattered from the object. The reference wave is conventionally a simple spherical wavefront but it may be any wavefront shape which can be conveniently duplicated when subsequently viewing the hologram.

The electric vector of the light wave from the object can be written as the product of an amplitude and phase term.

$$A_1(x, y)_e i[\omega t + \phi_1(x,y)] \qquad (6)$$

Similarly, the reference wave is

$$A_2(x,y)_e i[\omega t + \phi_2(x,y)] \qquad (7)$$

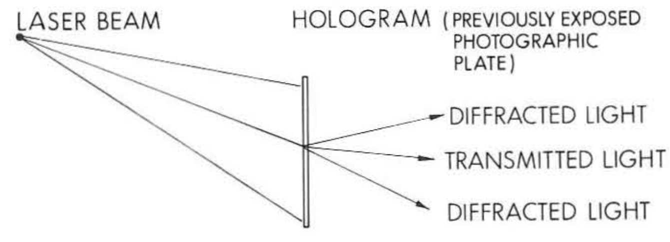
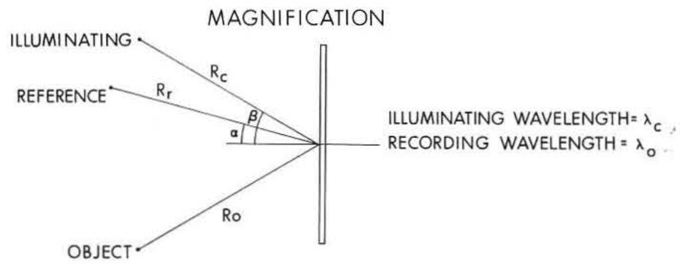


FIGURE 4: Reconstructing holographic images.



ANGULAR MAGNIFICATION = $M_{ang} = \pm \frac{\lambda_c}{\lambda_o}$

LATERAL MAGNIFICATION = $M_{lat} = \left(1 + \frac{\lambda_o}{\lambda_c}\frac{R_o}{R_c} - \frac{R_o}{R_r}\right)^{-1}$ (VIRTUAL IMAGE)

$\left(1 - \frac{\lambda_o}{\lambda_c}\frac{R_o}{R_c} - \frac{R_o}{R_r}\right)^{-1}$ (REAL IMAGE)

LONGITUDINAL MAGNIFICATION = $-\frac{\lambda_o}{\lambda_c} M_{lat}^2$

FIGURE 5: Magnification resulting from changes in wavelength and wavefront curvature.

where x and y are Cartesian coordinates in the plane of the film. The intensity recorded by the film is then

$$I(x,y) = \left[A_1 e^{i\phi_1} + A_2 e^{i\phi_2}\right]\left[A_1 e^{i\phi_1} + A_2 e^{i\phi_2}\right]^* \quad (8)$$

$$= A_1^2 + A_2^2 + 2A_1A_2 \cos\left[\phi_1(x,y) - \phi_2(x,y)\right] \quad (9)$$

or equivalently

$$I(x,y) = A_1^2 + A_2^2 + A_1A_2 e^{i(\phi_1 - \phi_2)} + A_1A_2 e^{i(\phi_2 - \phi_1)} \quad (10)$$

Equation 10 represents the result of the recording process which was described in the preceeding section. It is obvious that both the ampltitude A_1 and the phase ϕ_1 have been recorded. Since A_2 and ϕ_2 are known functions it should be possible to recover an image of the object. The procedure for accomplishing this is illustrated in Figure 4.

The photographic plate which was exposed in the apparatus of Figure 3 is developed to make it ready for viewing. The resulting hologram is viewed as shown in Figure 4. A beam of laser light is projected through the hologram. Viewed from the other side a completely three-dimensional image of the original object is seen. This reconstruction is easily explained.

Assuming that the photographic recording medium is linear in intensity (ie$\gamma = 2$)*1 the transmitted laser beam is

ABERRATION

	CONDITION WHICH ELIMINATE EACH ABERRATION	
	GENERAL CASE	PLANE WAVES $R_r = R_c = \infty$
1. SPHERICAL ABERRATION	1. $R_r = R_o$	1. $\lambda_o = \lambda_c$
2. COMA	2. $R_r = R_o$ $R_c = \pm R_o$	2. $\lambda_o = \lambda_c$ $\tan\beta = -\frac{\lambda_c}{\lambda_o}\tan\alpha$
3. ASTIGMATISM	3. $\tan\beta = -\frac{\lambda_c}{\lambda_o}\tan\alpha$ $R_c = -\frac{\lambda_c}{\lambda_o}R_o$	3. $\lambda_o = \lambda_c$ $\tan\beta = -\frac{\lambda_c}{\lambda_o}\tan\alpha$
4. FIELD CURVATURE	4. SAME AS 3	4. SAME AS 3 ABOVE
5. DISTORTION	5. $\lambda_o = \lambda_c$ $\tan\beta = -\frac{\lambda_c}{\lambda_o}\tan\alpha$	5. SAME AS 3 ABOVE

FIGURE 6:

modulated by the intensity pattern of Equation 10. Describing the reconstruction beam as

$$A_3(x,y)e^{i\phi_3(x,y)} \quad (11)$$

the resulting transmitted intensity is proportional to the product of Eqns. 10 and 11

$$I_{Transmitted} = \left.(A_1^2 + A_2^2)e^{i\phi_3}\right\} \text{Transmitted Directly}$$

$$\left.\begin{array}{l} + A_1A_2A_3 e^{i(\phi_1 - \phi_2 + \phi_3)} \\ + A_1A_2A_3 e^{i(\phi_2 - \phi_1 + \phi_3)} \end{array}\right\} \text{Diffracted} \quad (12)$$

This transmitted intensity is seen to be composed of three terms. One has the phase function of the reconstruction beam which indicates that it is the laser beam transmitted directly through the film. The phase factors of the other two terms are modified however. They represent waves with different radii of curvature and direction of propagation than the reconstructoin beam.

Since the reference beam (No. 2) was chosen to be a simple wavefront it is possible to duplicate it in the reconstruction apparatus. Assume then that $\phi_2(x, y) = \phi_3(x, y)$. Then Eq. 12 becomes

$$I_{Transmitted} = (A_1^2 + A_2^2)e^{i\phi_2} + A_1A_2A_3 e^{i\phi_1} + A_1A_2A_3 e^{i(2\phi_2 - \phi_1)} \quad (13)$$

The second term of Equation 13 differs from the original object wave only by a multiplicative constant, A_2A_3. Therefore, for this special choice of reference wave one of the diffracted waves is an exact reproduction of the original light wave from the object. It is a virtual image which is viewed by looking through the hologram. The full three dimensional detail and parallox are preserved. If a large enough angle is used between the reference beam and the object beam in making the hologram there is no overlap of the two undesirable images into the reconstructed image.

It is apparent from Equation 12 that another condition exists which causes a reconstructed image to be formed. That is, $\phi_3 = -\phi_2$, in which case the relevant term is

$$A_1A_2A_3 e^{-i\phi_1} \quad (14)$$

*1 When $\gamma \neq 2$ the resulting reconstruction contains spurious images. These images occur at large angles to the desired image and are usually not noticeable.

Notice that this is not quite the original form due to the change in sign of the exponent. Where the original expression represented light scattered from the object, this expression represents waves converging toward the object. Hence this is a real image which can be seen in front of the hologram plate as if suspended in space. This image is difficult to view hovever, as it is "psuedoscopic" i.e., depth is reversed. Rotz and Friesem[6] have recently developed a technique to eliminate this effect.

Holographic Images

The proceeding analysis of holographic recording and reconstruction has been quite general. In particular it has been shown that the only requirement for reconstruction of a faithful image is that the reference and reconstruction beam be identical.*2 In practice, of course, the reference wave is usually a simple spherical wave. Specializing to this case of spherical reference wave and reconstruction wave it is possible to extend the analysis to the case of $\phi_2 \neq \pm \phi_3$. Figure 5 shows an elementary hologram recording and reconstruction situation. The object is a point located at distance R_o while the reference and illuminating beams are spherical wave originating from points R_r and R_c. The final image is affected also by any change in wavelength between recording and reconstruction. Denoting these wavelengths by λ_o and λ_c respectively and performing a first order analysis of the image magnification[7, 8] results in the relations shown in Figure 5. Note that the relation between longitudinal and latural magnification is not that of a conventional optical system but is dependent upon wavelengh. These magnifications depend only upon the distances R_o, R_r and R_c and not upon the angle α and β. The only result of varying β (to first order) is an angular displacement of the image.

The relations of Figure 5, being derived from linearized equations do not indicate the aberrations which results from changes in λ_c and R_c. These aberrations can be quite severe for large ratios of $\frac{\lambda_c}{\lambda_o}$ or $\frac{R_c}{R_r}$. Although it is possible to utilize combinations of λ_c and R_c to eliminate certain aberrations there is no condition which yields aberration free images except $\lambda_o = \lambda_c$ and $R_c = R_r$. The exact conditions which eliminate each aberration are shown in Figure 6.[7, 8] Note in particular the conflict between the condition required for aberrations 1, 2 and 3 in the general case.

Applications

An oft heard dialogue among workers in holography goes something like this. "It's marvelous! It's fantastic! It has tremendous potential! What can we do with it?" This question has begun to take on a particularly urgent character as the time and money expended begin to appear on balance sheets across the country. In the past year the scientific applications of holography have begun to bear fruit. Techniques have been developed using holography for micromeasurement, particle size determination, 3-dimensional shock wave photography and numerous others. The pay-off in the field of information storage and display has been slow in coming, however.

This is somewhat surprising. The most striking feature of a hologram is its visual effect of reality. The reaction of most people upon first viewing hologram is to speculate upon the revolution it is going to cause in graphic display. Why has it failed so far to create such a revolution? This question could be answered quite easily by anyone connected with the various ill-fated 3-D movie ventures. Most of the visual impressions which a person receives come from objects which are remote enough that steroptic vision is completely inactive. Depth is judged by visual clues such as relative size and motion. Wide field of view and high quality images are much more desirable than the 3-D effect.

The lesson which is being learned is simple. One must seek applications which need the unique features of holography rather than trying to adapt holography to tasks it does not fit. Holography is intrinsically not adapted to mass audience display. It is most useful for individual or small group presentation of information which must be viewed at close proximity. At first this may seem to drastically reduce the potentials of holography but that is not the case. Two features of holography are the key to large potential markets.

1. A hologram can replace any object and stand up to the most exacting visual examination with cameras, magnifying glass or microscopes.
2. It is theoretically possible to calculate the pattern required on a hologram to produce any three-dimensional image whether such an object exists or not.

For the sake of convenience applications which make use of the first property will be called "information storage" applications while those that make use of the second property will be called "information display" applications. While this division appears rather arbitrary it provides a convenient basis for discussing the present limitations in holographic display.

Holographic Information Storage

Since the field of holographic display is undeveloped it is impossible to present details of actual applications. At this time the best that can be done is to present a spectrum of possible applications and to discuss the progress which is made toward overcoming those factors which presently limit the exploitation of holography.

1. Holograms are inherently high resolution recordings. The potential exists for storing a large quantity of printed information as is done with present microfiche techniques. Multiple holographic storage is accomplished by making multiple exposures while rotating the photographic plate a small amount between each exposure. The advantages to be gained by this process are improved image quality and insensitivity of the recording to minor damage from nicks and scratches. This is a direct result of the ability of a hologram to store information over its whole surface so that minor irregularities such as grain and defects do not cause visible defects in the image.

An additional factor which might be advantageous is that indexing is accomplished by angular position rather than linear position.

The major drawback is the theoretical loss of resolution of 2X under that of conventional imaging which results from the inability of photographic film to record absolute phase. This theoretical lack in resolution may be more than compensated by the aforementioned improvement in image quality.

The principle factor limiting exploitation of this technique is lack of laboratory evaluation of its practicality.

2. A holographic image can be photographed as if it were the original object and can be subjected to accurate measurements with optical instruments. It is possible that one or two holograms of a complex object (e.g., an automotive design model) could replace the many photographs usually taken from close range, a long range, and different perspectives plus the detailed measurements which are normally considered necessary for a complete record. The advantage in reduced storage requirements is obvious. There are two principle limitations.

One is the limited size of objects which can presently be holographed. The total extent of an object to be holographed cannot greatly exceed the coherence length of the laser light used in making the hologram. It was pointed out earlier that lasers possess very long coherence lengths (10-100 feet) compared to conventional light sources. This theo-

*2 This fact immediately suggests an intriguing technique for encoding information by using a special distorted reference wave. The resulting hologram would be meaningful only to those with identical beam distorters.

retical coherence length is greatly reduced in most lasers, however, by failure to restrict the laser to operation at only a single frequency. Typical gas lasers which oscillate at 20-30 closely spaced frequencies have a coherence length of only 1-2 feet. Work is presently under way at many laboratories on methods of controlling this effect.

The second major limitation is stability. Because the hologram records the interference pattern of two light beams, it is crucial that the object, hologram and associated mirrors be stable to less than one-quarter wavelength throughout the exposure. Present gas lasers with exposure times of 1 sec. to 1 min. allow only objects of rigid material to be holographed. Presently under development are very high energy pulsed lasers which can take holograms in 10^{-6} - 10^{-8} seconds[9]. A year or two will probably be required before lasers of this type possess the coherence length necessary for practical holographic recording.

3. As an educational and training aid holography has great potential whenever the learning process can be made easier by three-dimensional presentation. Examples ar numerous; training assembly workers and repair personnel who work on complex assemblies, training surgeons in new techniques, teaching differential geometry in non-cartesian coordinate systems. In all these cases the presentation of three-dimensional data greatly facilitates visualization and learning. Nor is it necessary that these training aids be restricted to still pictures. It is entirely feasible to make 3-dimensional motion pictures using holography.

The principle limitations are: only poor ability to copy holograms for mass production, lack of adequate color holograms, and the present necessity for making holographic movies by the time lapse technique. Experimental investigations of these problems are being carried out. The most striking recent success has been in color rendition.[10, 11] High quality 3-dimensional holograms have been obtained in two colors (red and blue) with every expectation that the technique will be applicable to three colors also. It is expected that extension of the pulsed laser development to pulse rates in excess of the visual flicker perception rate will eventually lead to true holographic movies.

4. The field of advertising display is a natural candidate for holography. This is particularly true when the object being advertised is too valuable or too scarce to allow distribution of samples. The major limitation is an economic one. The lasers needed to reproduce the image are too expensive for common use. Recent work by A. A. Friesem[11] has resulted in a hologram which can reproduce an acceptable image using ordinary noncoherent light sources. This special hologram acts not only as an image storage medium but also as a narrow band filter to produce the monochromatic light necessary for viewing.

Holographic Information Display

For the purposes of this discussion "information display" will be understood to mean the construction of a three-dimensional display from information sent to the display device by nonoptical means. Most commonly this would be by some electrical signal. The potential applications of such a technique are numerous and exciting. Some obvious examples are: presentation of positional data during space rendezvous; three-dimensional graphical output of data from electronic calculators; computer assisted design of structures and many others. An equally impressive list of challenging technical problems can also be drawn up, however, which must be solved if these applications are to be realized. In order to delineate these problems consider the following display situations.

1. Space rendezvous. Incoming data from Doppler radar and optical tracking and ranging devices. The incoming data is processed to obtain range and velocity for each object.

Assume the display requires a minimum of 20 bits to identify and label each target with velocity. A reasonable number of objects in near space, for example 10, will yield 200 points to be plotted. If the display is to possess reasonable fidelity it will have about 10^4 elements resolution on each axis, which requires 10^8 points; it is necessary to sum the phase of the coherent light from each of the 200 points or a total of 2×10^{10} additions in a reasonable display time of ½ to 1 second. The device which does this will be called the "phase calculator". The phase calculator will probably be a multiple channel analog device because the sheer volume of calculations precludes a digital device.

Once the information has been processed by the phase calculator it must be recorded upon a hologram plate. This recording can consist of either modulating the amplitude or phase transmission of a uniform transparent plate. The resolution required is 500-1000 line pairs per mm with a field of typically 10 X 10cm. The recording medium must be completely erasable within a fraction of a second. The device will be called the "writing transducer". Needless to say, neither of these devices exists today. The "writing transducer" is nearer to realization with the development of photochromatic glass but considerable development will be required to obtain the required resolution and response time.

A second display situation which has been widely discussed is:

2. Three-dimensional television. With television the need for a "phase calculator" disappears. The required phases are measured by simply bouncing the coherent light off the object and measuring the scattered amplitude.

This introduces the first requirement: a camera tube, whose resolution is 10 times higher than the best available today. The information from this camera must then be transmitted to a receiver. The bandwidth required is 10^8 bits/$\frac{1}{30}$ sec or $2 \times 10^9 H_z$ unless some bandwidth compression is accomplished. The possibility for bandwidth compression is great as much of the $3 \times 10^9 H_z$ information is redundant. This signal is not in such a form, however, that this redundant information is easily identified.

After reception of the transmitted signal, it must again be written onto a transparent plate for reconstruction.

The future of real time holographic display is seen to depend strongly upon the development of several devices or equivalent concepts which are beyond the present state of the art.

Summary

It has been the purpose of this paper to present the reader with a basic understanding of the holographic process, its potential uses and its limitations. The special section on display applications attempted to illustrate the impact which holography might have and to stimulate ideas for further development among the many workers in the display field. The references quoted throughout the paper represent a relatively complete survey of the holographic research which has bearing upon display applications. Those interested in perusing work in holography will find this reference list a useful starting place.

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Summary

A survey and analysis of methods of optical deflection of light beams is presented in this paper. Coherent light beams could be used for small or large screen displays similar to the electron beam magnetic or electrostatic deflection, if light beam deflection methods are available with adequate deflection angle. The methods discussed in this paper are known and available in experimental stages. However, most of them are not yet practical for display applications because of the presently available small visible range laser output energy and yet inadequate deflection angle of the systems. Further developments in both fields could lead to practical systems. The scanning systems discussed include electro-optical and mechanical solutions.

Scanning Techniques With Light Beams

by G. T. Nagy
Nortronics Division
Northrop Corp.

Introduction

On the cathode ray tube (CRT) faceplate a visible image is formed by the deflected and scanned electron beam from the CRT's electron gun.

Modulated or unmodulated narrow light beam from collimated monochromatic or spatially coherent laser sources could produce similar displays with special electro-optical methods of light beam deflection and scanning. There are applications in visual communications where the sequential formation of image elements with deflected and scanned light beams is the most advantageous, or possibly the only imaging technique available.

This paper surveys the presently known light beam scanning methods and discusses the most feasible representative types for various applications including facsimile scanning, large screen projection, information storage and retrieval, optical radar, underwater illumination and viewing "sync-scan" techniques, etc.

Light beam scanning methods can be divided into two categories. The first utilizes the electrically induced change in the scanning medium's optical properties. The second method scans the beam while changing the mechanical properties of the material. These two methods will be discussed separately because of their differing fundamental principles of operation and their limitations. The first method will be referred to as the electro-optical, the second the electromechanical, light beam scanning method.

Raster Displays

There are two methods for producing pictorial displays on a screen introducing millions of bits of information. One is the simultaneous method, or projection of photographic transparencies; the other is the sequential method, with electron or light beam scanning forming a raster display on the screen. An image forming scan pattern, known as a raster, is composed of a large number of equally spaced straight or curved lines.

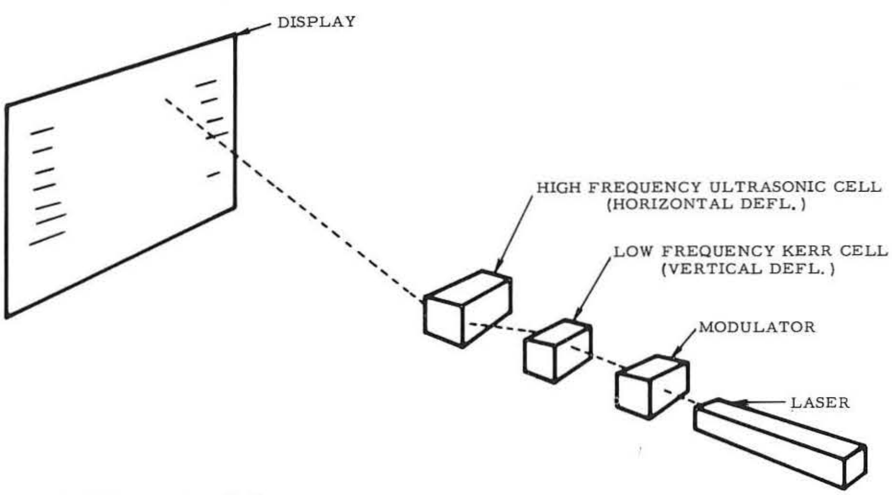


FIGURE 1: TV type raster display.

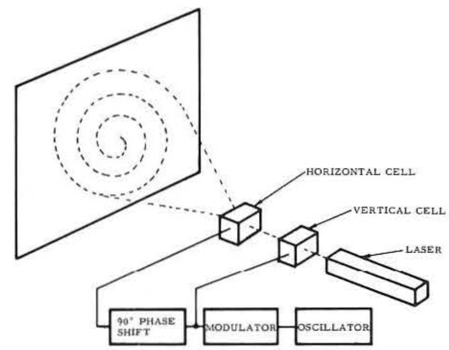


FIGURE 2: Spiral scan display.

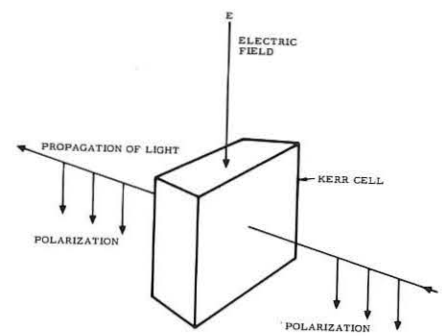


FIGURE 3: Kerr effect.

A TV type raster can be formed with two dimensional deflection of the light beam. As illustrated in Figure 1, the deflections of two cells should be perpendicular to each other and the driving frequencies should correspond to the horizontal and vertical scanning frequencies. The horizontal deflection in this case could be an ultrasonic high frequency cell and the vertical deflection a Kerr type low frequency cell.

A circular, or spiral type raster can be produced if both cells are driven at the same frequencies but with a 90-degree phase shift between them and with amplitude modulation (Figure 2).

The radius of the scanning circle in modulated with low frequency.

Electro-Optical Scanning

There are several electro-optical scanning methods and they are common in that the scanning takes place while a device introduces a controlled distortion into the phase front of a propagating light wave. If the properties of a distorting medium can be electrically controlled, this distortion can be introduced continuously with refraction or reflection or in discrete elements through diffraction or interference.

The most commonly known systems are the Pockel and the Kerr effects in solid or liquids, which control the refractive index of such materials. The Pockel effect is a change in the refractive index proportional with the applied voltage. The Kerr effect changes with the square of the applied voltage. Figure 3 shows a schematic illustration of the Kerr effect where an electrical field is introduced to the material perpendicular to the direction of the light propagation.

The function of the index of refraction of the material and the electrical field are

$$n = n_o + K E^2 \qquad (1)$$

where K is the Kerr constant of the material. The direction of the polarization is parallel to the applied electrical field. Deflection systems utilizing the Kerr effect are discussed in the following two scanning methods.

Deflection with Prism

The Kerr effect utilizing the optical refraction of prism, where the material of the prism has a large Kerr constant K, is shown in Figure 4. The deflection angle of the light beam varies if the electrical field E applied perpendicular to the ABC plane is varied. Angular deflection achieved in this way can be analyzed by applying the Snell law:

$$\sin \phi_r = n \sin (\alpha - \delta_r) \qquad (2)$$

$$\sin \delta_i = n \sin \delta_r \qquad (3)$$

where all angles are with respect to the prism plane normals (Figures 4). The light beam scanning with the Kerr prism takes place when the refractive index n of the prism material varies due to the electrical field E variation and causes a change in the deflection angle $d\phi_r$. Thus $d\phi_r$ could be calculated by the differentiation of equations 2 and 3.

$$d\phi_r = \frac{\sin \alpha}{\cos\phi_r \cos \delta_r} dn \qquad (4)$$

This is the deviation angle which can be obtained with the dn refraction variation.

The resolution during the scan can be expressed by the number of scanned resolution elements or by the best angular resolution obtainable. This latter is the diffraction limited beam width from the aperture length $L \cos \phi_r$, shown in Figure 4. The minimum angular width for a light beam with λ free space wavelength is approximately

$$\Delta\phi = \frac{\lambda}{L \cos \phi_r} \qquad (5)$$

The maximum $d\phi_r/\Delta\phi$ ratio is a measure of the scanner performance related to resolution

$$\frac{d\phi_r}{\Delta\phi} = \frac{L \sin \alpha \cos\phi_r}{\lambda \cos \delta_r \cos\phi_r} dn \quad (6)$$

The $d\phi_r/\Delta\phi$ ratio is a measure of the resolution could be a maximum if the angle α of the prism and the angle ϕ_r are also maximum when selected. Values should be selected to the largest value, but less than the critical angle. This restriction could be expressed with the value of ϕ_i, where $n \sin \phi_i \leqq 1$ or $\cos \phi_i \leqq \sqrt{n^2 - 1/n}$ and for α where $\alpha \leqq 2\ (\phi_i)$ max (see Appendix C).

With this restriction the $(d\phi_r/\Delta\phi)$ max

$$\left(\frac{d\phi_r}{\Delta\phi}\right)_{max} = 2 \frac{L}{\lambda} \frac{dn}{n} \qquad (7)$$

Materials and sizes currently available can provide from 12 to 200 resolution elements per scan. Resolution elements ranging from 12 to 200 per scan are represented by a prism dimension $L = 10^{-3}$ to 10^{-2} meter with dn/n $\cong 3 \times 10^{-3}$ to 5×10^{-3}, and with an applied voltage 2-5 kv. A possibility for future development with more stages of deflection is an array of 4×10^4 element.

This scanning method is limited by its requirement for a very high scanning rate. For instance, potassium tantalate-niobate (KTN) crystal has a response time of better than 10^{-9} seconds. In addition, and the dn/n ratio should be high which can be achieved by development of materials with $dn/n \geq 2 \times 10^{-2}$ or better. Finally, the size of the prism should be such that a clear aperture of 2-3 cm could be obtained. With such improvements this scanning method would provide a 1000-2000 line resolution.

Deflection with Rectangular Optics

A second scanning method based on the Kerr effect is Kerr optics with a rectangular format crystal. A straight transmission of the light beam is conducted through this rectangular format crystal (Figure 5). The electric field in direction of z axis is varied in strength from y = 0 to y = w with such a uniformity, which changes the n index of refraction in a linear form

$$n(x) = n_o + dn \frac{y}{w} \qquad (8)$$

Here dn is the maximum change in the index of refraction. As seen in Figure 5, a twist of the wavefront in the crystal could be achieved by changing this wavefront gradually. The scanning of the light beam is performed with the light propagation always perpendicular to these wavefronts.

The light beam enters the crystal at AB, where the rays are in phase with each other, but as a result of the twisted wavefronts in the crystal, the light rays traveling from AB to CD are shifted in phase. This phase shift is proportional with the Δn change in the refraction index and the distance x. The phase difference at CD is $\Delta\phi$ with the light beam of free space light wavelength λ.

$$\Delta\phi = \frac{4\pi \cdot L \cdot \Delta n}{\lambda} \qquad (9)$$

The path length difference δ at CE, where the light beam emerges as a deflected beam from the crystal, is due to the $\Delta\phi$ phase shift at CD. Through the distance δ, the $\Delta\phi$ phase shift corresponds to a phase shift in free space propagation.

$$\Delta\phi_o = \frac{2\pi\delta}{\lambda} \qquad (10)$$

The phase shift $\Delta\phi_o = \Delta\phi$, and, from equations 9 and 10,

$$\delta = 2 L \Delta n \qquad (11)$$

is derived the θ deflection angle

$$\theta \doteq \sin\theta = \frac{\delta}{w}$$

$$= \frac{2 \cdot L \cdot \Delta n}{w} \qquad (12)$$

With a narrow laser beam in mind, the diffraction limited, theoretical, minimum light beam cone angle, or half-intensity beam angle, is

$$\psi = \frac{\lambda}{v} \qquad (13)$$

where λ is the light beam wavelength and v the deflected beam width at the emerging point from the crystal.

Resolution can be expressed as a ratio of the deflection angle and the beam angle

$$N = \frac{\theta}{\psi} \qquad (14)$$

with approximate value

$$N = \frac{2 \cdot \Delta n \cdot L \cdot v}{\lambda \cdot w} \qquad (15)$$

Experimental values for N with a KH_2PO_4 crystal, N = 100. The Δn change of refracting index was somewhat larger than 10^{-4}, the length L = 30 cm, v is nearly equal to W and a gas laser source with wavelength $\lambda = 6328$ A.

Figure 6 illustrates the construction of a light beam deflector with hyperbolic shaped electrodes to achieve the linear variation of the electric field in the direction of the Y axis.

Ultrasonic Light Beam Deflection

Another electro-optical scanning method is based on diffraction of the light beam. When a beam of ultrasonic waves is propagated through a medium, alternate compression produces a regular variation of the optical density. These progressive ultrasonic waves have a similar effect on a light beam as a moving phase grating (incident perpendicular to the direction of ultrasonic propagation). For instance, liquids which are traversed by ultrasonic waves, while being irradiated by perpendicular propagated light waves, produce diffraction, similar to gratings. This phenomenon is called the Debye-Sears effect.

The grating interval is equal to the wavelength λ_u of the ultrasonic waves. If λ_u is large compared with the optical wavelength λ_o where m is an integer (pos, neg, or zero), then maximum diffraction is obtained.

$$\gamma_{max} = m \frac{\lambda_o}{\lambda_u} \qquad (16)$$

The schematic and principle of operation of such light beam deflection is illustrated in Figure 7. This method consists of a cell, which contains a material (liquid or solid) whose index of refraction depends upon the pressure, or the variation of the pressure, introduced to it. If this pressure varies with the rate of the ultrasonic waves from a piezoelectric transducer, a standing wave is formed in the cell, as a linear array of the pressure variations.

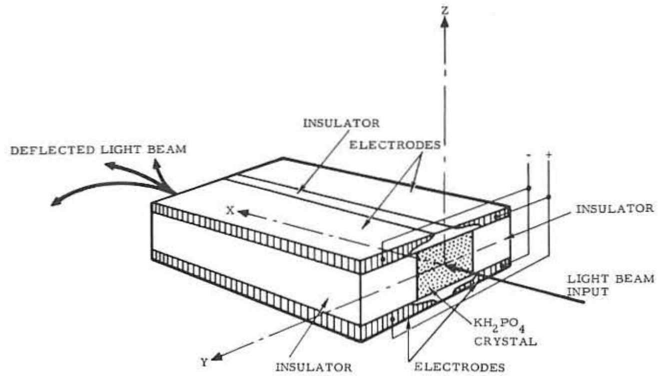


FIGURE 6: Experimental light beam deflector.

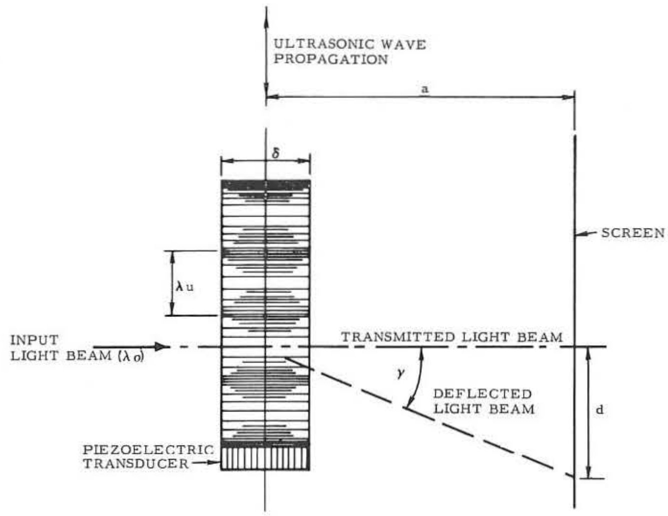


FIGURE 7: Ultrasonic light beam deflection.

The light beam which is irradiated with an incident, perpendicular to the ultrasonic wave propagation, sees this pressure variation (or standing waves) as a periodic variation of the index of refraction.

The cell, in this way, is equivalent to a transmission diffraction grating. The deflection angle of the diffracted light beam is γ. This angle of diffraction derives from the two wavelengths

$$\sin \gamma = \frac{\lambda_o}{\lambda_u} \qquad (17)$$

The wavelength can be expressed with the frequency and propagation velocity as

$$\lambda_u = \frac{v_u}{f_u} \qquad (18)$$

This expression will be used for further analysis of the resolution of this device.

The diffraction limited beam divergence is

$$\beta = \frac{\lambda_o}{\delta} \qquad (19)$$

where δ is the length of the cell. The resolvable diameter of an element is

$$\frac{\gamma}{\beta} = \frac{\delta}{\lambda_o} \sin^{-1} \frac{\lambda_o f_u}{v_u} \qquad (20)$$

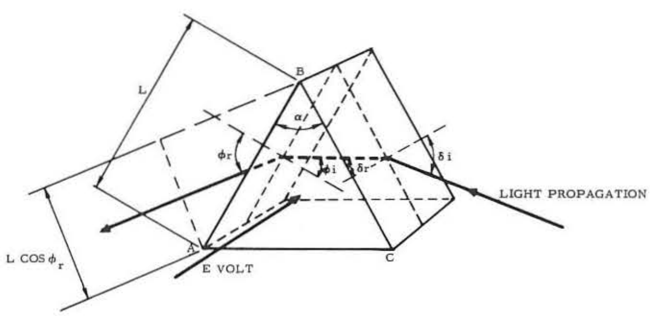


FIGURE 4: Light beam deflection by prism.

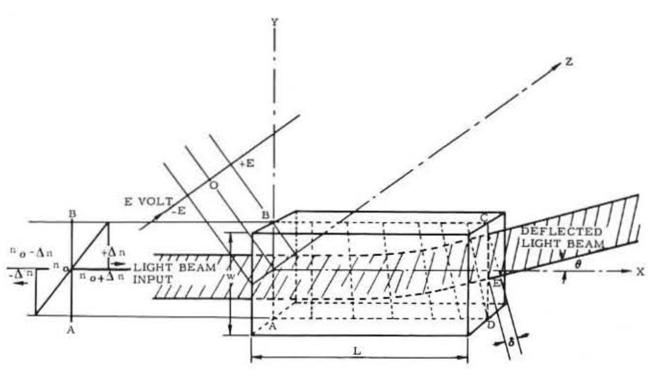


FIGURE 5: Rectangular optics scanner.

This can be reduced to

$$\frac{\gamma}{\beta} \doteq \frac{\delta \cdot f_u}{v_u} = \frac{\delta}{\lambda_u} \quad (21)$$

The density variations in the cell and the change in the index of refraction will bend a spatially coherent laser beam periodically. This beam width, however, should be much smaller than the ultrasonic wavelength.

The standing waves constantly change the refractive index and the interacting stationary light beam will be bent into an index region of greater refraction. The radius r, in which the light beam is bent, is

$$r = \frac{n}{\frac{dn}{dx}} \quad (22)$$

A relationship between the Δn refractive index change and the pressure variation in the cell, is given with the Lorenz-Lorentz equation wherein the compressibility constant of the medium k and the pressure change ΔP, as

$$\Delta n = \frac{1}{6n} k\,(n^2-1)\,(n^2+2)\,\Delta P \quad (23)$$

From the geometry shown in Figure 7 and equations 22 and 23, the deflection d_{max} on a screen in a distance of "a" from the center of the cell is represented as

$$d_{max} = \frac{2\pi a \delta k}{6n^2 \lambda_u}(n^2-1)(n^2+2)P_{max} \quad (24)$$

The limitations of this device are similar to those of the Kerr effect, that is, a low number of resolution elements per scan and a high driving frequency.

Experimental results with the propagation speed of 5×10^3 m/sec of a driving wave and a cell length of 1 cm indicate the scan frequency could be 400 c/s with 2000 resolution elements. With a 5 cm cell length, however, this scan frequency would drop to 16, but the scan length would increase significantly. Further experimental results with solids and liquids are shown in Table 1.

TABLE 1: Driving frequencies of various solids and liquids.

Material	Driving Frequency	Deflection Angle
Quartz Crystal	450 kc	1.2 deg
Water	150 kc	1.5 deg
Tetrachlorethylene	120 kc	2.2 deg
	150 kc	3.5 deg
	320 kc	6.0 deg

Further improvement for an increased deflection was obtained by increasing the path length δ with a series of small reflecting mirrors loacted in the cell. Such a light beam, after entering the cell, is reflected successively back and forth through the ultrasonic wave. With a nine fold, reflection lengthened light beam path, the deflection angle could be increased approximately 6 to 8 times.

Electromechanical Scanning

Electromechanical scanning methods, introduced earlier as a function of changes in the mechanical properties of materials, can also be generated by piezoelectricity and electromagnetic devices. The flying spot scanner type of electromechanical scanners, however, mechanically rotate or vibrate either reflecting or refracting optical materials and achieve a scan by continuously changing the path of the reflected or refracted light beam.

Details follow of several known mechanical scanners. Their limitations are more or less applicable to all electromechanical scanning methods, regardless of design complexity.

Piezoelectricity

Piezoelectricity is a reversible phenomenon, wherein an electrical charge is generated in a substance by a mechanical stress. The shape of the substance and the electrical charge are directly related; variance of one effects a proportional variance in the other. These substances are single crystals of polar symmetry and shaped as plates that are cut in exactly specified orientation. This device, therefore, is a means of a converting mechanical energy into electrical energy and vice versa.

The state-of-the-art piezoelectric materials or PZT ceramics expand or contract when placed in an electric field. The change in shape depends on the instantaneous polarity applied to them. The deformation is normally small; however, with special geometry, a significant deformation increase is possible.

Piezoelectric Cantilever Beam

One of the piezoelectric deflection systems for light beams is a cantilever beam shaped from a piezoelectric crystal. The beam bends under an applied voltage, thus, a light beam striking a reflecting surface on its end will change the angle of light reflection. A PZT ceramics bimorph (a combination of two opposite oriented length expenders) can be used to produce large motions, since one length expands as the other contracts, much the same as a bimetallic strip. With one end held taut and potential pressure maintained across its breadth, the bimorph will behave as a force driven cantilever beam and can be analyzed as such.

A piezoelectric cantilever beam scanner and an exaggerated view of a strained configuration are shown in Figure 8. The active elements of the bimorph are two piezoelectric ceramic plates rigidly bonded together with a metal plate between them. On the external surfaces are metal conductors for the electrical connections.

The piezoelectric material undergoes a change in length when an electric field is applied transverse to the length. This change in length is

$$\Delta L - d_{31} \cdot L \cdot E \quad (25)$$

where d_{31} is the transverse strain constant, E the applied electric potential, and L the length.

The cantilever beam illustrated in Figure 8 has been bent by the differential expansion of the two bonded plates into a circular arc of radius r. The length of the center of the bonded plates is unchanged, but the two outside surfaces change in length with $+\Delta L$ and $-\Delta L$. The length L of the unchanged interface can be expressed as

$$L - (r + t_o)\,\psi \quad (26)$$

and the changed exterior length as

$$L - \Delta L = r \cdot \psi \quad (27)$$

$$L + \Delta L = (r + t)\,\psi \quad (28)$$

From equations 26 and 27 the radius of the curvature is

$$r = \frac{L \cdot t_o}{\Delta L} \quad (29)$$

The angle of the light beam reflection θ, which is related to r is

$$\cos\frac{\theta}{2}\,\sin\frac{\theta}{2} = \frac{L}{2r} \quad (30)$$

or, for small angles,

$$\theta \doteq \frac{L}{r} \quad (31)$$

From equations 25, 29, and 31,

$$\theta = \frac{\Delta L}{t_o} \quad (32)$$

or

$$\theta = \frac{d_{31} \cdot L \cdot E}{t_o} \quad (33)$$

For the transverse strain constant of zirconate ceramic material, 142×10^{-12} m/volt is a typical value. A deflection angle of 4 degrees can be achieved with a plate of 5 cm length and 0.2 cm thickness. The applied voltage in this case is approximately 20 kv.

Since the mass of the vibrating cantilever beam effects the deflection and the frequency, the weight of the reflecting mirror should be kept at a minimum. The resolution can be 1300 elements with a 1 cm mirror and a diffraction limited light beam width of 3×10^{-3}

degrees. The efficiency of such a device can be significantly increased when operated at resonant frequency. The free vibration of a uniform cantilever beam can be expressed with the help of the d'Alambert principle. When computing the periods and normal modes of transverse horizontal vibrations, the form of natural frequencies of the piezoelectric cantilever beam is

$$f = \frac{1}{2\pi}\lambda_n^2 \sqrt{\frac{E \cdot I}{\mu L^4}} \qquad (34)$$

where

E = Young modulus of elasticity

I = moment of inertia

μ = unit weight length

L = length of the beam

λ_n = 1.88, 4.69, 7.85, 10.9 . . . . .

n = 1, 2, 3, 4, ...

as solution of graphical computation.

The first fundamental frequency for a bimorph piezoelectric PZT-5 ceramic with a thickness of t is

$$f_1 = 15 \times 10^3 \frac{t}{L^2} \text{ cps} \qquad (35)$$

(Appendix A)

The resonant frequency is related to only two parameters of the cantilever beam. A graphical illustration in Figure 9, shows in a nomographic form, frequency versus L/t for different L beam lengths.

The deflection d of the bimorph cantilever beam can be related to the V potential, t thickness, and L length. The applied potential related to the induced strain in the same equation gives the numerical form of d displacement for frequencies below resonance

$$d = K \cdot d_{31} \cdot \frac{L^2}{t^2} \cdot V \qquad (36)$$

as illustrated in Figure 10.

The constant K = 56 in equation 36

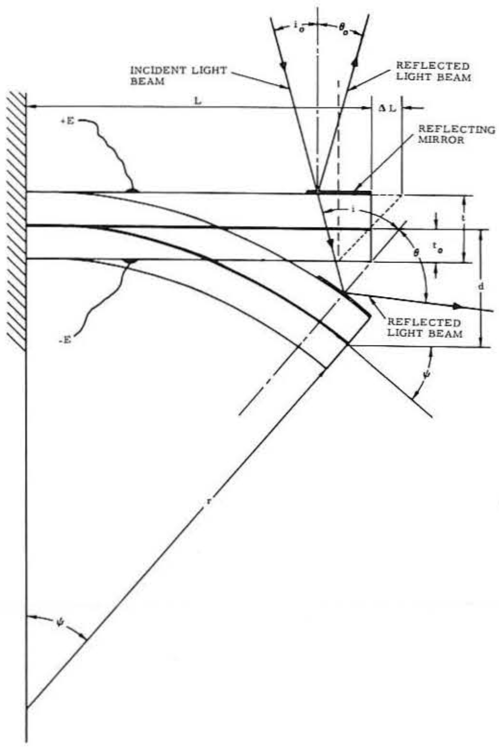


FIGURE 8: Bimorph piezoelectric cantilever beam.

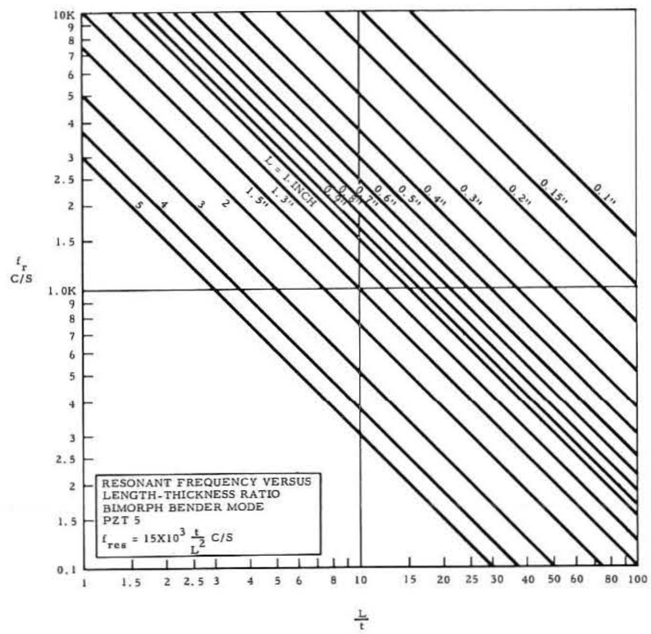


FIGURE 9: Nomogram of bimorph resonant frequencies.

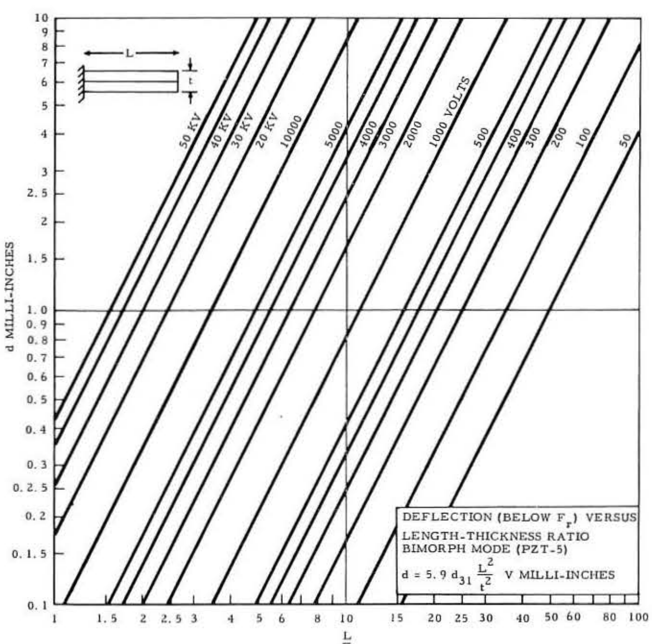


FIGURE 10: Nomogram of cantilever beam deflection.

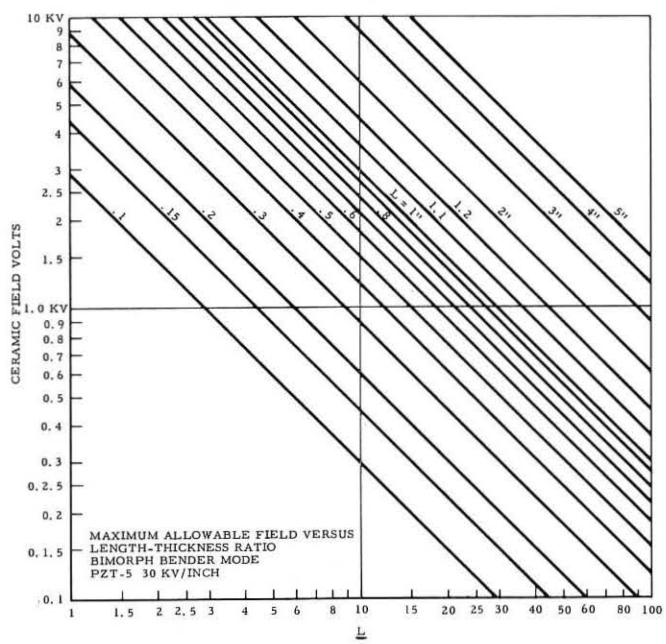


FIGURE 11: Nomogram for allowable electric field.

assumed that d is in milli-inches, d_{31} is the short circuit charge density developed per unit area applied stress and V is the applied field in volts.

At resonant frequencies, the deflection is

$$d = K \cdot d_{31} \cdot \frac{L^2}{t^2} \cdot Q \cdot V \quad (37)$$

where Q is the mechanical quality factor of the cantilever beam. For PZT-5 ceramics $Q \cong 50$. The operation at resonant frequency is quite efficient; however, the scan is not linear. This nonlinearity could be compensated with sawtooth driving waveforms, well below the resonant frequency. This, however, requires high sawtooth voltages. The primary limitations of these types of scanning devices are the operating frequency, drive voltage, and power requirement. Figure 11 is a graphical illustration of maximum allowable applied potential versus length-thickness ratio.

Piezoelectric Shearing Deformation

To obtain a shearing deformation with a piezoelectric material, the crystal must be cut to a specific shape and a certain orientation of the crystal. The Rochelle salt, with its historic importance and high electromechanical activity, can supply plates with an X cut which provides the shearing deformation. This plate, illustrated in Figure 12, is a crystal cut with its face plate perpendicular to the crystal X axis. This type of plate operates in what is called the shear mode because it responds electrically to a shearing motion and conversely shears when excited electrically.

The square shape changes into a diamond shape when electrically excited with an applied voltage to the two face plates. Two opposite corners extended and the other two corners move toward each other. Figure 12A illustrates this deformation (greatly exaggerated) to show the action. The same face shear deformation could be obtained with quartz crystals, however, this must be a Y cut, having the face plates perpendicular to the quartz crystal Y axis.

As a special application of the piezoelectric effect, this shear deformation will be utilized as a light beam scanner and therefore the significant parameter is the $\Delta\phi$ angle of deformation. The same X cut Rochelle crystal, Y cut quartz crystal or corresponding ceramics with 45 degree rotation converts to a rectangular, keeps the rectangular format but changes in length, width, and thickness as illustrated in Figure 12B. This ΔL length deformation has to be related to the $\Delta\phi$ angle. The ΔL length deformation value below the natural frequency is stated

$$\Delta L = d_{31} \cdot \frac{L}{t} \cdot V \quad (38)$$

where d_{31} is the short circuit strain developed while V potential is applied to the faceplates across t thickness.

As illustrated in Figure 13, the light beam is incident to one side of the rectangular plate and the θ deflection angle of the light beam is the angle between the two reflections before and after deformation

$$\theta = 2 \cdot \Delta\phi \quad (39)$$

Assumed that the undeformed shape of the plate is a square, the light beam deflection angle θ is derived from the geometry in Figure 13 and with the substitution of equations 38 and 39 in Appendix B.

$$\theta = 2 \cdot d_{31} \cdot \frac{V}{t} - \left(d_{31} \cdot \frac{V}{t}\right)^2 \quad (40)$$

The above equations apply again at frequencies below the natural resonant frequency. At resonance the change in dimensions is further amplified approximately by the mechanical Q of the crystal plate. The resonant frequency of a longitudinal extending plate

$$f = \frac{1}{2 \cdot L \cdot \sqrt{\zeta s_{11}}} \quad (41)$$

where L is the length, ζ the density, and s_{11} the inverse of the Young modulus along the length of the crystal.

Piezoelectric Torsion Scanner

Another operational mode of a piezoelectric crystal or ceramic is the torsion deformation. A special cylindrical shape of such piezoelectric material can be electrically excited to obtain a torsion effect, where the frequency is controlled by the shear elastic constant of the material. The operation and construction of such a thin wall torsional cylinder is illustrated in Figure 14.

The length of this thin wall cylindrical crystal is the direction of the X axis by quartz crystal. Four metal electrodes are at the surface of the cylinder, whose central lines are at 45 degrees to the Y axis with opposite pairs connected together. This way a torsional deformation can be generated in the crystal. The two pairs of electrodes generate reverse fields and, thus,

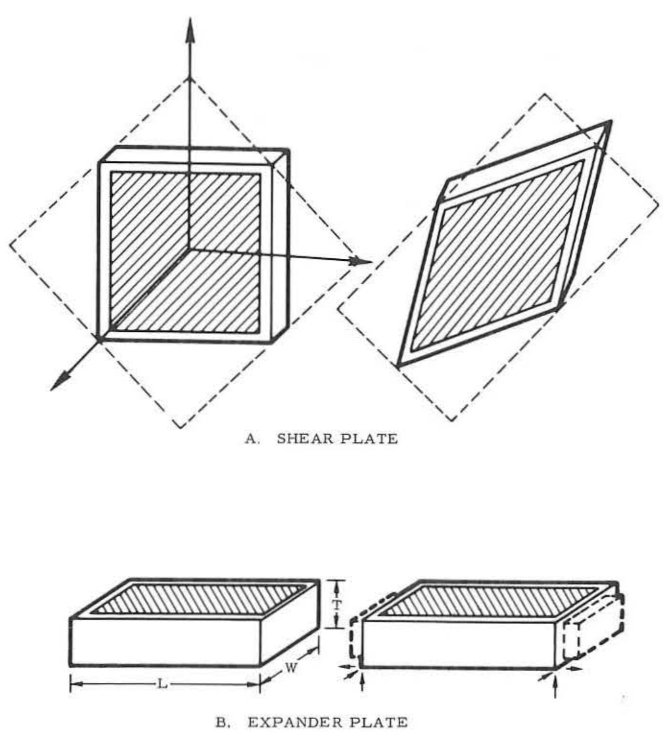


FIGURE 12: Piezoelectric shear and expander plates.

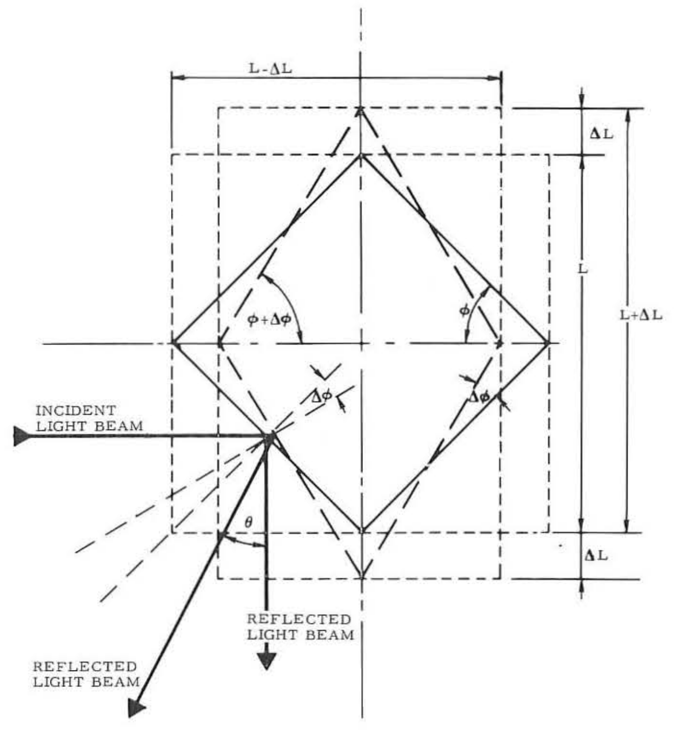


FIGURE 13: Light beam deflection with piezoelectric shearing deformation.

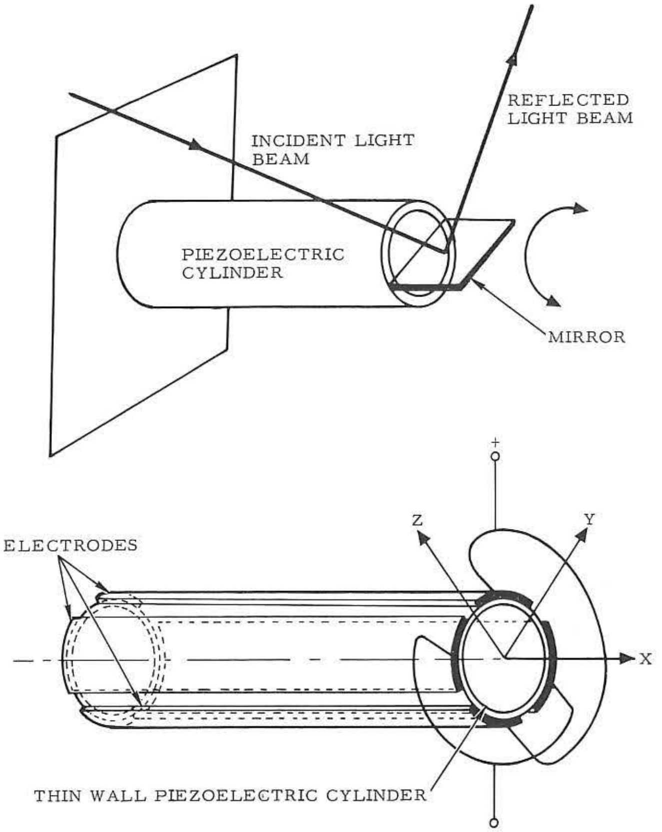


FIGURE 14: Piezoelectric torsion scanner.

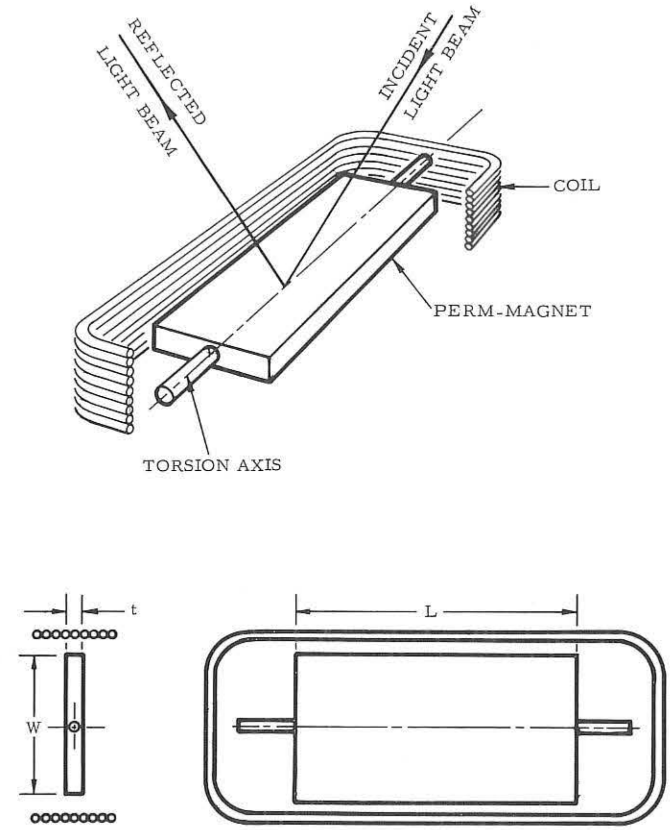


FIGURE 15: Mirror galvanometer.

reverse shear in the two halves of the crystal.

This combination of the top side with respect to the lower plane of the crystal cylinder produces a torsional stress. The natural resonant frequency of this torsion cylinder is

$$f = \frac{1}{2L}\sqrt{\frac{c_{66}}{\zeta}} \qquad (42)$$

where c_{66} is the shear elastic constant for shears around the Z axis, ζ the density and L is the length of the cylinder. With an elastic constant value $c_{66} = 40.5 \times 10^{10}$, the natural resonant frequency has a value of 1.95×10^5 cps for an $L = 1$ cm length. At the end of the torsion cylinder is attached a mirror, which reflects an incident light beam.

With this torsion scanning mode, some increase in the scanning frequency can be obtained, but at the expense of fabrication costs.

Mirror Galvanometer

Another electromechanical scanning device is based on the alternate electromagnetic field, where the light beam scanning is achieved with a galvanometer mechanism and a vibrating mirror. Figure 15 illustrates the galvanometer design concept, with a fixed coil and a rotating permanent magnet plate mounted on a torsion axis. The light beam will be reflected and deflected by the mirror face of the magnet plate. An electric current i passes through the coil which has n turns. This current creates a magnetic field in the coil. The permanent magnet plate has a B flux density, L length, W width, and T thickness.

The torque acting on the magnet plate armature is proportional to the ampere turns of the coil, the magnetic field strength and the coil parameters. The T torque is

$$T = i \cdot n \cdot B \cdot t \cdot w \cdot L \qquad (43)$$

The angular rotation of the magnet armature plate is proportional to the torque,

$$T = K \cdot \theta \qquad (44)$$

The angle of the light beam deflection on the mirror side of the armature plate is also proportional to the torque. The theoretical angular deflection of the light beam derives from equation 44.

$$\theta = \frac{T}{K} \qquad (45)$$

Considering that the deflection on the armature mirror is actually $\pm\theta$ the light beam is deflected twice the angle of the mirror angular displacement, the actual scan angle of the light beam being

$$\theta_s = 4\,\frac{i \cdot n \cdot B \cdot t \cdot w \cdot L}{K} \qquad (46)$$

The diffraction limited beam width is

$$\delta_\theta \doteq \frac{\lambda}{w} \qquad (47)$$

and the number of resolvable beam widths

$$R = \frac{\theta_s}{\delta_\theta} = 4\,\frac{i \cdot n \cdot B \cdot w^2 \cdot L}{\lambda K} \qquad (48)$$

The frequency limitation of the scan is the natural resonant frequency of the mechanical system, the armature and the torsion axis. The natural resonant frequency is

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{I}} \qquad (49)$$

where I is the moment of inertia,

$$I = \delta\,\frac{L \cdot w \cdot t}{12}\,(t^2 + w^2) \qquad (50)$$

and where δ is the density of the armature plate.

Rotating Polygonal and Pyramidal Mirrors

Other scanning mechanisms utilize mechanical flying spot scanner techniques. With spatial coherent laser beams, flying spot scanning devices can accomplish high resolution with a high speed scan (Figure 16). By keeping the position of the axis of rotation constant, the flying spot continuously traverses the same line. A raster scan would require a low frequency periodic tilt of the axis with the rotating mirror around an axis perpendicular to it, or a second deflection around a perpendicular axis using any low frequency scanning method. These mechanical systems could be used at speeds of 10,000 to 20,000 rpm.

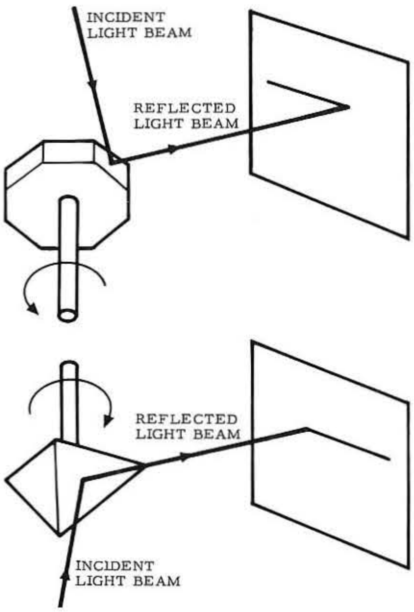


FIGURE 16: Rotating polygonal and pyramidal mirrors.

The scanner can be used to scan and illuminate with the light beam an opaque object and, simultaneously, a synchronized scanning receiver or a TV camera to provide the image of the reflected light beam. The synchronized scanning can be achieved by generating a synchronizing signal at the scanner, prior to each scan. This would trigger and synchronize the receiver or the scanner could generate during scan, a sweep signal to be fed into the receiver. Or, an external synchronizing circuit could produce the centralized sweep signal and supply to the scanner and the receiver.

However, the limitations and disadvantages of a motor driven rotating scanner are the problems of precise synchronization and maintaining an accurate speed. Furthermore, in motor driven mechanical optical devices, the resolution is limited by the optics, the diffraction, the spot size, the light requirements, and other mechanical precision requirements.

Appendix A

Natural Frequency of Cantilever Beam

$$f_n = \frac{1}{2\pi}\left(\frac{\lambda_n}{L}\right)^2 \sqrt{\frac{E\cdot I}{\mu}}$$

$\lambda_n = 1.88$ for $n = 1$
E = Young modulus
I = moment of inertia
μ = mass per unit length
L = length
w = width
t = thickness
ζ = density

$$f_1 = \frac{1}{2\pi}\left(\frac{\lambda_1}{L}\right)^2 \sqrt{\frac{E\cdot w\cdot t^3}{12\cdot\mu}}$$

where

$$I = \frac{w\cdot t^3}{12}$$

and

$$\mu = \frac{\zeta\cdot w\cdot t}{386}\ \text{lb./in.}$$

$$f_1 = \frac{1}{2\pi}\left(\frac{\lambda_1}{L}\right)^2 \sqrt{\frac{E\cdot t^2\cdot 386}{12\zeta}}$$

for

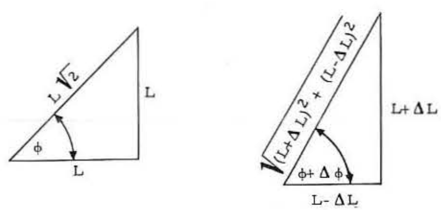
PZT-5 $E = 6 \times 10^6$ psi $\zeta = 0.28$ lb/in.^{3}

$$f_1 = \frac{1}{2\pi}\left(\frac{1.88}{L}\right)^2 t \sqrt{\frac{(6\times 10^6)(386)}{(12)(0.28)}}$$

$$f \approx 15\times 10^3 \frac{t}{L^2}\ \text{cps}$$

Appendix B

Light Beam Deflection Angle With Piezoelectric Shear Deformation



$$\sin(\phi + \Delta\phi) = \frac{L + \Delta L}{\sqrt{(L+\Delta L)^2 + (L-\Delta L)^2}}$$

with approximation that $\phi\Delta$ is very small

$$\sin\phi + \Delta\phi \cos\phi = \frac{L + \Delta L}{\sqrt{2L^2 + 2\Delta L^2}}$$

because

$$\phi = 45\ \text{deg}$$

$$\frac{1}{\sqrt{2}}(1 + \Delta\phi) = \frac{1}{\sqrt{2}} \frac{L + \Delta L}{\sqrt{L^2 + \Delta L^2}}$$

$$\Delta\phi = \frac{L + \Delta L}{\sqrt{L^2 + \Delta L^2}} - 1 \doteq \frac{L + \Delta L}{L + \frac{1}{2}\frac{\Delta L^2}{L}} - 1$$

$$= \frac{1 - \frac{\Delta L}{L}}{1 + \frac{1}{2}\frac{\Delta L^2}{L^2}} - 1 = \left(1 + \frac{\Delta L}{L}\right)\left(1 - \frac{1}{2}\frac{\Delta L^2}{L^2}\right) - 1$$

$$\Delta\phi = \frac{\Delta L}{L} - \frac{1}{2}\frac{\Delta L^2}{L^2}$$

$$\theta = 2\Delta\phi \quad \text{and} \quad \Delta L = d_{31}\frac{L}{t}V$$

(equations 38 and 39)

$$\theta = 2d_{31}\frac{V}{t} - \left(d_{31}\frac{V}{t}\right)^2$$

Appendix C

Snell's law

$$\sin\phi_i = \frac{n'}{n}\sin\phi_r$$

At critical angle

$$\phi_i = \phi_c$$

and

$$\phi_r = 90°$$
$$\sin\phi_r = 1$$
$$n' = 1\ \text{(in air)}$$
$$n\sin\phi_i = n'\sin\phi_r$$
$$n\sin\phi_i = 1$$

$$\sin^2\phi + \cos^2\phi = 1$$
$$\cos\phi_i = \sqrt{1 - \sin^2\phi_i}$$

at critical angle

$$\sin\phi_i = \frac{1}{n}$$
$$\cos\phi_1 = \sqrt{1 - \frac{1}{n^2}}$$
$$= \sqrt{\frac{n^2 - 1}{n^2}}$$
$$= \frac{\sqrt{n^2 - 1}}{n}$$
$$\alpha = \phi_i + \delta_r$$

The angle of δ_r is reduced to a min if ϕ_i is a max.

The max possible value of ϕ_i is the critical angle. When α is equal to twice the (ϕ_i) crit. there is the limit of light beam emergence.

No rays can be transmitted through the prism if $\alpha > 2(\phi_1)$ max.

For further detail see Figure 4.

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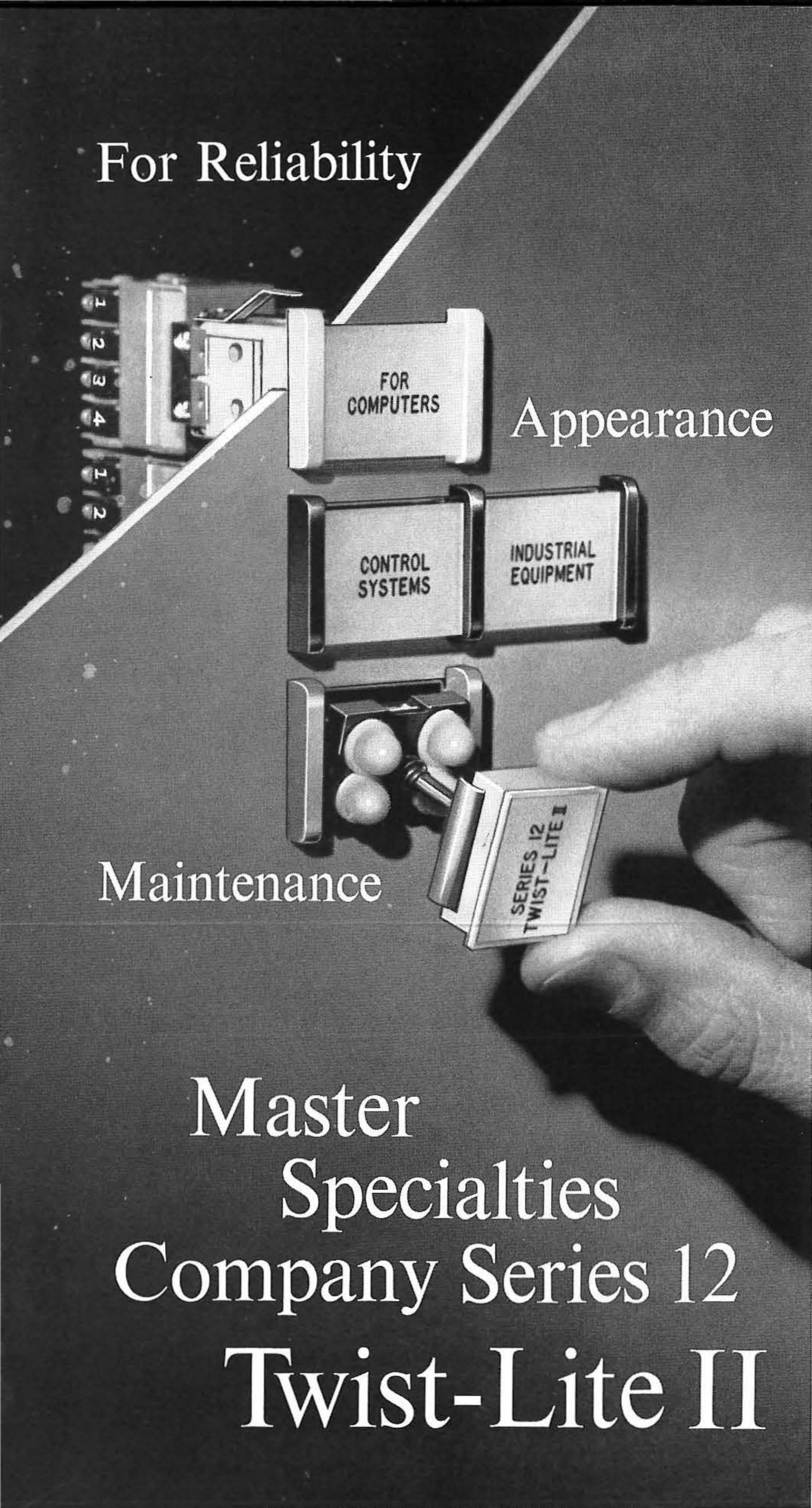

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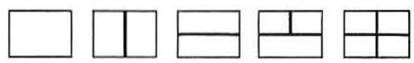

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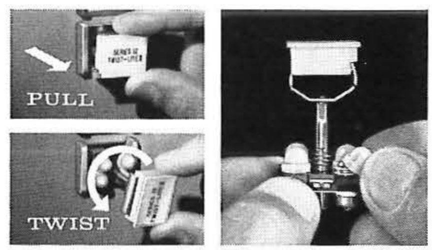

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The Perception Of Flicker In Cathode Ray Tube Displays

by Rodger Elmo Turnage, Jr.

Chief, Electronics Design
Data Products Division
Stromberg-Carlson Corp.
San Diego, Calif.

Abstract

Experiments were conducted to measure the critical fusion frequency (cff) of flicker in cathode ray tube (CRT) displays under the conditions prevalent in information display system. Much published data is not applicable because CRT's were not used and the humans were adapted to scotopic vision, wide angle flickering fields, or low contrast targets.

Apparatus was constructed consisting of interchangeable CRT's with seven different phosphors and electronic equipment to modulate the CRT beam current with sinusoidal and rectangular pulse signals of variable frequency. Experimental data were obtained on a 5/32 inch sharp edged spot surrounded by a surface of 3 foot Lambert brightness and viewed at 12 to 15 inches. Curves of cff versus modulation index with sine modulation were determined on each phosphor at 10, 32, and 100 foot Lambert average brightness with from one to four observers. Curves of cff versus brightness with pulse modulation were obtained with three observers.

Results show that the cff of a phosphor-human system is reduced substantially below the cff of a human by phosphor persistence. The relative ability of phosphors to reduce flicker can be predicted from their persistence characteristics. The phosphors ranked in order of their reduction of cff are: P12 (greatest reduction), P7 yellow component, P1, P28, P4, P31, and P20. The P28 phosphor tested exhibited neither the expected reduction of cff nor its published persistence.

Purpose of the Experiments

Cathode ray tubes are often used as the final display device in contemporary information display systems, in both military and commercial applications. When the display on the phosphor of the CRT is directly viewed by a human operator, it is desirable that it appear flicker free. Often a means of predicting whether a display will flicker or not, before the equipment is built and installed, is desired. It was the purpose of the experiments described herein to obtain data which permit a reliable prediction of the critical fusion frequency of flicker to be made.

A great deal of data has been obtained in the past which deals with the ability of the human visual system to perceive flicker. Helmholtz began experiments in 1863 in which a rotating disk with black and white sectors was used to determine the critical fusion frequency (cff) of flicker. Southall has summarized, "In the case of a disk illuminated by bright sunlight, Helmholtz states that he found an exposure of each sector lasting one forty-eighth of a second was required in order to make the flicker disappear for his eye, whereas when the experiment was tried in bright moonlight the corresponding duration of the stimulus had to be more than twice as long, namely, one twentieth of a second."[1]

Since then Ives[2], de Lange[3], and Kelly[4], among others, have added a wealth of quantitative data on the human system, but most of the work since 1863 has continued to rely upon the rotating disk as a light modulator. Engstrom, doing pioneering work on television in 1935, perceived that the persistence of the phosphor of a CRT might alter the critical fusion frequency of flicker, but was unable to determine the relation by direct experiment, since the variety of phosphors available then was quite limited. He therefore resorted to a rotating disk to simulate hypothetical long persistence phosphors.[5] Since 1935 over 32 different phosphors have been registered with the industry group, Electronic Industries Association, and a predecessor group, RETMA, and the persistence characteristics of 29 of these have been published.[6] Little or no data has been published on the cff obtained with each of the phosphors, although it is clear that the cff of a system including a phosphor and an eye must be a function of both characteristics.

The experiments described herein were aimed principally at the direct measurement of the cff of a display system including both a human visual system and a CRT phosphor, operating in an environment typical of contemporary information display systems. Direct measurement is believed to be the only reliable way of obtaining applicable data, for the following reasons:

1. Many of the available data on the human system apply to conditions not found in modern display systems.[7] Data taken with the eye adapted to scotopic vision[2] (low ambient light levels or dark surroundings) do not apply since darkened display rooms are currently in disfavor. Lighted rooms are desired to permit tasks such as reading and writing to proceed simultaneously with display viewing. Likewise, data taken with 60 degree "edgeless" fields of light[4] are of questionable applicability since the CRT information display consists of a number of sharp edged characters, each subtending less than 1 degree at the eye of the observer. Data taken on small sharp-edged flickering lights surrounded by steady light of the same average brightness[3] are not applicable without question, since legibility requirements dictate that the contrast between characters and background be substantial.[7] Also, much of the published data were obtaining using fixed aperture artificial pupils which are obviously not present in operational CRT display systems.

2. Cathode ray tube phosphors exhibit numerous nonlinear phenomena which make it difficult to obtain a combined phosphor-eye characteristic by analytic or graphical methods. The rise time of a phosphor subjected to a rectangular pulse of current may be much shorter than its fall time. The resulting implied non-linearity prevents application of linear transform methods to obtain an analytic transfer function, and insures the generation of harmonic distortion under any form of modulation. Phosphors also exhibit saturation or amplitude distortion under any form of modulation; i.e., the brightness of the output light is not proportional to the power of the input electrical excitation. Furthermore, the conversion efficiency, persistence, and color of a phosphor are often functions of the operating temperature, accelerating voltage, and beam current density of the CRT.[8]

3. The color of the light from a phosphor is a function of the phosphor type, and in most cases it is not white. Thus selection of a phosphor type having desirable persistence may entail acceptance of an undesirable color. If the phosphor's emission is not white, published data on the cff of white light is of questionable value. Furthermore, light sources having the same apparent color may have different spectral energy distributions. A pertinent case is phosphor P4 whic his considered nominally white. Its spectral energy distribution reveals a narrow peak of energy at a wave-length of 4500 Angstroms (blue) and a broader one from 5500 through 6000 Angstroms (yellow).[6] The peaks are on opposite sides of the chromaticity diagram and the P4's light output appears white, although its spectral energy distribution is not uniform. Cff data obtained with gelatin[9] or interference filters[3] producing relatively saturated primary colors should not be used to predict the performance of a phosphor of the same apparent color, but not of the same spectral distribution of energy. Furthermore, where two peaks of energy occur in the spectrum, they may represent light of different decay rates, as is the case for phosphor P7.[6]

For the above reasons, it appeared that the most reliable method of determining the cff of information display systems using CRTs was to measure the combined eye-phosphor characteristics for a number of suitable phosphors, under the conditions prevailing in such systems. The conditions assumed for the experiments were:

1. *Ambient Light:* Light sufficient to read and write is required, but more light than necessary should be avoided, since it tends to reduce display contrast, and hence display legibility.[10] Ten foot candles incident on the surface of a table was chosen as typical.[7]

2. *Target Characteristics:* A sharp edged spot of light 5/32 inch in diameter was chosen, to simulate the alphanumeric characters and symbols used in the typical information display. Brightness levels from 5 to 40 foot Lamberts were chosen. The resulting range of contrasts includes the 5:1 and 10:1 figures which some authorities consider optimum for legibility.[11]

3. *Choice of Phosphors:* Phosphors having medium-short to long persistence and high visual efficiency are most prevalent in directly viewed displays. Phosphors having short and very short persistences and intended for exposure of photographic films, excitation of photomultipliers. and other applications involving non-human reception of the light, were excluded from these experiments. The phosphors selected were P1, P4, P7, P12, P20, P28 and P31.

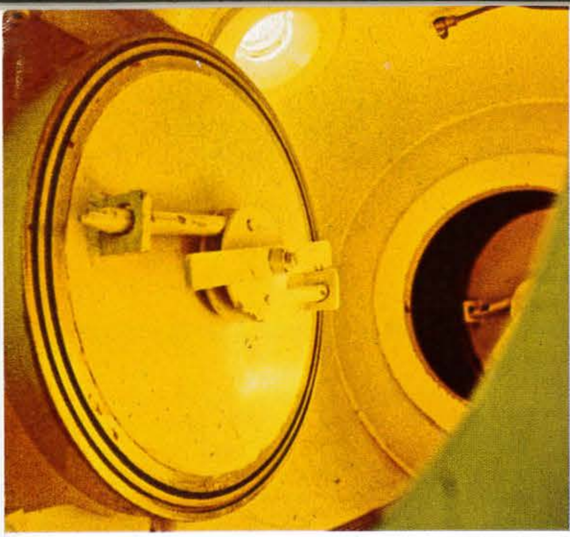
4. *Modulation:* Two types of modulation were selected. Sine wave modulation of CRT current was chosen for the initial experiments, to enable comparison of the results with the body of existing data taken with sine wave modulation of light intensity. Pulse modulation of CRT current was chosen for the final series of experiments, as this is the method typically used in information display systems. Data from the final series of experiments is thus applicable directly to such systems, with a minimum of extrapolation and assumption. A constant pulse duty cycle of 2% was selected as a compromise between higher duty cycles to achieve higher average brightness, and lower duty cycles to more closely simulate operational systems.

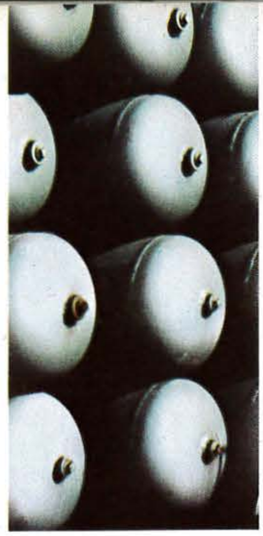
In summary, the experiments were intended to obtain data on the critical fusion frequency of systems combining CRT phosphors and human visual systems under conditions of 10 foot candle ambient illumination, utilizing sharp edge characters of 5/32 inch height, on phosphors suitable for direct viewing, with both sine wave and pulse modulation of the CRT phosphor excitation. The experiments did not determine the cff of the visual system alone, nor the response of a phosphor alone. While the phosphors were of various colors, the experiments did not determine the influence of color on flicker perception.

The experiments were intended to provide data which may be used directly to predict the cff of a display system conforming to the assumed conditions. They were not intended to determine the lowest repetition rate which may be used with satisfactory results.

Theoretical Considerations

If simplifying assumptions are made, it is possible to predict approximately some of the flicker characteristics of phosphors from published data. While no means have been found to predict the cff of every phosphor at all average



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It arrived at their Tonawanda complex in pieces: a Model 40 central processing unit, a printer, three tape drives and lots of other blue boxes.

By noon the next day, it was ready.

Dr. S. L. Wang, Manager of the Computing Center, was impressed by the installation speed. Especially since it was the first SYSTEM/360 to be installed for industrial use in the East.

Within a week, SYSTEM/360 was helping to solve all kinds of engineering and scientific problems ... problems in cryogenics, problems in deep-sea pressure calculations, problems in air separation column design, problems in space vehicle insulations for Union Carbide's Linde Division, a major producer of industrial gases and cryogenic products.

Union Carbide credits the efficiency and flexibility of SYSTEM/360's ASSEMBLER language for the rapid conversion.

With it, they wrote a simulator program so that programs for their old computer could run on SYSTEM/360 six and seven times faster than before.

IBM held seminars to help Linde engineers learn to program their own problems in FORTRAN, the language used for engineering problem-solving. Initially, 115 engineers attended. They found out how easy SYSTEM/360 is to use.

Now they get answers fast.

Their next SYSTEM/360 will take care of commercial problems now handled by another system and also allow more engineers to solve problems.

Union Carbide will be getting additional SYSTEM/360's.

A lot of other companies like SYSTEM/360, too. They like its performance, speed and versatility.

We have a hunch you will too.

IBM®

got results Friday.

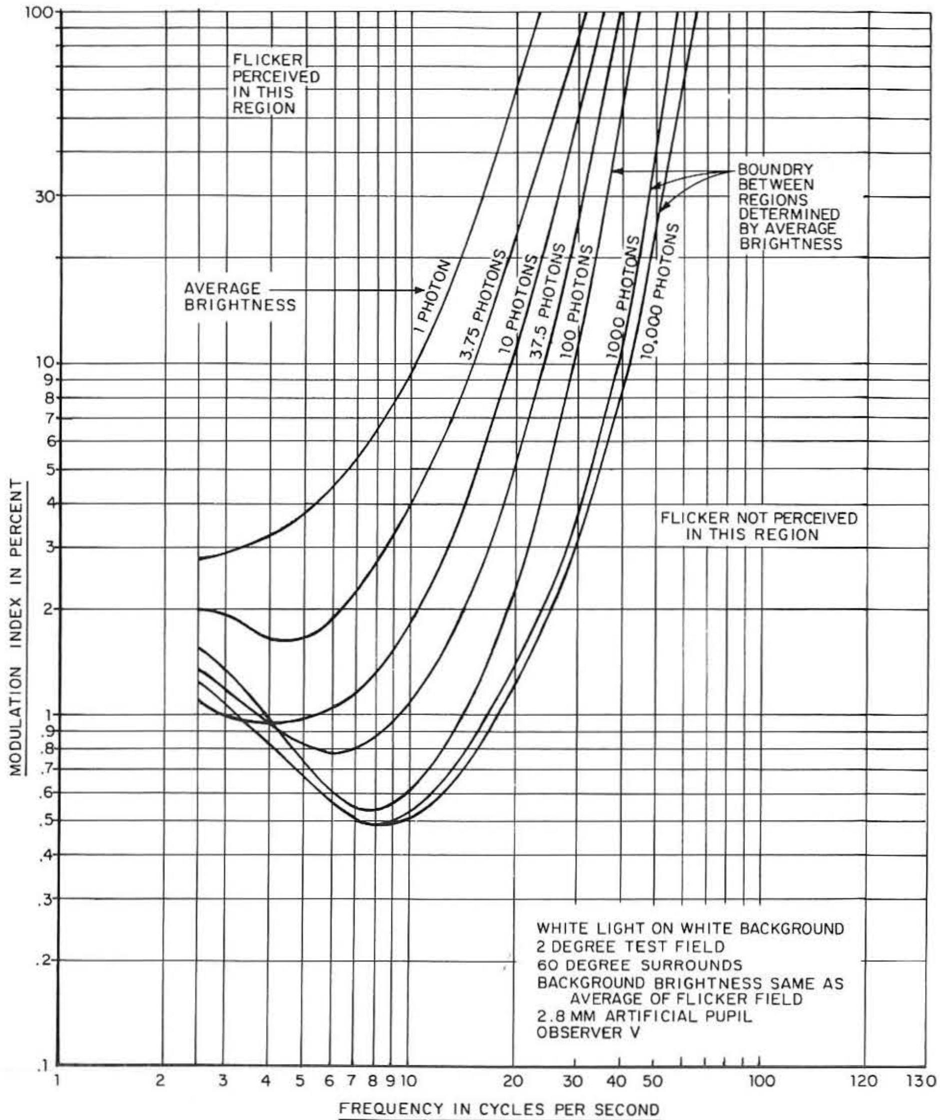

FIGURE 1: Critical fusion frequency data of De Lange.

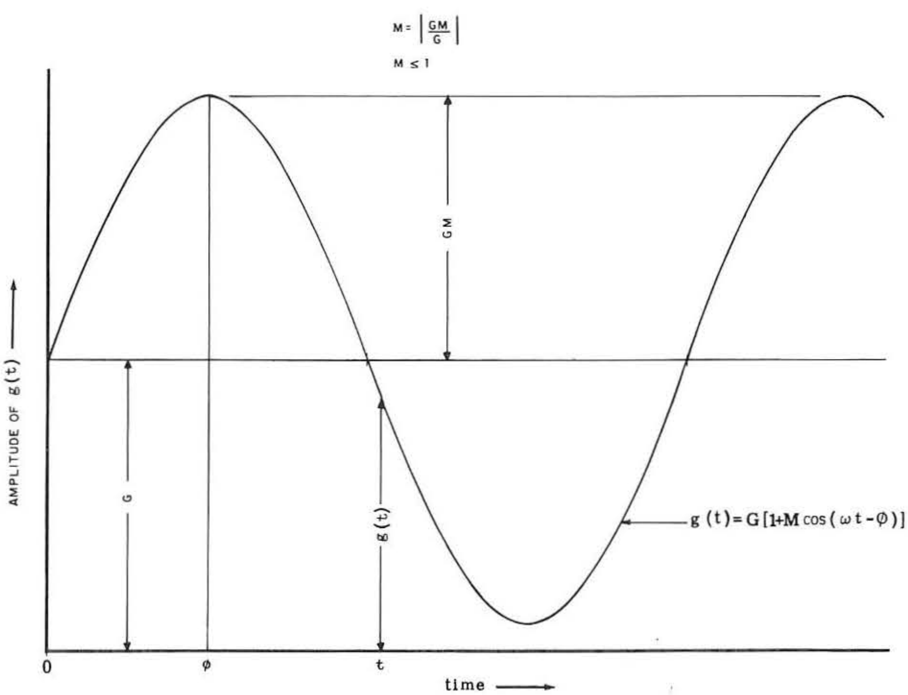

FIGURE 2: Definition of modulation index, M.

brightness levels, it is possible to determine at least whether one phosphor is more likely than another to flicker in a given situation. Hence a choice of phosphors can be made.

The perception of flicker by the human visual system is a function of three principal parameters of the observed light source, average brightness, frequency, and modulation index. This is illustrated in Figure 1, taken from the data of De Lange.[3] Note that Figure 1 represents the human response only, since no CRT was used; it was obtained with a rotating disk. Modulation index has the meaning:

$$g(t) = G\ [1 + M\ \cos(t\text{-}\emptyset)]$$

where

g is the instantaneous brightness of the time varying light.
G is the average brightness.
M is the modulation index.

Thus when M = 1, the preceding equation defines a sinusoidal variation from zero to twice the average value. Figure 2 illustrates the definition of modulation index.

It is assumed throughout this discussion that the phosphor is to be used in a CRT which is intensity modulated with the rectangular pulses so that the beam current striking any incremental area of the phosphor is on and constant for a minor portion of each repetition period and completely off for the balance of the period. This is the case when a single gun CRT is used to produce a large number of bright alphanumeric characters, symbols and lines dispersed about the tube face, while the balance of the screen (the display background) remains dark. The off period then includes both blanking time during deflection transitions and the time that the beam is exciting other phosphor areas.

The modulation index of the rectangular pulse train which excites the CRT phosphor is now of interest. The spectrum of any periodic time function f(t) may be calculated by Fourier analysis,[12] as defined below:

$$f(t) = \frac{A_o}{2} + \sum_{k=1}^{\infty} A_k \cos(k\omega t) + B_k \sin(k\omega t);$$

$$\frac{A_o}{2} = \text{average value}$$

$$A_k = \frac{1}{\pi}\int_O^{2\pi} f(t)\cos(k\omega t)\,dt$$

$$B_k = \frac{1}{\pi}\int_O^{2\pi} f(t)\sin(k\omega t)\,dt$$

$$C_k = \sqrt{A_k^2 + B_k^2}\ ;$$

C_k = amplitude of k-th harmonic

The pulse train is defined to have the following parameters (see Figure 3):

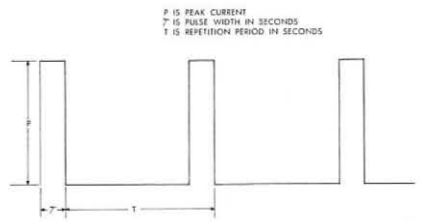

FIGURE 3: Rectangular pulse train of CRT beam current.

P is peak current.

τ is pulse width in seconds

T is repetition period in seconds.

The average value is: $\frac{A_o}{2} = \frac{P\tau}{T}$

The fundamental component is found by Fourier analysis to be:

$$C_1 = \frac{2P}{\pi} \sin\left(\frac{\pi\tau}{T}\right)$$

De Lange and others have assumed that the amplitude of the second harmonic and higher harmonics in a complex wave has little or no effect on the perception of flicker, provided the fundamental frequency is greater than 20 cps.[3] This appears reasonable since the second harmonic is then greater than 40 cps where the observer has low sensitivity to flicker, and all other harmonics are above 60 cps, where virtually no sensitivity exists. Under these conditions the modulation index of the pulse train can be defined in terms of the fundamental and the average value only. For the rectangular pulse train:

$$M = \frac{C_1}{A_o/2} = \frac{\frac{2P}{\pi}\sin\left(\frac{\pi\tau}{T}\right)}{\frac{P\tau}{T}}$$

$$M = \frac{2T}{\tau\pi}\sin\left(\frac{\pi\tau}{T}\right) = \frac{2\sin(y)}{y}$$

$$y = \frac{\pi\tau}{T}$$

Thus the modulation index, or ratio of the amplitude of the fundamental component to the average value, varies according to the $\frac{\sin(y)}{y}$ function. Here y is a function of the ratio $\frac{\tau}{T}$, which is defined as the duty cycle of the pulse train, or the ratio of the on time to the period. The values of M corresponding to various duty cycles are plotted in Figure 4.

If it is assumed that only the fundamental modulation is significant to the observer, it appears that the exact value of the duty cycle is unimportant, provided it is small. This follows from the flatness of the curve in the region near $\frac{\tau}{T} = 0$. A pulse train of .02 duty cycle (2%) has 199.84% modulation; as the duty cycle is lowered further the modulation index asymptotically approaches 200%, which is the same thing for the practical purposes.

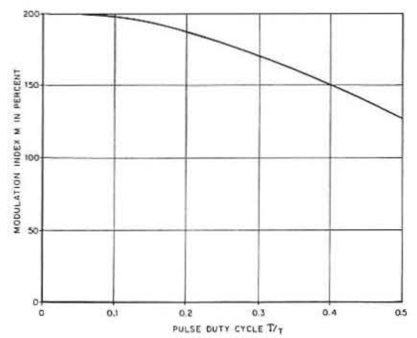

FIGURE 4: Modulation index of a rectangular pulse train.

In the case of a phosphor having both rise and decay times which are short with respect to the pulse width and period involved, the light output may be assumed to have substantially the same wave shape as the input current, and it may be intuitively deduced that the curve of Figure 4 applies to the brightness of the display as well as to the CRT current. Such phosphors were excluded from this experiment, however, since short persistence phosphors are seldom used for direct viewing.

According to Leverenz[8], solid crystalline phosphors can be divided into two classes called exponential phosphors and power-law phosphors. Their decay characteristic curves can be empirically approximated by the following expressions:

Exponential: $L = L_o e^{-at}$

Power-law: $L = L_o \left(\frac{b}{b+t}\right)^n$

where

- L is the instantaneous luminescence emission.
- L_o is the peak luminescence emission.
- a is the reciprocal of the time constant of the excited state.
- t is the time after removal of excitation.
- b and n are constants over limited ranges of L_o.

The exponential phosphors have decay curves substantially independent of temperature and excitation current density. Their decay curves from the simple exponential and become power-law functions at large values of t, however. Power-law decays are sensitive to both temperature and excitation density. In both classes, the efficiencies of the phosphors are functions of the accelerating voltages of the CRT beams and of the durations of excitation pulses.

Two of the phosphors included in these phosphor-off experiments belong to Leverenz's exponential decay class, viz. the phosphor P1, Zn_2SiO_4:Mn, and P12, ZnF_2:Mn plus MgF_2:Mn, hence they should have relatively stable decay curves. Furthermore, the decay curves published by EIA[6] corroborate the close adherence of P1 to the exponential curve from 100% to 4% of peak brightness, and the close adherence of P12 to the exponential curve from 100% to 2% of peak brightness, for at least one set of excitation conditions each. This suggests that it is reasonable to assume an analytic expression for the output of an idealized exponential phosphor. The analytic time function can then be analysed by the Fourier method and a modulation index obtained for comparison with the index of the exciting pulse train.

For the purpose of obtaining an analytic time function a hypothetical phosphor having the following idealized exponential decay is assumed:

$$b = Pe^{-t/T_p}$$

where

- b is the instantaneous brightness in foot Lamberts.
- P is the peak brightness in foot Lamberts.
- t is the time in seconds after excitation is removed.
- T_p is the time constant of the phosphor in seconds.

It is further assumed that if the duty cycle is very low, the period of time during excitation may be ignored and the brightness of the output light may be simply represented by the curve of Figure 5. In the figure, T is the repetition period in seconds.

The representation of Figure 5 assumes that the decay curve under repetitive short pulse excitation is the same as under the single long pulse gen-

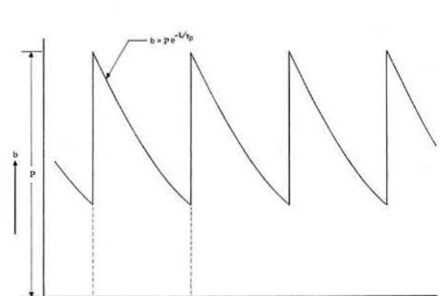

FIGURE 5: Exponential pulse train of CRT phosphor brightness.

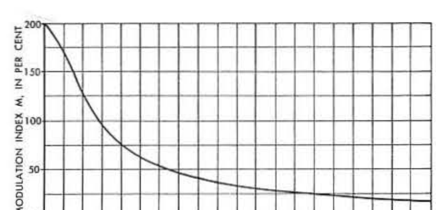

FIGURE 6: Modulation index of an exponential pulse train.

erally used to obtain published decay curves. It assumes that the energy of each excitation pulse is added to the energy residual from the preceding pulses, below a maximum or saturation level. It assumes that the train of exciting pulses has been applied for sufficient time to establish an equilibrium, i.e. a constant average value. It assumes that the total light output during decay follows the exponential curve with t measured from the last excitation pulse even though some of the light is the result of prior pulses.

Fourier analysis of this hypothetical periodic wave may be performed to determine its modulation index. The average value is:

$$\frac{A_o}{2} = \frac{PT_p}{T}\left[1-e^{-T/T_p}\right]$$

The fundamental component may be computed to be:

$$C_1 = \frac{2PT_p}{T^2+4\pi^2 T_p^2}\left[1-e^{-T/T_p}\right]\sqrt{T^2+4\pi^2 T_p^2}$$

The modulation index M is the ratio of the fundamental to the average value, hence:

$$M = \frac{\frac{2PT_p}{T^2+4\pi^2 T_p^2}\left[1-e^{-T/T_p}\right]\sqrt{T^2+4\pi^2 T_p^2}}{\frac{PT_p}{T}\left[1-e^{-T/T_p}\right]}$$

or,

$$M = \frac{2T}{\sqrt{T^2+4\pi^2 T_p^2}} = \frac{2}{\sqrt{1+4\pi^2 (T_p/T)^2}}$$

The expression above gives the modulation index for the light output of the hypothetical exponential phosphor excited by a pulse train of low duty cycle. The modulation index is determined by the ratio of the phosphor's decay time constant to the repetition period. The curve of Figure 6 represents this relationship.

In the case of a phosphor having the assumed exponential form and a decay time constant which is short compared to the repetition period:

$M \simeq 2$, for $T_p << T$.

Therefore it is possible to predict that the perception of flicker is independent of the hypothetical phosphor's persistence provided that both the duration of the excitation pulse and the phosphor decay time constant are small compared to the repetition period. The previous intuitive deduction is thus verified mathematically.

In the case of a phosphor having the assumed exponential form and a decay time constant which is long compared to the period:

$$M \simeq \frac{1}{\pi}\,\frac{T}{T_p}\text{, for } T < T_p$$

From the preceding discussion, it is clear that the modulation index and hence the apparent critical fusion frequency of an exponential phosphor is a function of its decay time constant. The large number of assumptions used, however, to derive an analytic expression for the modulation index indicates that any theoretical computation of the cff of a phosphor is likely to be quite inaccurate. The insight afforded by the theoretical exercise does nevertheless permit a successful heuristic approach to the problem of ranking a group of phosphors in the order of their relative abilities to reduce flicker or increase cff. If all the phosphors to be considered have the hypothetical exponential decays, the lowest modulation index, M, is achieved when the ratio of decay time constant to repetition period is greatest, hence the phosphor having the longest decay time constant produces the least flicker. Not all phosphor decay curves are exponential, however. In the case of power-law phosphors, it can be seen intuitively that a decay curve which falls rapidly at first, followed by a slow decay of the last 10% of its brightness is likely to generate a large fundamental component, and hence produce much flicker. On the other hand, a curve which falls slowly at first and rapidly later produces little flicker, especially if the repetition period falls within the slow portion of the decay curve.

The suggested ranking procedure is to first determine a repetition rate, which may be arbitrary if not dictated by other considerations. From this the repetition period is derived. Next, a list is made of all available phosphors of interest. For each phosphor, the percentage of peak light remaining one period after the removal of excitation is obtained from published data, found for example in the EIA publication, "Optical Properties of Cathode Ray Tube Screens."[6] It is then a simple matter to rank the phosphor having the greatest residual brightness after one period as the one producing the least flicker, etc. A ranking table prepared for the case of 30 cps repetition rate is shown in Table 1.

TABLE 1: Ranking chart of six phosphors for 30 cps operation.

Ranked in ascending order of probable modulation index:

Phosphor	Residual after 33 milliseconds
P28	85%
P12	70%
P7(y)*	45%
P1	4%
P4(y), silicate	1.3%
P20	0.1%

*(y) indicates that the phosphor's light output is passed through a yellow filter before it is viewed or measured; the blue component is thus eliminated.

Description of the Apparatus

The apparatus used to experimentally determine the cff of phosphor-human systems consisted of a number of CRTs having a variety of phosphor types, electical equipment to power and modulate the CRTs and a photometer to measure the average brightness of the CRTs. Two configurations were used. Figure 7 shows the configuration used to modulate the CRT beam current sinusoidally.

In Figure 7 the sinusoidal oscillator was of the RC bridge type, utilizing a bridged T network. It was continuously variable in one band from 2.5 to 18 cps, and in a second band from 12.5 to 90 cps. The output amplitude was 20 volts peak to peak. The output amplitude was held constant within 3% by a termistor circuit within the oscillator which regulated the internal positive feedback. The frequency control of the oscillator was calibrated from the 60 cps power line by observing Lissajous patterns on an oscilloscope.

The output of the oscillator was connected through a trimming potentiometer (SET 100%) to a linear wire wound potentiometer located on the control panel. The wire wound potentiometer had a dial calibrated in percent modulation. (A 10 turn Helipot was used initially, and controlled by a 10 turn dial readable to 1 part in 1000. This was replaced by a single turn potentiometer and a manually calibrated dial during the experiments because of operator annoyance with the "slow" response of the 10 turn control.) The attenuated signal from the calibrated potentiometer was connected to the input of the sine wave modulator.

The sine wave modulator was a high gain dc coupled feedback amplifier. Its input grid junction received a signal of −5 v dc and the attenuated sine wave from the control panel, which had a mean level of 0 volts. The amplifier's output drove the grid of the CRT being tested. Feedback voltage was taken from a resistor connected from the cathode of the CRT to ground. The CRT cathode resistor was varied to obtain control of the average brightness of the CRT's spot. The modulation system was adjusted as follows.

The modulation control was set to 0 and the CRT cathode assumed a positive voltage level proportional to the dc reference voltage in the modulator. The CRT cathode voltage was observed on an oscilloscope and its average value, and the 0 reference level were carefully noted. The modulation control was then set to 100% and the "SET 100%" trimmer on the control panel was adjusted until the cathode voltage varied from 0 to twice its average value. Both the average and the instantaneous value of CRT cathode current were exactly proportional to the ratio of cathode voltage resistor's resistance. As a consequence average cathode current could be controlled by varying the cathode resistor without affecting the calibration of the modulation control. Also, any non-linearities in the grid voltage versus cathode current transfer function of the CRT were virtually eliminated, since the grid-cathode transfer was within the feedback loop. The amplifier had a low frequency loop gain of about 18,000.

The low voltage power supply and the 10 kv power supply were regulated units of conventional design.

The 1, 2, 4 kv power supply was a single regulated supply, whose output could be set to any one of the three values by moving a wire on its output barrier strip to the proper terminal.

The CRT filaments were heated by a 6 volt automotive type storage battery, which was charged overnight when the equipment was not in use. When the equipment was in use, the battery charger was completely disconnected from the battery, to avoid the introduction of 60 or 120 cps ripple into the CRT cathode circuit.

The photometer was used to measure and set the average brightness of the CRT spot. It was normally mounted on a tripod which was set in front of the apparatus when brightness was to be measured. It included an f.3.5, 2-inch objective lens, a front surface mirror, an aperture plate, a Wratten No. 106 spectral correction filter, a 931A photomultiplier tube, and a regulated power supply for the tube. The Wratten filter was used to correct the S4 response of the photomultiplier's cathode, so that it then matched closely the spectral sensitivity curve of the standard CIE observer.[13] The lens and aperture plate provided an acceptance angle of 2.24 degrees focused on a surface 4 inches in front of the lens. A microammeter in the photometer read the anode current of the photomultiplier tube, and a 10,000 ohm resistor in series with the meter provide a video output signal for viewing on an external oscilloscope.

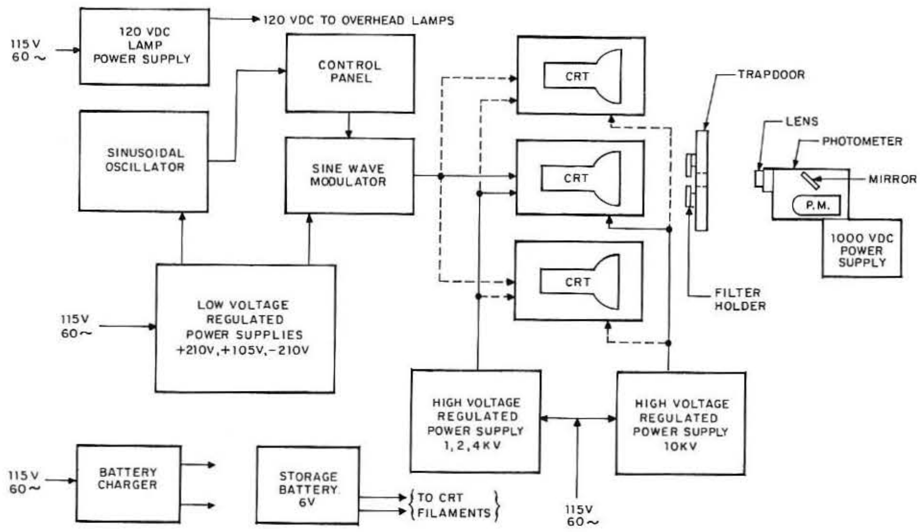

FIGURE 7: Block diagram of apparatus configured for sine modulation.

The photometer was calibrated with an incandescent lamp and a white diffusing plate, both of which were previously calibrated with a Leeds and Northrup Macbeth Illuminometer. The meter was calibrated to read 0 to 50 foot Lamberts and the readings could be reproduced consistently within 5%.

Four CRTs having seven different phosphors were used in the apparatus. The tubes and phosphors used were:

- Tube #1: RCA type C-7523B (similar to 3JP1), a 3 inch tube having a P1 phosphor.
- Tube #2: RCA type 5AZP4, a 5 inch tube having a P4 aluminized phosphor.
- Tube #3: National Union type 3FP7, a 3 inch tube having a P7 phosphor.
- Tube #4: Stromberg-Carlson type G3102, a 7 inch tube having 4 aluminized phosphors on its face. The faceplate was divided by radial lines into 4 sectors, each having a different phosphor. The phosphors were reported by Stromberg-Carlson to be P12, P20, P28, and P31.

The CRTs were mounted on subassemblies together with the voltage dividers and alignment controls required in each case to apply proper operating potentials to them. Only one of the subassemblies could be mounted in the experimental apparatus at one time; the apparatus could be converted rapidly from one phosphor to another by removing the CRT subassembly and replacing with another.

A hinged "trapdoor" was provided directly in front of the CRT faceplate in the apparatus. A slotted holder for 2 inch x 2 inch filters was mounted on the back of the trapdoor, directly behind a ¾ inch viewing aperture. It was used to hold gelatin neutral density filters, color filters when required, and a thin sheet metal aperture plate. The aperture plate had a 5/32 inch round hole, which formed the sharp edge of the spot seen by the observer. The plate was painted to match the front of the cabinet. The arrangement of the optical portions of the apparatus is shown in Figure 8.

The front surface of the cabinet housing the apparatus was made of hardboard painted with satin textured gray paint having a reflectivity of 0.62. The front surface of the cabinet was extended by means of wings along the top and on one side, so the observer's head was centered before a 36 inch by 36 inch square surface, nearly all of which was painted with the same gray paint. The apparatus was located in a small windowless room 6 feet by 8 feet. The walls were painted with flat gray paint having a reflectivity of 0.58. Four 40 watt incandescent lamps were distributed over the ceiling to provide approximately uniform distribution of light over the room's area. The lamps were energized from a regulated dc power supply to avoid 60 or 120 cps fluctuation of the ambient light. Under the conditions described, 10 foot candles of light were incident on the surface of a table top 30 inches from the floor. The brightness of the gray front of the cabinet was 3 foot Lamberts. The observer's eye was thus adapted to the 3 foot Lambert level after he sat before the apparatus for several minutes. Figure 9 is a photograph of the apparatus configured for sine modulation.

When the apparatus was used for pulse modulation of the CRT beam current, the sine wave modulator of Figure 7 was replaced by a pulse modulator. The variable frequency signal from the

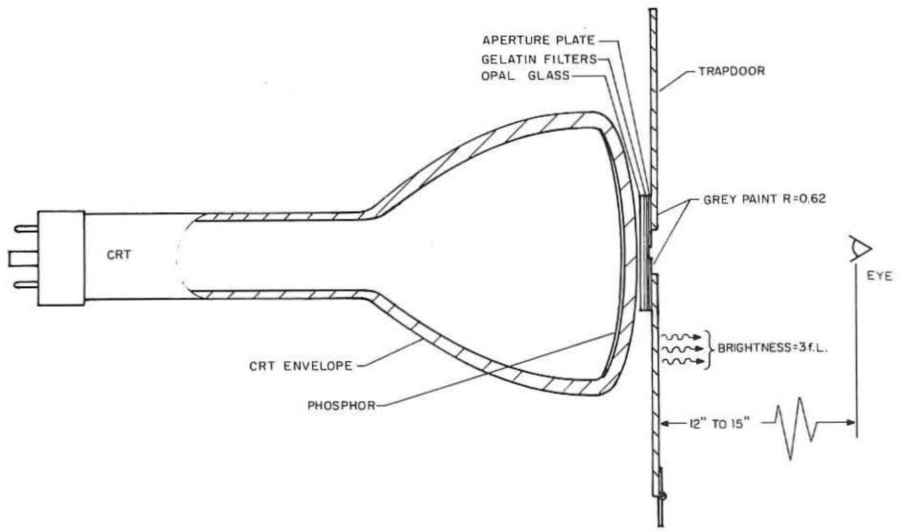

FIGURE 8: Arrangement of optical portions of apparatus.

oscillator was applied directly to the pulse modulator since the percent modulation control was not required. The cathode of the CRT was connected directly to ground during pulse modulation. The apparatus was otherwise identical to the configuration of Figure 7.

The pulse modulator was designed to produce a rectangular pulse to turn the CRT beam on for a period of time proportional to the period of repetition. Thus as the observer rotated the frequency control of the oscillator, both the pulse width and the repetition rate varied while the pulse duty cycle remained substantially constant. The duty cycle was held constant to prevent variation of average brightness as frequency was varied. To accomplish the constant duty cycle the pulse modulator circuit clipped the oscillator's sine wave to form a trapezoidal wave. The quasi-linear rise

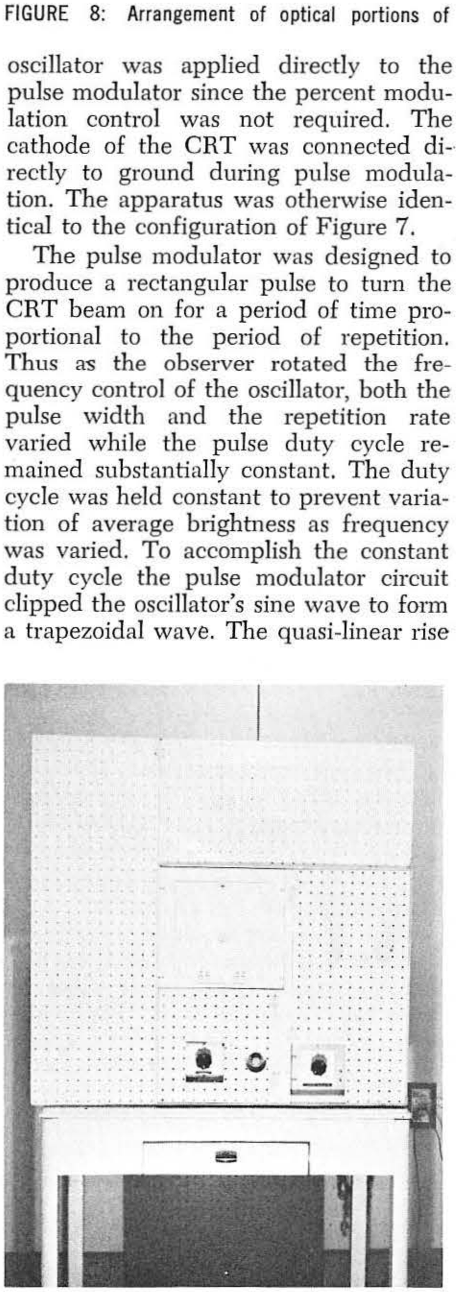

FIGURE 9: Photograph of apparatus configured for sine modulation.

and fall portions of this wave were formed into alternate positive and negative pulses by a short time constant RC differentiating circuit. The pulses so formed had a duration directly proportional to the repetition period of the applied sine wave, and an amplitude inversely proportional to the period. The negative pulses only were successively amplified, clipped, and inverted three times, resulting in positive output pulses with durations proportional to the period and constant amplitudes. The pulses were capacitively superimposed on a variable dc voltage and connected to the CRT grid. Manual control of the base line voltage of the pulses in turn controlled the peak voltage, which determined the intensity of the displayed spot. The pulse modulator provided rectangular pulses of 2% duty cycle over the frequency range from 15 to 90 cps.

Procedures and Results

The conduct of the experiment was divided into four phases, the testing of the human observers, the measurement of the sine modulation critical fusion frequencies, the measurement of the pulse modulation critical fusion frequencies, and a repetition of part of the pulse modulation measurements to determine the repeatability of the results.

Testing of Observers

The testing of the observers was limited to the determination of color perception and a near vision test for acuity. To determine color perception, each of the four observers was shown the first 12 plates of the Ishihara series and asked to name any visible numerals.[14] To determine acuity in near vision, each observer was asked to read a few words from the 4 point type on a Jaeger type reading card (American Optical Company Catalog 1980) at a distance of 12 inches and again at 18 inches.[15] All observers were found to have normal color perception and adequate near vision.

Measurement of Sine Modulation Critical Fusion Frequency

The sine wave modulator was installed in the equipment and the modulation control calibrated as detailed in the Description of Apparatus. Tube #1 (phosphor P1) was first installed in the apparatus and adjusted to produce a spot on its phosphor slightly larger than the 5/32 inch hole in the aperture plate and centered behind the hole. A neutral density filter of 0.5 density was installed in the filter holder and the photometer on its tripod was aimed at the lighted aperture. Correct aim and proper operation of the photometer was verified by observing that small deflections of its aim produced little or no reduction in the meter reading, but larger ones reduced the reading to 3 foot Lamberts, the brightness of the gray paint on the aperture plate. With the photometer aimed and the modulation control set to 0%, the average brightness control of the modulator was adjusted to give a reading of 32 foot Lamberts.

The neutral density filter was removed, thus increasing the brightness to 100 foot Lamberts, and the first observer was seated before the apparatus with his eye 12 to 15 inches from the aperture. Instructions and practice were given to the observer for a minimum of 15 minutes to permit adaptation to the ambient brightness of the apparatus room. The experimenter then set the frequency control to 3 cps and instructed the observer to (a) look directly at the spot, (b) increase modulation until definite flicker was seen, (c) reduce modulation until flicker was definitely absent, and (d) attempt to locate the exact threshold between flickering between flickering and steady brightness. All three modulation percentages were noted but only the last one was recorded. The frequency control was then set to the next higher frequency, and the observer was asked to repeat the determination of a threshold. The determination of threshold modulation was continued at successively higher frequencies until a modulation near 100% was obtained. Finally, the modulation control was set to 100% and the observer was instructed to set the frequency control to the threshold of flicker.

The neutral filter of density 0.5 was then inserted in the filter holder, thus reducing the brightness to 32 foot Lamberts and the sine modulation experimental procedure was repeated to determine the cff characteristic for this brightness level. Likewise, the procedure was again repeated with a filter of 1.0 density.

Experimental data using the phosphor P1 were obtained with each of the observers then available, by the procedure described above. The same average

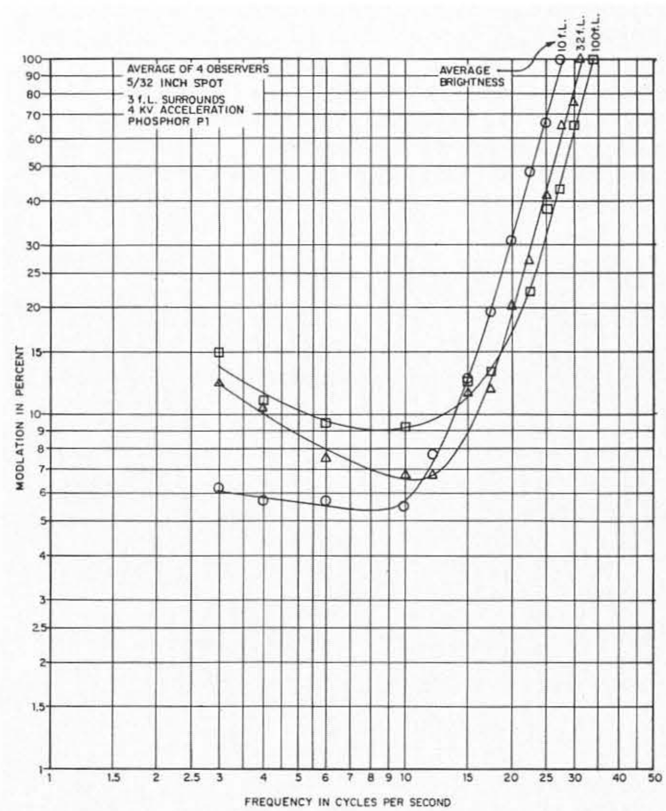

FIGURE 10: Sine modulation critical fusion frequency for phosphor P1.

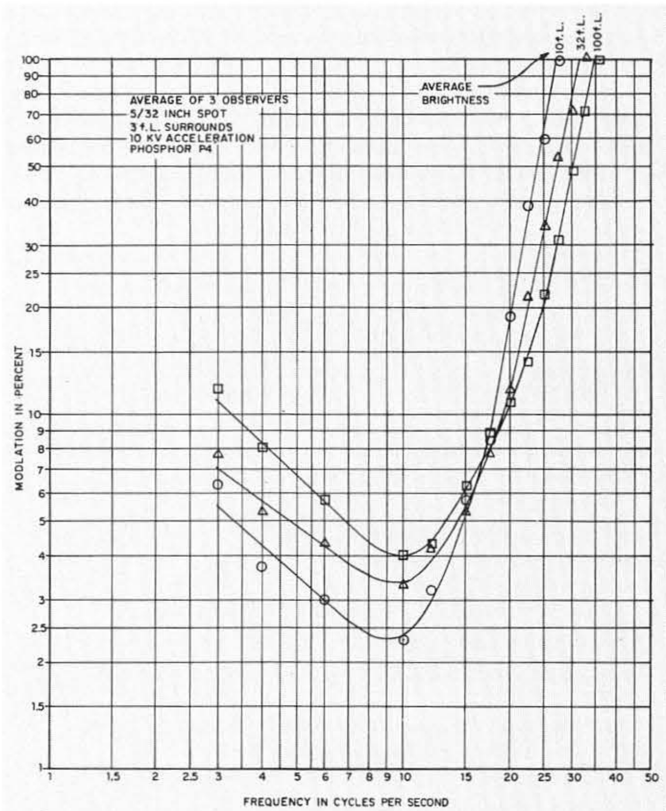

FIGURE 11: Sine modulation critical fusion frequency for phosphor P4.

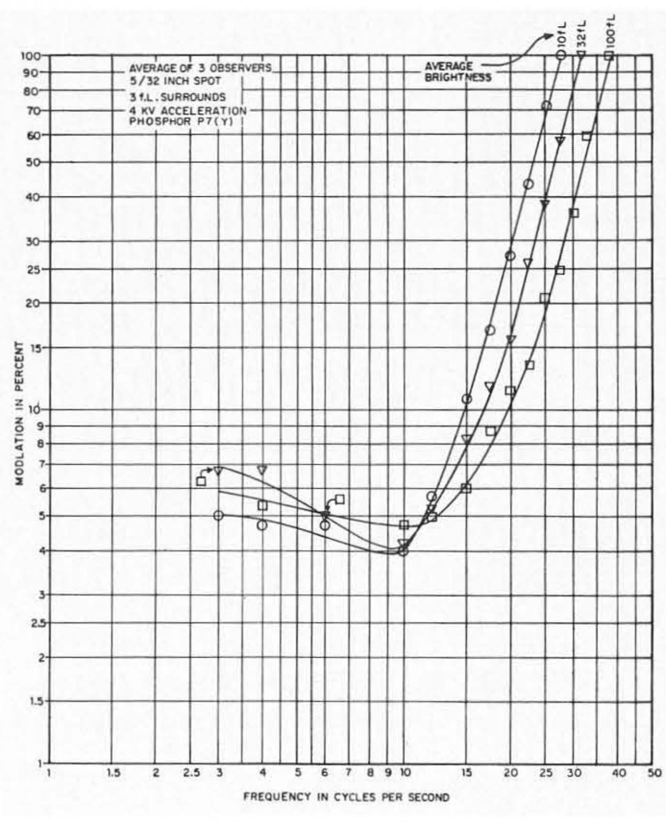

FIGURE 12: Sine modulation critical fusion frequency for phosphor P7.

levels and the same increments of frequency were used to enable arithmetic averaging of the data obtained from a number of observers. The averaged data of four observers, with phosphor P1, are plotted in Figure 10.

Experimental data using Tube #2 (phosphor P4) were obtained in the same manner as for the phosphor P1. The averaged data of three observers with phosphor P4 are plotted in Figure 11.

Experimental data using Tube #3 (phosphor P7) were obtained using the same procedure, but with a variation in the apparatus. A Wratten #21 yellow filter was installed in the filter holder in addition to the neutral density filter used in some steps. The yellow filter transmitted less than 0.1% of light with a wavelength less than 5200 Angstroms,[16] hence it effectively eliminated the shorter persistance blue component of the P7 phosphor but transmitted the longer persistance yellow component. The averaged data of three observers, with Phosphor P7, are plotted in Figure 12.

Experimental data for each of the four phosphors of Tube #4 were obtained using the same procedure as for phosphors P1 and P4; however only one observer was used with each phosphor. The data for P12, P20, P28 and P31 are plotted in Figures 13, 14, 15 and 16, respectively.

Measurement of Pulse Modulation Critical Fusion Frequency

The pulse modulator was substituted

for the sine wave modulator in the apparatus. Its rectangular pulse output was observed with an oscilloscope, and the duty cycle was adjusted to 2%. Tube #1 (phosphor P1) was installed, and its spot centered in the viewing aperture. The CRT foscus control was manipulated and auxiliary magnets were used to obtain a sharp edged evenly illuminated spot of 5/32 inch diameter. The photometer on its tripod was placed before the apparatus and aimed at the lighted spot. With the frequency control set at 30 cps, the average brightness of the spot was adjusted with the peak brightness control on the modulator until the photometer indicated 5 foot Lamberts. The phosphor was shielded from ambient room light during the adjustment of brightness so the indicated figure of 5 foot Lamberts was actually the average brightness level above ambient.

The first observer was seated in front of the apparatus at a distance of 12 to

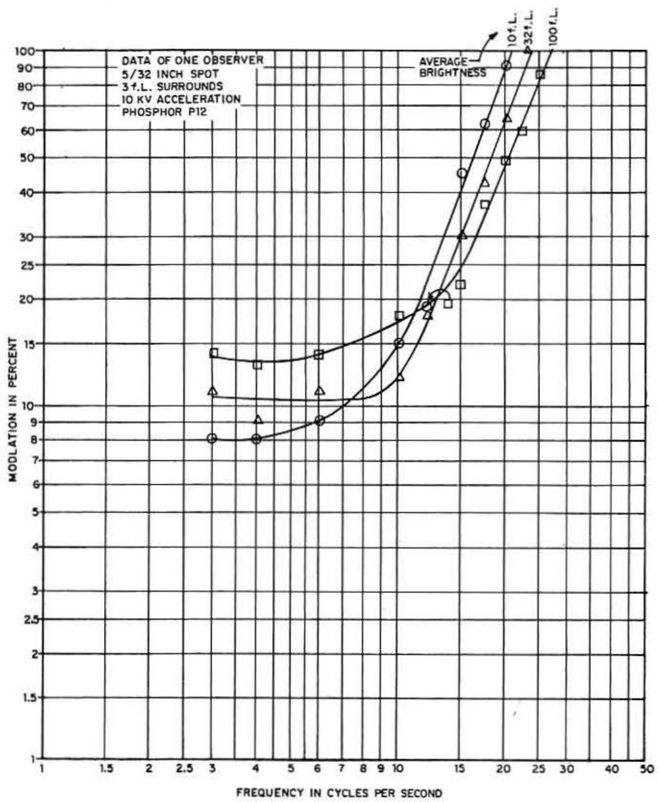

FIGURE 13: Sine modulation critical fusion frequency for phosphor P12.

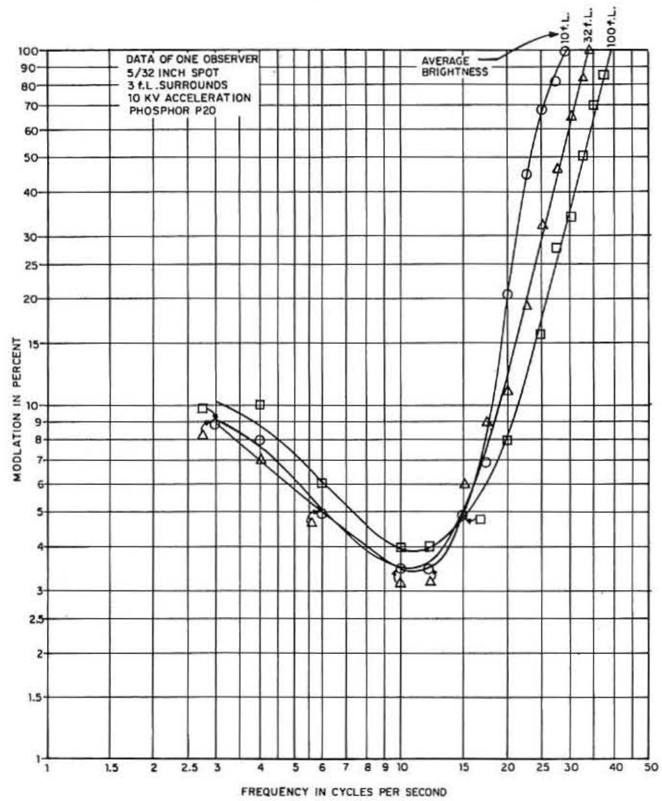

FIGURE 14: Sine modulation critical fusion frequency for phosphor P20.

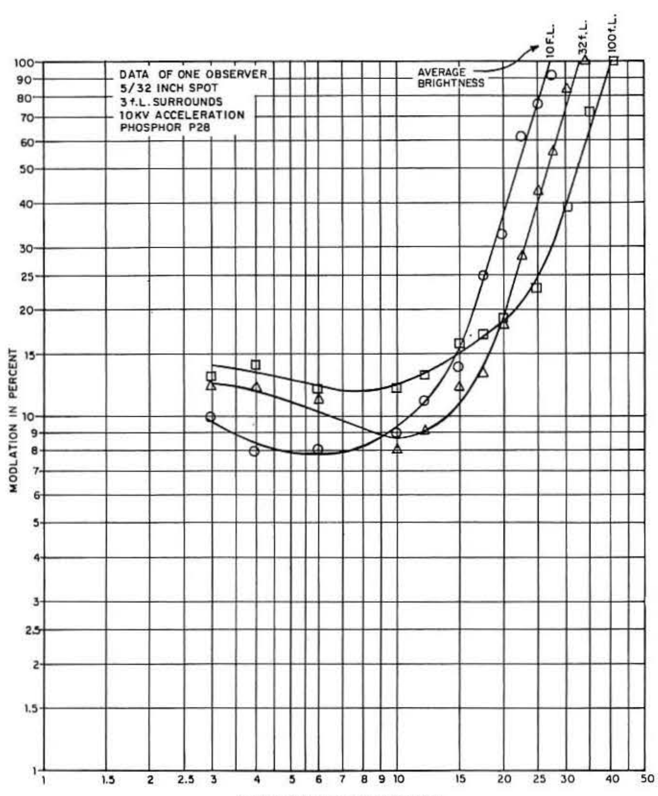

FIGURE 15: Sine modulation critical fusion frequency for phosphor P28.

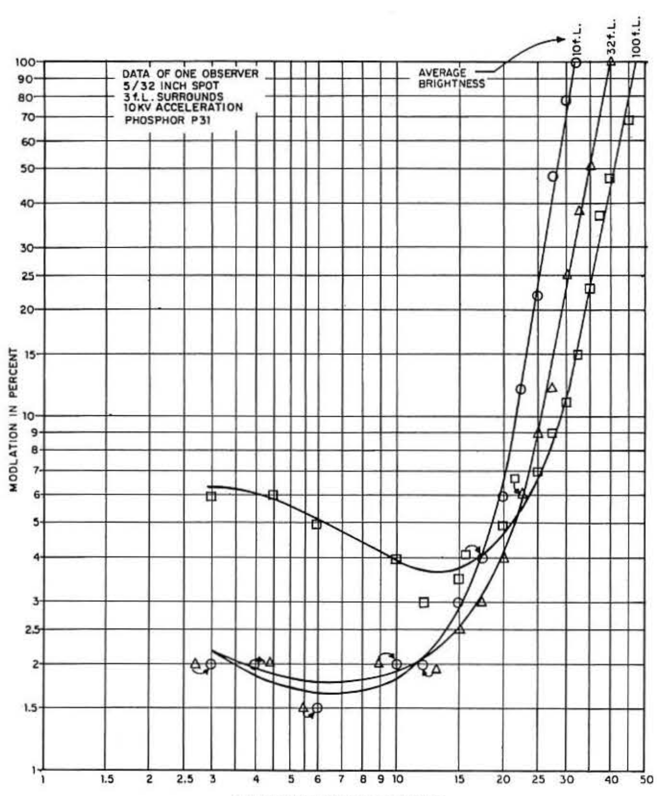

FIGURE 16: Sine modulation critical fusion frequency for phosphor P31.

15 inches, and instructions and practice were given for a minimum of 15 minutes to permit adaptation to the ambient brightness level. The experimenter then instructed the observer to (a) look directly at the spot, (b) decrease the frequency until flicker was definitely seen, (c) increase the frequency until flicker was definitely absent, and (d)

the procedure described above for the phosphor P1. When data were taken on the phosphor P7, the Wratten #21 yellow was inserted in the filter holder, as described in the sine modulation procedure. Three observers were used with each phosphor. The averaged data for each phosphor are listed in Table 2 and plotted in Figure 17.

TABLE 2: Pulse modulation critical fusion frequency data

Average of three observers

B is average brightness in foot Lamberts

f is critical fusion frequency in cycles per seconds

Phosphor P1		Phosphor P4		Phosphor P7*		Phosphor P12	
B	f	B	f	B	f	B	f
5	30.1	5	32.7	5	29.0	5	23.0
10	33.2	10	35.3	10	31.3	10	25.0
15	35.0	15	37.1	20	35.3	15	26.5
20	36.4	20	39.0	30	37.7		
30	37.0	30	40.5	40	41.3		
45	39.9	45	42.3	50	42.7		

Phosphor P20		Phosphor B28		Phosphor P31	
B	f	B	f	B	f
5	36.0	5	30.0	5	34.3
10	40.3	10	34.0	10	37.7
20	44.3	20	37.3	20	42.0
30	47.3	30	39.7	30	46.0
40	47.3	40	43.0	40	50.3

*With Wratten #21 yellow filter

attempt to locate the exact threshold between flickering and steady brightness. When the observer found the threshold the experimenter read the oscillator frequency dial and recorded the frequency. The observer was asked to repeat the determination until a total of three frequencies were recorded. Then the photometer was again aimed at the spot, the average brightness was set to 10 foot Lamberts, and the observer made three determinations of the critical fusion frequency at that brightness. This procedure was repeated at each brightness increment until a complete cff characteristic for the phosphor-observer pair was recorded.

Experimental data using the phosphor P1 were obtained with each of two additional observers, using the same procedure. Again the same increments of brightness with each observer were used to enable arithmetic averaging of the data. The data of each observer at each brightness level were first averaged to obtain individual average cff characteristics. The individual averages of the three observers were then combined to obtain a final average cff characteristic for the phosphor P1. The final average data are listed in Table 2 and plotted in Figure 17 along the line marked "P1".

Experimental pulse modulation data were obtained for each of the phosphors P4, P7, P12, P20, P28, and P31, using

When using phosphor P12, the average brightness obtained at maximum CRT grid drive was less than 20 foot Lamberts because of the low efficiency of the phosphor, hence the characteristic extended only from 5 foot Lamberts to 15 foot Lamberts.

Repeatability Measurements

About nine weeks after the completion of the experiments described above, the portions dealing with the pulse modulation of phosphor P4 were repeated to obtain an indication of the accuracy and reliability of the experimental data.

The photometer and the sine wave oscillator were first recalibrated, then Tube #4 (phosphor P4) was again installed in the apparatus and the pulse modulation procedure was repeated for each of three observers. The same observers were used for the original and the repeated experiments. All ambient conditions were duplicated as exactly as possible, although the increments of brightness selected for the second experiment did not coincide in every case with the original increments.

The data were averaged first for each individual, and the individual averages were then arithmetically averaged to obtain a final average cff characteristic for the phosphor P4 in the second experiment. The data of the repeated P4 experiment of March 14, 1965, are plotted in Figure 18 together with the data of the original P4 pulse modulation experiment of January 7, 1965 for comparison. The third cff characteristic line in Figure 18 is a plot of incomplete data taken on December 27, 1964, during exploratory preliminary investigations.

Discussion of Results

The experimental results, in general, support the theory that the critical fusion frequency of the observer may be modified by the characteristics of the phosphor and by the conditions found in information display systems to a degree which prohibits the reliable prediction of system performance from previously published data. The results also show that the ranking of phosphors according to their relative abilities to reduce flicker is possible, using accurate published persistence curves and the simple procedures described earlier in this paper.

Comparison of Sine and Pulse Modulation Data

For comparison purposes the sine modulation curves may be extrapolated to 200% modulation, and the cff values read at 10, 32, and 100 foot Lamberts. The pulse modulation curves of Figure 17 may be read directly for the 10 and 32 foot Lamberts values of cff and extrapolated for the 100 foot Lamberts values. The results of such an extrapolation are listed in Table 3.

TABLE 3: Comparison of sine and pulse modulation data

	10 foot Lamberts		32 foot Lamberts		100 foot Lamberts	
	Sine	Pulse	Sine	Pulse	Sine	Pulse
P1	34 cps	33 cps	38 cps	38 cps	42 cps	43 cps
P4	32	35	37	41	42	47
P7(y)	33	32	38	38	44	43*
P12	26	25	29	29	35	32
P20	37	40	42	47	55	54
P28	33	34	40	40	50	46*
P31	34	37	46	44	54	51*

The asterisked (*) data in the table were obtained from the figure by drawing straight line extensions of the lower portions of the curves. In each of these cases the upper portion bends to the right. The table shows substantial correlation, perhaps as much as can be expected considering the perils of extrapolation. It may be concluded from this that the actual characteristic curves for P7, P28, and P31 do not actually bend to the right, at least not as much as

Figure 17 indicates. The curves of Figure 17 are drawn to truly reflect the experimental data, of course. The bends may have been caused by the presence of beat frequencies between the pulse repetition rate and the 60 cps and 120 cps power frequencies, or by the variation of phosphor persistence with beam density. The latter effect may be expected with power-law phosphors.[8] A further significant conclusion drawn from Table 3 is that the data of both the sine and pulse modulation experiments is reasonably repeatable. This follows from the fact that the sine and pulse experiments were performed at different times, separated by a period of about two weeks.

Comparison of the Sine Modulation Data with Published Data

The data of de Lange[3] (see Figure 1) may be used for comparison since it is similar at least to the extent of the target size. The sine modulation experimental curves are roughly similar to de Lange's curves in that peak of sensitivity occurs in the frequency region near 10 cps, and all the curves tend to become more or less straight lines above 20 cps. Furthermore the straight line portions tend to become evenly spaced and parallel, and greater sensitivity to flicker is associated with higher average brightness levels at frequencies above 20 cps.

There are significant differences, however, between the experimental curves and de Lange's data.[3] The peaks of sensitivity on the experimental curves occur consistently at higher modulation percentages than reported by de Lange. This indicates that the sensitivity to flicker of the human observing a phosphor in the information display environment is far less than is predicted by the previously published data. There is some correlation between the persistence of the phosphor and the peak of sensitivity; generally, the shorter persistence phosphors have sharper peaks at lower modulation percentages than the longer persistence phosphors. The shorter ones thus approach the data of the de Lange more closely. The peaks are due to the human element in the system; peaks have been noted by experimenters who did not use phosphors.[3, 4] The reduction of sensitivity is due largely to the persistence of the phosphor, which in effect reduces the modulation index of the applied excitation.

An interesting observation is that the order of the curves of the three brightness levels is reversed in going from the low frequency region to the high frequency region; that is, the observer is more sensitive to flicker at 100 foot Lamberts in the high frequency region but more sensitive to flicker at 10 foot Lamberts in the low frequency region.

A similar reversal of low frequency order appears in the data of de Lange[3] but at different frequencies and brightness levels. The data of this experiment are not sufficiently precise in the low frequency region to enable any quantitative analysis or explanation. Insofar as information displays are concerned the region below 20 cps is of doubtful utility, and is of academic interest only.

The high frequency region exhibits at least qualitatively the expected departure from de Lange's data.[3] The experimental brightness units of foot Lamberts cannot be converted exactly to the photon units of de Lange without knowledge of the diameter of the observer's pupil.[17]

$$E_r = 2.69d^2B$$

where

d is pupil diameter in mm.
B is target brightness in foot Lamberts.
E_r is retinal illumination in photons.

If it is assumed that the pupil diameter was in the order of 3.3 mm, 1 foot Lambert corresponds approximately to 30 photons. Then it is obvious that the cff at 100% modulation of the phosphor-eye combination is significantly lower than for the eye alone. Furthermore, the cff with longer persistence phosphors is lower than with shorter persistence phosphors. These results are in agreement with the theory that the phosphor persistence effectively reduces the modulation index and that the reduction is greater when the persistence is longer.

The order in which the curves of the seven phosphors occur on Figure 17 may be compared with the order predicted from published persistence data (see Table 1). The phosphors are seen to actually have the predicted order, except for the notable case of the phosphor P28. The P28 discrepancy is so great that it was difficult to believe that the phosphor tested actually had the persistence characteristic registered with EIA.[6] Accordingly, the photometer and an oscilloscope were used to measure its decay curve. When the CRT grid was pulsed at 10 cps with a rectangular pulse of 2 milliseconds duration the signal at the anode of the photomultiplier tube was as shown in Figure 19. The measured decay time of less than 2 milliseconds accounts for the flicker characteristics of the tested P28. The fabrication records of the tube manufacturer, Stromberg-Carlson, were checked and they indicated that the phosphor was indeed a P28. The reason for the radical departure from the published decay curve has not been definitely established, but it is probably related to the temperature used during CRT processing. Stromberg-Carlson has reported that very long persistence was obtained with a P28 screen in a CRT which was baked at lower than normal temperatures during evacuation.

Reliability of the Data

Two aspects of the experimental data which are of interest to display system designers are (a) its repeatability and (b) the degree of variation to be expected among individual observers. Some information on these subjects is provided by Figure 18 and Figure 20.

In Figure 18 the pulse modulation cff data for the phosphor P4 obtained during the original experiments on January 7, 1965, are plotted along with equivalent data obtained during a repetition of the P4 experiment on March 14, 1965. When the best straight line is drawn representing each set of points, the two lines are seen to be parallel but separated by about 2 cps along the frequency axis. A third set of data obtained on December 27, 1964 during exploratory experiments is also shown in Figure 17, and is represented by a dashed curve. Since the exploratory data points are too few to justify a smooth curve, the dashed curve is drawn as a number of straight line segments connecting the points. It falls generally between the two complete curves. The differences between the three curves are believed to be due to inaccuracies inherent in the calibration and use of the oscillator and photometer, and to the drift of these instruments between calibrations. The oscillator was calibrated at the beginning of the initial experiments in November, 1964, and found to be about 2 cps in error upon recalibration in March, 1965. The photometer was also calibrated in November, 1964 and found to be reading 10% high upon recalibration in March, 1965. Figure 17 thus establishes the order of measurement errors in cff as about 2 cps.

In Figure 20, the average P4 pulse modulation cff for each individual observer is plotted to the same scales used for Figure 17. Each curve of Figure 20 is the average of the individual's original data (January 17) and his repeated data (March 14). Each plotted point thus represents the average of six determinations of the cff at a given brightness by one individual. In averaging the old and new data, some points were obtained by arithmetic averaging, where the old and new brightness levels were identical, while other points were obtained by averaging the old data points with new points obtained by straight line interpolation of the new data, where the old and new brightness levels did not coincide. For example, the new data cff value at 45 foot Lamberts was obtained by straight line interpolation between the cff values at 40 and 50 foot Lamberts. The curves were drawn as a series of straight line segments connecting the points, hence they give a visual indication of the degree of random variation remaining after averaging six de-

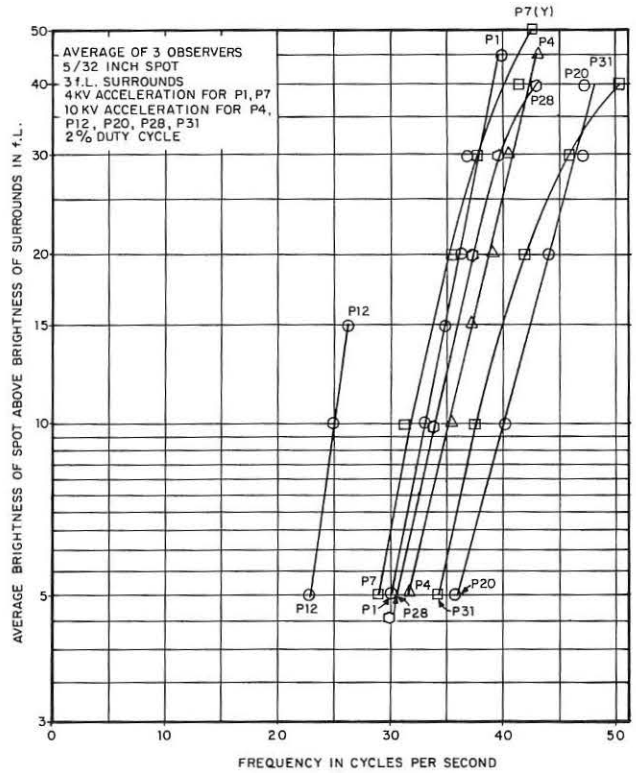

FIGURE 17: Pulse modulation critical fusion frequency.

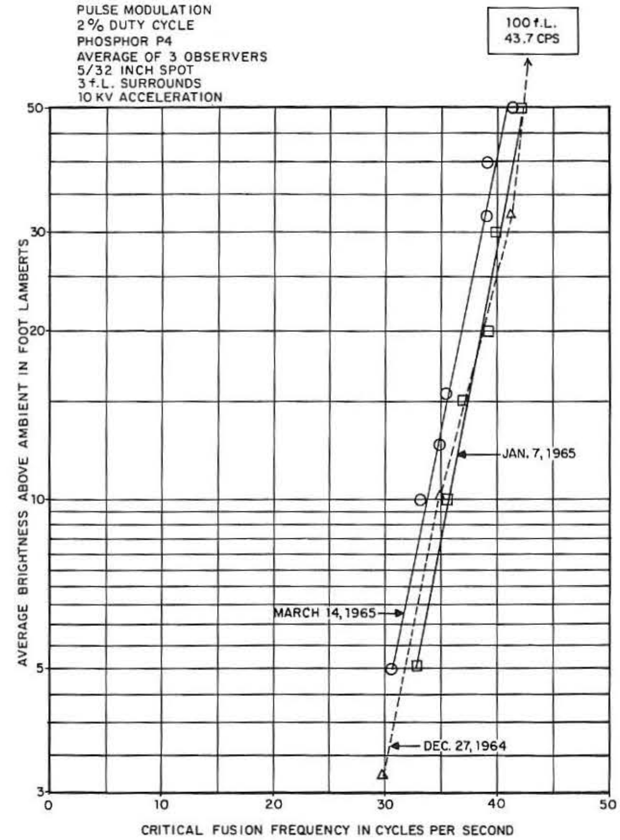

FIGURE 18: Repeatability of critical fusion frequency data.

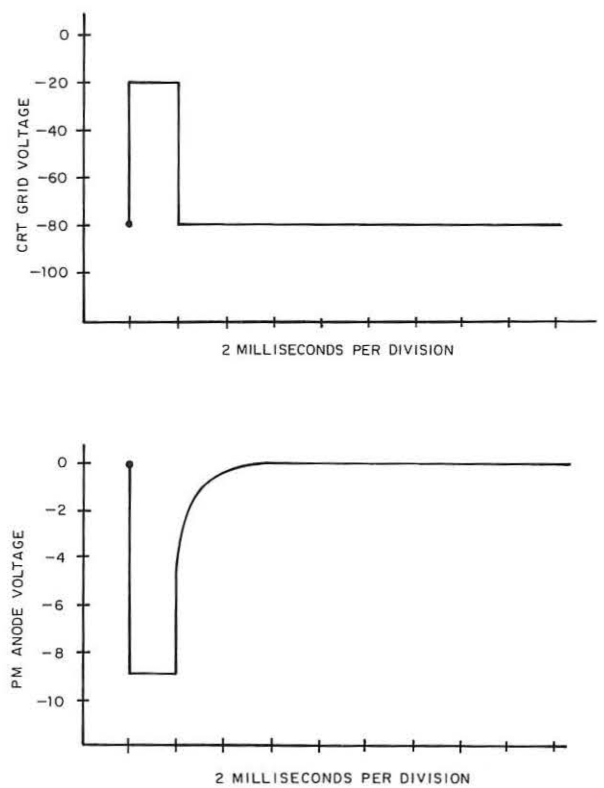

FIGURE 19: Experimental persistence characteristic of phosphor P28.

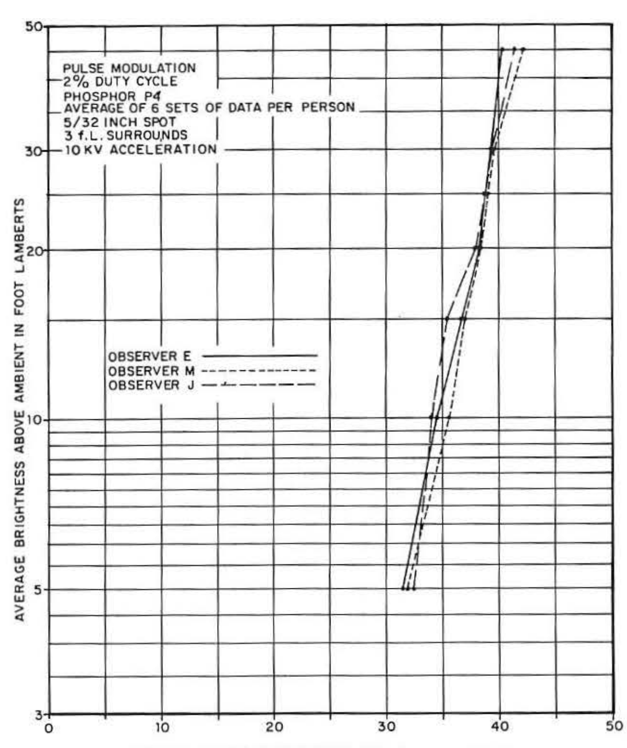

FIGURE 20: Critical fusion frequency variations among individuals.

terminations as well as a visual indication of the differences among the individuals. It appears that any individual differences which may exist are quite small. Indeed, if a best straight line were drawn for each observer, the three lines would very nearly coincide. This indicates that individual differences among humans of normal color perception and normal near vision acuity are negligibly small in the case of pulse modulation of a P4 phosphor in the 30 to 43 cps range. In view of Kelly's findings,[9] it should not be assumed that color blind persons have the same cff versus brightness characteristic.

The curves of Figures 10 through 16 indicate that experimental data in the region below 15 cps are subject to more random variation than data in the region above 15 cps. This reinforces the observation that the experimental observers had much more difficulty in deciding upon flicker thresholds in the low frequency region. Observers exhibited considerable indecision and frequently changed their control settings after having indicated that a threshold had been located. The original data of the sine modulation experiments also indicate substantial variations among the individual observers at the lower frequencies. The low frequency portions of the sine modulation data should therefore be considered less reliable than the high frequency portions.

Summary of Results and Conclusions

The results of the experiments and the conclusions drawn from them may be summarized as follows.

1. Predictions of a phosphor's relative flicker characteristics are possible to the extent of ranking the phosphors according to their relative ability to reduce the modulation index of the exciting signal, provided that accurate and applicable decay curves are available.

2. The critical fusion frequencies obtained by experiment on phosphor-human systems are substantially lower than is predicted by cff data on humans alone.

3. The phosphors tested ranked according to their ability to reduce flicker under conditions of repetitive pulse modulation are:

Least flicker P12
P7 (yellow component)
P1
P28
P4
P31
Most flicker 20

4. The sample of phosphor P28 tested did not have the persistence characteristic published by EIA,[6] at least under the conditions of these experiments.

5. The results obtained in these experiments are reasonably repeatable although variations in the order of 2 cps in the measured cff may occur on repeated experiments.

6. There were no significant individual differences among the three observers used in the pulse modulation experiments on phosphor P4.

Application of the Results

If it is desired to predict the cff of a CRT information display operating in an ambient of 10 foot candle illumination, with low duty cycle rectangular pulse modulation of the CRT, and the desired average brightness is between 5 and 40 foot Lamberts, the curves of Figure 17 may be used to obtain the cff directly. If the conditions of the proposed display system vary considerably from the conditions described herein, the curves should be used with caution, since these experiments indicate that the extrapolation of phosphor and fliker data generaly yields unsatisfactory accuracy.

Some deviation from the curves of Figure 17 may be expected when more than one flickering character is placed in the view of the observer (see data of Hecht and Smith reproduced on page 961 of Stevens handbook[18]). The cff in operational displays having many characters will therefore be higher than shown in Figure 17.

If the ambient light level exceeds 10 foot candles in an operational system, it may be expected to have a lower critical fusion frequency than predicted by Figure 17. The brighter surroundings will cause a reduction in the observer's pupil diameter, thus reducing the image brightness at the retina.

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Six New SID Fellows Elected

During its National Seminar at Santa Monica's Miramar Hotel on Thursday, March 31, the **Society for Information Display** announced the election of six new Fellows. One, to Mrs. Frances R. Darne, was posthumous. Photographs of the actual presentations to four others appear elsewhere in this issue of **Information Display,** as part of the coverage of the meeting. Those honored, in addition to Mrs. Darne, were Edith M. Bairdain, William P. Bethke, Carlo P. Crocetti, H. R. Luxenberg, and Petro Vlahos. The new awards bring to 10 the number of persons honored as Fellows. Those previously elected are Ruth M. Davis, Anthony Debons, James Howard, and R. L. Kuehn.

Edith M. Bairdain

"For contributions to the display and man-machine interface of vehicular traffic systems."

Edith M. Bairdain, of Communications Systems Inc., Paramus, N.J., a subsidiary of Computer Sciences Corp., received her BS and MA from Columbia University, and her PhD from Emory University. In her present position, she is responsible for systems analysis, development of design criteria, operational requirements, and human factors of large scale information processing and display systems. Previous employment has included Supervisor, Command and Control Personnel Subsection, ITT Data and Information Systems Division; Project Director on group development research at Columbia University, and consultant to several government and industrial agencies. She is a charter member of **SID** and has recently been elected National Treasurer for 1966. Other affiliations include membership in the American Psychological Association, Eastern Psychological Association, and the Human Factors Society.

Petro Vlahos

"For research and development in projection and photographic display systems, and contributions to display literature, and activities in display education."

Petro Vlahos is on the Special Studies Staff, Defense Systems Division, System Development Corp. He received his BS in EE from the University of California. His initial work with displays was as Engineering Group Head at Douglas Aircraft (1941), and later, with radar displays, at Western Electric (1944). From 1946-60, he engaged in research and development for the Motion Picture Research Council where he did extensive work in acoustics, lighting, projection optics and screens, camera rate stability, 3-D, and special photographic processes. He holds several patents in widely-used systems for traveling matte photography. He is a Fellow, Society of Motion Picture and Television Engineers; Charter Member of **SID;** and Member, American Ordnance Society.

Frances R. Darne

"For contributions to the science of information displays, particularly in the standardization of cathode ray and scan converter tubes. Also, for the initiation of scientific efforts for development of electron and CRT military specifications."

Frances Rice Darne, who died Dec. 21, 1965, was honored posthumously. A native of Philadelphia, Pa., she was the first woman to be graduated from Cornell University with a degree in Electrical Engineering (1923). She entered government service with the Navy at the beginning of World War II, after being associated with Dr. V. K. Zworykin of RCA, one of radio's pioneers. She became a national authority on electronic display devices and published numerous authoritative technical works in the field. She was the Navy representative on the Working Group on Special Services, Advisory Group on Electron Devices (DOD/R&E). She was a charter member of **SID** and instrumental in forming the Washington/Baltimore Chapter. She was Chairman of the IEEE Group on Electron Devices, and a member, ARRL and SWE.

William P. Bethke

"For leadership in advancing the state-of-the-art in display devices and theory, encouragement of research in displays, and service to the Society for Information Display."

William P. Bethke, Director of Engineering at the Air Force's Rome Air Development Center, N.Y., received his BS-EE from Marquette University, and conducted graduate studies at Illinois Institute of Technology. He presently serves as Chairman of the RADC Scientific and Professional Committee, in addition to his other responsibilities. He has been with RADC since 1952. Prior to that he was associated with Watson Laboratories, Eatontown, N.J., as a Project Engineer. He has served as **SID** Regional Director and Chairman of the Definitions and Standards Committee, is a charter member of the **ID** Editorial Advisory Board, and was recently elected National President for 1966. In addition to his other professional activities, he is Chairman of the Mohawk Valley Section of IEEE, and Chairman of the Vocational Advisory Board for the Rome, N.Y., Board of Education.

Carlo P. Crocetti

"For research on display theory and applications and contributions to standards."

Carlo P. Crocetti, Chief, Display Techniques Branch, Rome Air Development Center, N.Y., received his AB, MA, and PhD degrees from Columbia University. During the Korean War, he served on active duty with the Air Force. He has been employed at RADC since 1953. His fields of specialization include photometry, and colorimetry, systems and human factors in displays. In addition to **The Society for Information Display,** his memberships include The American Association for the Advancement of Science, Sigma Xi, Psychonomic Society, American Psychological Association, and the Armed Forces Vision Committee.

H. R. Luxenberg

"For dedication and perserverance in the founding and growth of the Society for Information Display, and for contributions to display research, education, and literature."

H. R. Luxenberg, Consultant and head of Lux Associates, Sepulveda, Calif., received his BA, MA and PhD from the University of California at Los Angeles. During World War II, he served as weather officer/instructor in the Aleutians. He is a consultant to both industry and government on visual data systems covering information display, document storage and retrieval, image processing, automated graphic production, and related topics. He was previously VP and Director of Engineering, Houston-Fearless; Manager, Display Department, Ramo-Wooldridge; Manager, Computing Center, Litton Industries; and Head, Simulation and Analysis Group, Remington Rand UNIVAC Division. He was a Co-Founder and first President, the **Society for Information Display,** and is presently National Executive Secretary.

New National Officers Named

Bethke

New national officers of the *Society for Information Display* were announced and inaugurated during the March 31 Directors' meeting at the well-attended Seminar in the Miramar Hotel, Santa Monica, Calif. Results of the election were compiled by Anthony Debons, Chairman, Nominating Committee, who could not be present. Retiring President James Redman presented the report.

New National Officers are W. P. Bethke, President; Sol Sherr, Vice President; Carl Machover, Secretary; and Edith Bairdain, Treasurer; H. R. Luxenberg remains Executive Secretary. In addition, the following Regional Directors were elected: Fordyce Brown, Northeast; J. Hoagbin, Central; R. Aiken, Western; and Ernest Storrs, Southern. Later, Glenn Whitham was appointed a Northeast Director to fill the post vacated by Carl Machover, new Secretary.

Biographies of new National Officers appear below, with the exception of Bethke and Bairdain, whose biographies appear in a separate story on page 53 of this issue of *Information Display*, covering their election as Fellows in *The Society*.

Solomon Sherr

Vice President

Mr. Sherr is the Display Section Head at Sperry Gyroscope Co., Great Neck, Long Island, N.Y. Prior positions include Chief, Data Processing and Display at the Budd Co., and Associate Chief Engineer at General Precision Inc.,, also in Data Processing and Display. He has 24 years of experience, and holds the BA and MS degrees, both from New York University. He is a charter member of *SID*, and has served as a regional director. He has published numerous articles, and holds several patents. He was awarded the Distinguished Service Award by the Mid-Atlantic Chapter of *SID* in 1965.

Carl Machover

Secretary

Mr. Machover is Manager of Sales, Information Displays Inc., Mt. Vernon, N.Y. During the past 15 years, he has been concerned with the design and marketing of display devices, servo components, and related equipment. He was with Skiatron Electronics, TV Corporation, and the Norden Division of United Aircraft Corp. prior to joining IDI. Mr. Machover holds two patents, and is the author of two books and several articles about displays. He has served as Northeast Regional Director of *SID*, as chairman of the Mid-Atlantic Chapter, and as program chairman for the *SID* Sixth National Symposium.

Ernest N. Storrs

Southern Director

Mr. Storrs is presently employed as Chief, Data Displays Branch, Systems Research and Development Service, Headquarters, Federal Aviation Agency. Among other accomplishments, he initiated developments for the Air Force 465-L and 473-L command and control systems; and initiated establishment of the Display Laboratory at Rome Air Development Center; he was Technical Director

Sherr Machover Bairdain Brown Hoagbin Aiken Storrs Whitham

for Plans and Operations at RADC. As Eastern Technical Director for Thompson-Ramo-Wooldridge, he supervised development programs of command and control display systems for DOD. He received his BA-Physics from Western States Teachers College.

William Ross Aiken

Western Director

Mr. Aiken is a consultant and Electrical Engineer. He received his BS-EE from the University of California, and is a lecturer, author and inventor. Among his 75 or more patents are the Kaiser-Aiken thin CRT, a basic solid state TV screen switching method, the audio expressor, the constant contrast TV control, and the electrostatic changeable message sign. He was engaged previously at the Lawrence Radiation Laboratory (1948-53); Director of Research, Kaiser Aircraft and Electronics (1953-62); and is presently an independent consultant. Other memberships include the IEEE.

Fordyce M. Brown

Northeast Director

Mr. Brown is President of Photomechanisms Inc., Huntington Station, Long Island, N.Y. He was Chairman of the *SID* Sixth National Symposium in New York in 1965, and has also served as Chairman of several SPSE symposia. Prior to joining Photomechanisms Inc., he was with Kenyon Instrument Company and the Eastman Research Laboratories. He is a graduate of the University of Wisconsin and a member of the Society of Motion Picture and Television Engineers, and the Optical Society of America.

Joseph E. Hoagbin

Central Director

Mr. Hoagbin received his degree from the University of Michigan, and has been associated with that school the past 15 years in the areas of operations analysis and research, as group head and department manager. His work has involved the study and applications of CRT displays, photographic and data storage and retrieval techniques applied to command and control, aerial reconnaissance, and ground surveillance systems.

Glenn E. Whitham

Northeast Director

Mr. Whitham is Staff Consultant, Control Systems Dept., Surface Radar and Navigation Operation, Raytheon Co. He holds a BS-EE from MIT, and has engaged in graduate studies at Northeastern University. He has been a staff member of the MIT Radiation Lab, and of Los Alamos Scientific Lab. At Raytheon, he has been associated with display or information systems in Tartar, Hawk, Mauler, on-board logistic spacecraft displays, FAA bright displays, and numerous control center display systems. He has served as chairman of the New England Chapter of *SID*.

More Than 200 Scientists, Engineers

More than 200 scientists and engineers from throughout the nation attended the first **Society for Information Display** National Seminar, at Santa Monica's Miramar Hotel March 31. The event, sponsored by the Los Angeles Chapter, is considered to have been extremely successful.

A challenging and provocative message was provided by luncheon speaker N. Petersen, President, Resources Synergistics Inc., Chatsworth, Calif.

He outlined the need for world-scope human affairs planning in which the "pulse rate and blood pressure" of global man is constantly measured and displayed to societies' leaders throughout the Earth. His challenge was directed to a professional audience who could very well influence the achievement of such a goal.

The seminar sessions dealt with new ideas and directions for research and development in the youthful industry of Information Display.

Included was a SID business meeting where national officers for the 1966-67 term were installed. They are W. P. Bethke, President; S.

(Top Left): National President William Bethke delivers acceptance address, as retiring President, James Redman (right) and other dignitaries listen. (Upper Left): Raymond Bernberg, chairman of host Los Angeles Chapter, calls Santa Monica seminar to order. (Lower Left:): Crowded sessions emphasize success of, and great interest in seminar. (Bottom Left): Luncheon was well attended. (Below): Louis Seeberger, new Publications Committee Chairman, addresses group on the importance of ID written word.

Attend LA-Chapter-Sponsored Seminar

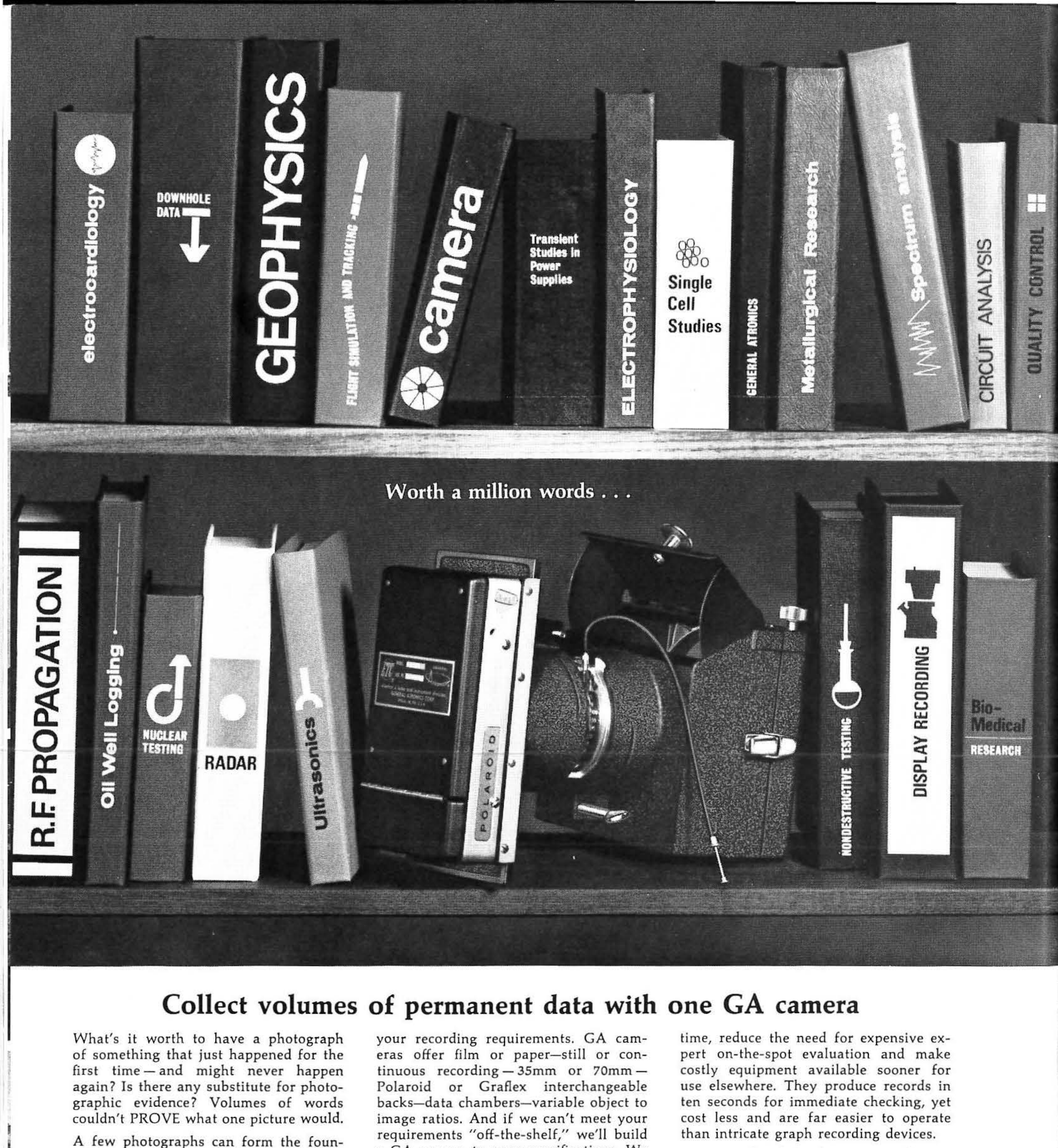
Sherr, Vice President; C. Machover, Secretary; and E. Bairdain, Treasurer. New Directors include F. Brown, North East; J. Hoagbin, Central; R. Aiken, Western; and E. Storrs, Southern. A separate story concerning the new officers appears on page 54 .

During the meeting, announcement was made by Awards Committee Chairman R. L. Kuehn, of the election to Fellow status of six prominent members. The late Frances Darne, one of the six, was eulogized by E. Storrs, chairman of the Washington Chapter, who was also among those elected a Fellow. Others include William Bethke, Edith Bairdain, Petro Vlahos, Harold Luxenberg, and Carlo Crocetti. A separate story concerning the new Fellows appears on page 53.

R. Bernberg, Chairman, host Los Angeles Chapter, presided. He introduced J. Redman, retiring National President, who gave a brief welcome address.

In his acceptance address, Bethke, the new National President, spoke of the need for improved communications, and of growth possibilities, particularly in the central region.

(Top Left): R. L. Kuehn (right), Chairman, SID Awards Committee, presents Fellow Scroll to William Bethke, one of six whose elections were announced. (Top Right): Ernest Storrs, Chairman, Washington Chapter, eulogizes the late Frances Darne, elected SID Fellow posthumously. Other Fellows elected, shown receiving their scrolls at Santa Monica, are (Center Right) H. R. Luxenberg, (Bottom Right) Edith Bairdain, (Bottom Center) Carlo Crocetti who could not attend, and (Bottom Left on centerfold) Petro Vlahos.



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New Literature

Stack Switches

Switchcraft has announced a Catalog No. 310, which presents detailed engineering specifications of the firm's line of stack switches. The 8-page catalog covers general purpose stack switches, telephone relay type stack switches, and "Tini-Stack" switches. Four stack switch kits for prototype design and production assembly are also listed.

Circle Reader Service Card No. 23

Waveform Display Analyzer

General Precision's Lnnk Group, Binghamton, N.Y., has announced an 8-page illustrated brochure describing its new graphic input/output device called the Waveform Display Analyzer. Designed to be coupled with any large digital computer, the manufacturer claims, the product can help reduce computer time and programming costs significantly.

Circle Reader Service Card No. 24

1-Digit EM Counter

Hengstler Numerics Inc., Palisades Park, N.J., has announced a 4-page bulletin describing its Hecon Decade FR 967. This is a single-digit electromagnetic counter, with visual and electric readout, electric transfer, and electric reset.

Circle Reader Service Card No. 25

Digital Motion Display

Theta Instrument Corp., Saddle Brook, N.J., has announced a new 12-page, 2-color engineering bulletin which fully describes the firm's unusual mechanical and electronic modules which convert mechanical motion into a remote digital display. Employed in such applications as weighing scales, antenna pedestals, rotating tables, film readers, and positioning devices, it provides a remote, illuminated digital display of the appropriate parameter.

Circle Reader Service Card No. 26

Mobile Communication Tubes

Amperex Electronic Corp., Hicksville, L.I., N.Y., has announced a "Push-To-Talk-Service" reference guide which contains the basic specifications and PTTS ratings for 11 of the most popular mobile communications tubes. PTTS is a tube rating system originated by Amperex based on the actual operating conditions that now prevail in mobile communications.

Circle Reader Service Card No. 27

Submin Indicator Lights

Dialight Corp. has announced a new 12-page catalog which presents a full line of two-terminal, fully insulated subminiature indicator lights for mounting in 15/32- and 17/32-in. clearance holes. All products meet or exceed MIL-L-6723 and MIL-L-3661. *Catalog numbers have been changed* to reflect the firm's new unified part number system. Part numbers now designate the appropriate finish, built-in resistor (when necessary) and hardware for each unit.

Circle Reader Service Card No. 28

Digital CRT Displays

Digital Equipment Corp., Maynard, Mass., is offering a 4-page color brochure on its lines of Digital CRT Displays, including the Type 340 Precision Incremental Display, Type 338 Programmed Buffered Display, Type 30 Precision Display, Type 34 Oscilloscope Display, 370 Light Pen, and others.

Circle Reader Service Card No. 29

Fiber Optics Brochure

Chicago Aerial Industries Inc., Barrington, Ill., is making available a new 4-page brochure which provides a comprehensive list of fiber optics applications and the basic principle of fiber optics is graphically explained. The wide variety of CAI fiber optic products, quality standards and material combinations are also specified.

Circle Reader Service Card No. 30

Sealed Pushbutton Switches

Micro Switch, Freeport, Ill., has announced a data sheet describing its new 2PB900 Series of small, momentary action (push-on release-off) pushbuttons sealed at panel, with bushing, plunger and terminals designed to shrug off water, dust, and dirt. These meet MIL-STD-108D submergence requirements up to 10 psi water pressure for one hr. Two SPDT subminiature snap-action switches potted in brass enclosure to prevent contact contamination are used in each pushbutton. Data Sheet No. 242.

Circle Reader Service Card No. 31

Document Storage/Retrieval

A new 12-page booklet, No. D001, describing the Ampex Videofile document storage and retrieval system is now available from Ampex, Redwood City, Calif. The booklet features a complete flow chart of document filing and retrieving, in addition to an explanation of the concept of recording document images on magnetic tape.

Circle Reader Service Card No. 32

Illuminated Pushbutton Switches

Master Specialties Co., Costa Mesa, Calif., has announced a new 24-page 1966 catalog of information display illuminated pushbutton switches, word indicators and other devices for display and control.

Circle Reader Service Card No. 33

Digital Plotting Newsletter

California Computer Products Inc., Anaheim, Calif., regularly publishes a bi-monthly newsletter highlighting performance of various products. The recent Jan/Feb issue graphically portrayed certain specialized capabilities through presentation of a computer-generated reproduction of Mona Lisa.

Circle Reader Service Card No. 34

Information Display Devices

Master Specialties Co., Costa Mesa, Calif., announces the availability of a 24-page, 2-color catalog which details its line of information display illuminated pushbutton switches, word indicators, and other devices for display and control. Specify "1966 Catalog #2007a".

Circle Reader Service Card No. 35

Miniature CRT Socket

Connector Corporation, Chicago, Ill., offers without cost Data Sheet 35A, just published. It illustrates and describes new Type 546 miniature CRT socket with simplified cost reducing design for mating with the new miniature JEDEC E7-91 basing cathode ray tubes.

Circle Reader Service Card No. 36

on the move

In a series of high-level appointments, Amperex Electronic Corp. has promoted **John J. Doherty** to VP, **Hubert van Meurs** to VP/Mfg., and **Edward Meagher** to VP/Mktg., Semiconductor and Receiving Tube Div. Other appointments include **A. W. Patterson,** Midwest Regional Mgr.; **Edward King,** Product Mgr., Industrial Tubes; and **Louis A. Arpino,** Asst. Product Mgr., Electro-Optical Devices Dept.

The Magnavox Co. has appointed **Arthur P. Stern** VP/Research, and Gen. Mgr., The Magnavox Research Laboratories. Stern is a prominent scientist and author, as well as vice chairman of the IEEE Professional Group on Cicuit Theory, a director of the San Fernando Valley Engineers Council, director of the International Solid State Circuits Conference, member, R&D Committee of NSIA, and member, board of advisors, of the IEEE Journal, Spectrum.

Granger Associates has appointed **F. J. Haines** Mgr., Video Products.

Haines

Wiechers

James E. Wiechers has been named Mgr., Information Systems Co., a newly-created department of Lear Siegler Inc., and **Will A. Cummins** is Dir., Computer Technology.

Donald P. Vaughan has been named VP/Mktg., at Duncan Electronics Inc.

Conrac Div. of Giannini Controls Corp. has promoted **Robert G. Parks** to Alphanumeric Display Product Mgr., and **A. L. Landsperger** Sls. Mgr. of the Alphanumeric Display Department.

Ampex Corp. has named **Thomas E. Davis** VP/Gen. Mgr., Audio/Video Communications Div.; **Robert J. Weismann,** VP/Gen. Mgr., Instrumentation Div.; **Robert R. Owen,** Gen. Mgr., Mktg. Div.; and **Bernard M. Brenner,** Mgr., Instrumentation Engrg., Instrumentation Div.

TRW Systems, Redondo Beach, Calif., has appointed **Edwin A. Goldberg** to the position of manager for its newly-formed Guidance System Development Department, Guidance and Navigation Laboratory, Electronic Systems Division. The department Goldberg heads is responsible for the design and development of guidance and navigation systems including gyrocompasses, inertial attitude references, and strapdown guidance systems.

James W. Hulfish, prominent in the audio-visual field, has been appointed national products manager, audio visual division of Elco Optisonics Corp., Willow Grove, Pa., according to **Leo Kagan,** Elco's marketing VP.

(Continued on page 67)

ID Readout

Condensed Minutes, March Directors' Meeting

To keep *SID* membership updated on activities of the National Office, it is planned to print brief abstracts of the Minutes of the Board of Directors and the Executive Committee Meetings in the Journal. Members' comments about any of the Board or Committee actions will be appreciated; just send them to the National Secretary.

The first meeting of the newly-elected *SID* Board of Directors was held on 31 March 1966 in Santa Monica, California. Glenn Whitham was appointed to fill the Northeast Regional Director vacancy which was created when C. Machover was elected Secretary of the society.

Discussions about National repositories continued.

Based on early returns from the membership poll, the Board decided that there should be one full symposium and one technical meeting per year. The full symposium will include exhibits and published proceedings; but the technical meetings will have no exhibits and will probably not publish the proceedings.

The schedule for the next three years was tentatively established as:

Fall '66	Boston	Full Symposium
Spring '67	San Francisco	Full Symposium
Fall '67	Mid-West	Technical Meeting
Spring '68	Far-West	Technical Meeting
Fall '68	East Coast	Full Symposium
Spring '69	Far-West	Technical Meeting

Plans for an *SID* lapel button were approved. Chairmen for the standing committees were appointed: Membership, P. Damon; Nominating, J. Redman; Convention, F. Brown; Honors and Awards, R. Kuehn; Publications and Archives, L. Seeberger; Definitions and Standards, Dr. Crocetti.

G. Whitham and R. Bernberg were appointed to a long range Planning Committee. Administrative questions were discussed. — C. Machover, *Secretary*

Honors and Awards Committeemen

Rudolph L. Kuehn, Chairman of the **Society for Information Display** Honors and Awards Committee, has announced today the appointment of three committee members. They are Dr. Carlo Crocetti, and Messrs. James H. Howard and Petro Vlahos.

The Honors and Awards Committee is planning an early campaign throughout **SID** for nominations to Fellow. A format for use by local chapters and individuals is being prepared and will be made available in the near future. This marks a departure from the less formal Fellow elections which have been the custom in the past. The Committee hopes thereby to sample a broader cross-section of **SID** membership early enough to enable awards to be reviewed and prepared in time for the annual business meeting.

This year, for the first time, the Committee is also investigating the possibility of establishing other awards and recognition for outstanding professional achievement in the field of displays. Inquiries, comments, and suggestions may be addressed to the Chairman of the Honors and Awards Committee, **Society for Information Display,** 11168 Santa Monica Blvd., Los Angeles, California 90025.

Control Displays for Automatic Aircraft Landings

The Bunker-Ramo Corp. has received additional funding for continuation of its human engineering support to the Air Force Pilot Factors Program. Objective of the program is to provide the control-display technology necessary to integrate the pilot into an automatic landing system during approach and landing. Results, in addition to improving the capabilities of current commercial and military aircraft, may have direct application to the problem of providing an all-weather landing capability for supersonic transports. To date, control display concepts have been generated which allow manual instrument approaches to 50 ft. altitude. Investigation is now centering on additional control-display techniques for flight between 50 ft. and surface. The approach being taken to all-weather landing is development of a system that provides the precision of an automatic landing while retaining the flexibility and decision-making capabilities of the human pilot. The Program is directed from WPAFB where engineering is conducted, with in-flight validation experiments performed by the R&D Branch, Air Force Instrument Flight Instructors' School, Randolph AFB. Bunker-Ramo's Human Engineering Support Group develops each test syllabus, assists in data collection, analyzes results, and reports on effectiveness of the various control-display concepts.

1-Microsec Memory, Keyboard-Display Announced

Raytheon Co. has incorporated in its recently-announced 520 Computer System a 1-microsecond main memory and a new keyboard-display station which makes possible on-line display and editing. Other improvements in the 520 Computer System include a compatible disc pack, improved analog interface units, and read-time FORTRAN IV. The 1-microsec memory makes possible the execution of floating point additions, 24-bit and 39-bit mantissas, in 18-33 microsecs and 31-32 microsecs, respectively. Floating point multiplications of the same size words are accomplished in 22-23 microsecs and 65-66 microsecs, respectively. The 2-microsec memory will continue to be available for lower performance requirements. The keyboard display station combines a 6½ by 8½ in. CRT and a 64-character keyboard to provide on-line display and editing of stored data. For on-line program debugging, programs can be displayed in a format identical to the programmer's coding sheet, a page of coding at a time, and changed a line of code at a time.

High-Speed Camera for CRT Displays

The 3-M Co. has announced the development of a high-speed 16-mm camera designed for recording CRT displays and other high-speed transitory data, the Wollensak Fastax WF-32. With special CRT equipment, plus phenomena with trace widths in the submicrosecond range, rise times in the nanosecond range and repetition rates in the megacycle range can be recorded. The WF-32 is a continuous-motion type camera featuring highly-accurate speed regulation and rapid start, stop, and restart operation over a wide speed range of 12½ to 100 ft/sec (150 to 1200 in/sec). Maximum speed is reached in 3.2 secs with a fully-loaded 1200-ft. supply spool and is regulated to with 2% of the running value. The camera may operated over its entire speed range without gear or motor changes. For ultra-high-speed framing, a pick-up for synchronization with a stroboscopic flash unit is available. The standard camera has a 1200-ft. capacity darkroom-loading magazine.

Automatic Mapping System

The B-8 Steromat, a system for automatic mapping, has been introduced by the Autometric Operation of Raytheon Co.'s S&ISD, Alexandria, Va. Produced jointly with Wild-Heerbrugg Ltd., Switzerland, the new system is three instruments in one – an automatic orthophotoprinter, automatic stereo model digitizer, and automatic contour compiler. The B-8 is stated to have potential in controlling machine tools in industrial processes.

Technical Meeting Schedule

THE AMERICAN DOCUMENTATION INSTITUTE will hold its 1966 national convention Oct. 3-7 in Santa Monica, Calif., with "Progress in Information Science and Technology" as its theme . . . The New England Chapter of THE SOCIETY FOR INFORMATION DISPLAY will host the Seventh National Symposium in Boston at the Somerset Hotel in Oct. 18, 19, and 20, 1966 . . . THE SOCIETY OF PHOTOGRAPHIC SCIENTISTS AND ENGINEERS will hold an international "Colloquium on the Photographic Interaction Between Radiation and Matter" Oct. 26-29, 1966 . . . The XIIIth INTERNATIONAL SCIENTIFIC CONGRESS ON ELECTRONICS was held in Rome, Italy, June 15-20, simultaneously with the XIIIth INTERNATIONAL EXHIBITION OF ELECTRONICS, NUCLEAR ENERGY, RADIO, TV AND CINEMA.

Man-Computer Graphics

Lockheed-Georgia Co. has developed a system to be utilized in the manufacture of airplane parts, called Man-Computer Graphics (MCG), which ties together more closely the designer, computer, and machine producing the parts. Sitting at a computer console and communicating with the computer through a "display scope", the operator draws the part directly on the display. The design appears in three views, giving a 3-D representation. Precise dimensions are input numerically. A computer-produced tape controls the machine cutting the part. Immediate corrections of errors may be made by the operator. Lockheed states that the probability to tape error is greatly reduced, and tape-production time is reduced by a factor of ten.

Aircraft Weighing/Displaying System

Fairchild Controls Div., Fairchild Camera and Instrument Corp., Hicksville, L.I., N.Y., has produced operational versions of the STAN™ (Sum Total And Nosegear) integral weight and balance system. The system accurately weighs an aircraft and displays the weight data and center of gravity information on cockpit-mounted indicators. STAN functions by taking pressure force measurement in the oleo struts of the landing gear and summing the outputs for display on the digital indicators. CG data is displayed as a percent of the mean aerodynamic chord of the aircraft. Through a cockpit display which provides the pilot "at-a-glance" CG safety confirmation, the system provides an important safety function by confirming or refuting manually calculated data prior to takeoff – the most critical point in the aircraft's operation.

1600-sq.-ft. Data Display System

Kollsman Instrument Corp., Elmhurst, N.Y., has developed a data display system, the Delphic II, which displays visual information in real time on an illuminated screen (up to 40 x 40 ft.) from radio, radar, telemetry systems, data links, computers, teletypes, and other sources. Capable of displaying data simultaneously in four colors, the system was initially developed for tactical command centers and is now available for varied defense and commercial applications.

Dynamic Data Displays

Experimental data records of physical phenomena ranging from Lake Michigan current circulation patterns to seismic disturbances have been computer-transformed into dynamic displays at IIT Research Institute. These novel displays, similar to animation movies, extend the scope of computer applications from quantitative to qualitative analysis. IITRI's Cognitive Systems Simulation Laboratory is preparing a film illustrating dynamic displays generated both from empirical sources and mathematical models. The 16-mm film includes dynamic displays of Lake Michigan current circulation patterns, triaxial strain gauge data, three-axis seismometer data, orbiting asteroid position-time points, and missile silo response to a shock wave.

Laser Television System

In a current Perkin-Elmer laser TV system, a CW laser light beam is deflected by a pair of rotating mirrors so as to completely scan the subject in a series of contiguous lines every sixtieth of a second. The energy reflected from the target is sensed by a photo-multiplier and used to intensity modulate the CRT in a TV monitor whose election beam is scanning in synchronism with the transmitted laser beam. The laser utilized is a helium-neon unit with approx. 15 mw output in a 1 milliradian beam at 6328 angstroms. The scanner consists of a 16-sided, 1.5 in. diam. polygon prism mounted integrally with the scanner motor rotor. Driven from a 2 kc solid-state power oscillator, the motor drives the line scanner at approx. 60,000 rpm or 16,000 scans/sec. Following the line scanner, the beam strikes the 24-sided frame scanner running at 150 rpm or 60 frames/sec. The beam reflected off the frame scanner continues toward the target. The line and frame scanners, in combination, cause target scanning at rates similar to commercial TV (15,750 lines/sec; 60 frames/sec). The 1 milliradian beam results in resolution similar to commercial TV. A portion of the laser energy reflected from the target is detected by an 11-stage photomultiplier with an S-20 photocathode. A special 90-angstrom filter in front of the photocathode rejects 99% of the background light and precludes saturation from background. A preamplifier (with a gain of 26 db and bandwidth of 5 mc) raises the signal to a level sufficient to drive the video amplifier of a commercial TV set and intensity-modulate the trace on the picture tube. Photocells in the scanning beams synchronize the TV monitor deflector circuits with the scanning laser beam.

Pulsed Laser Holography

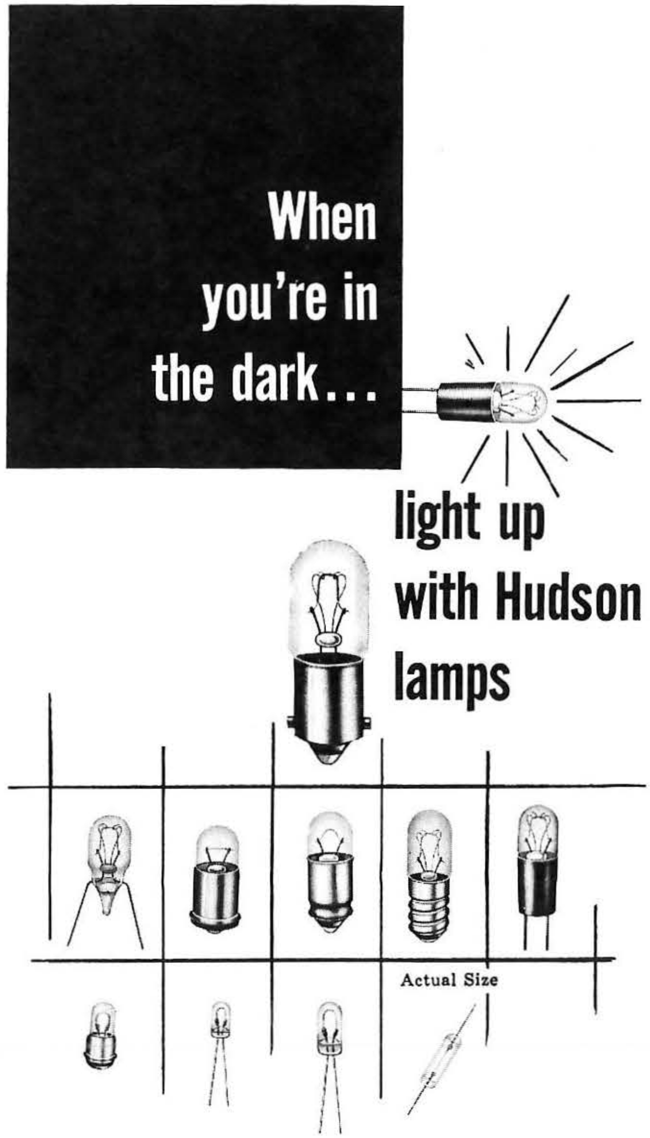
Three technical staff members of the Physical Research Center, TRW Systems, Dr. Robert E. Brooks, Dr. Lee O. Heflinger, and Dr. Ralph Wuerker, recently presented a paper on "Pulsed Laser Holograms" at the Fourth International Conference on Quantum Electronics, Phoenix, Ariz. Readers of *Information Display* may study another technical discussion on the subject "Holography and Display", by Jerald V. Parker, of Electro-Optical Systems Inc., in this issue of *ID*. Although the basic idea of holography was developed nearly 20 years ago by Gabor, the relatively recent invention of the laser has made holography practical and created many new possibilities for its application. According to the TRW scientists, in contrast to ordinary photography, holography permits complete recording and reconstruction of the light waves scattered by or reflected from a subject illuminated by laser light, an ability unique to holography. The most striking feature of the hologram image is its absolute realism — it retains all the three-dimensional and parallax aspects of the original subject. First, image resolution and detail is great, permitting microscopic examination of the image; secondly, lenses and other focusing devices are eliminated, allowing an almost unlimited depth of field; and, thirdly, the recording of a wide range of subject-brightness values may be recorded with fidelity. A pulsed laser hologram can record the subject in 20 billionths of a second or less. Applications of holographic microscopy appear important in the studies of air pollution, biology, oceanography, electrification of fluid streams, combustion processes, colloid rocket engines, and other fields. Another important application is interferometry, in areas such as aerodynamics, fluid dynamics, plasma and explosion research, material strain and vibration, erosion, optical testing, and quality control.

Business Notes and News

Nortronics Div., NORTHROP CORP., has been awarded a feasibility contract from the Photographic Management Div., BuWeps, for development of a digital code writing device . . . CONTROL DATA CORP. has announced the acquisition of SAMARUGHI & C., S. p. A., by purchase of all outstanding capital stock from the Swiss corporation, GEM ESTABLISSEMENT, in exchange for Control Data common stock . . . The Optics Div., ARGUS INC., has been awarded a contract to design and manufacture the guidance lens and window for the Walleye program of THE MARTIN CO., in conjunction with a $12 million Martin contract awarded earlier this year . . . PHILCO CORP. has received a contract from the Navy Electronics Laboratory for the delivery of a new type of message-handling unit featuring a visual display for experimental use in a system known as CAPE (Communications Automatic Processing Equipment) . . . A computer-based scanning system to study bacteria, viruses, and other microorganisms which infect man is being built by the UNIVERSITY OF CALIFORNIA, BERKELEY under a grant from the Public Health Service, as part of a 5-year, $1.24 million program to be administered by hte NATIONAL INSTITUTE OF GENERAL MEDICAL SCIENCES . . . Under a $1.3 million subcontract from THE BOEING CO., prime booster contractor, RAYTHEON CO. has developed and produced five electronic display systems which will be utilized to test and check out the first stage of the NASA Saturn V, in the Apollo program . . . BMA CORP., computer components manufacturer, has completed the move of its ferrite and ceramics grinding div. from North Hollywood to Chatsworth, Calif. . . . CALIFORNIA COMPUTER PRODUCTS INC., has concluded an agreement to acquire DATA-PLOT ASSOCIATES INC., a Maryland corporation, for an undisclosed stock consideration, making it a wholly-owned subsidiary . . . SQUIRES-SANDERS INC. has completed arrangements for exclusive distribution in the U.S., Central, and South America of a line of closed-circuit TV products made by the NESS CORP., Tokyo . . . The Board of Directors of C. P. CLARE & CO. has announced the acquisition of PENDAR INC. as a wholly-owned subsidiary. Pendar will operate as CLARE-PENDAR CO., with headquarters in Post Falls, Idaho. Lewis G. Zirkle has been named VP and gen'l mgr., and C. E. Fisher will continue as president . . . ELECTRO INSTRUMENTS INC. has become the San Diego Operation of HONEYWELL INC., Test Instruments Div.

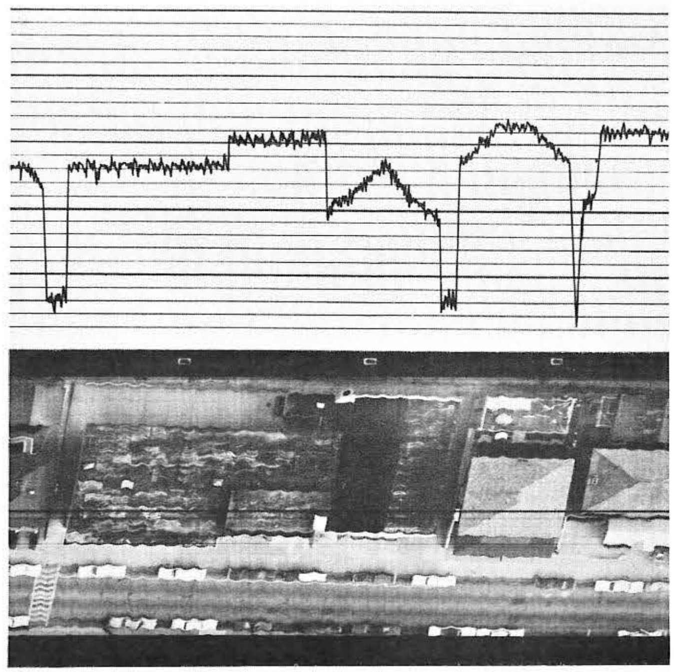
Integrated-Circuit Information Retrieval

ASCAM Inc., Palo Alto, Calif., has developed a complete integrated-circuit information retrieval system (ICIRS) which contains, on microfilm, complete specs of the integrated circuits offered by a specific industry, as well as



all available application notes and price lists. The system includes film cartridges and index cards (updated every 60 days), a coincidence card reader, a push-button selector device, and DATA's printed IC listing. A printer-reader machine is optional. The simple, fast-access memory system allows any combination of 250 descriptors and ranges to be used in file search. Each descriptor card locates every spec in the file which fulfills the description. Search may be made in any order of descriptors, and negative searches are readily accomplished.

Laser Distance-Measuring Device



Spectra-Physics has developed a laser distance measuring device having an accuracy of a small fraction of an inch per mile. Called the "Geodolite", it uses a modulated light beam from a continuous-wave gas laser and provides analog or digital readout of phase difference comparisons between transmitted and returned beams. Digital readout has resolution as fine as 0.001 ft. Readout can also be obtained in metric units. Relatively compact design includes separate electronic and optical packages, and unit can be easily set up in the field by one man. With the Geodolite, measurements can be made from point-to-point on the ground, ground-to-air, or shore-to-ship. The device is especially suited for first-order geodetic surveys at distances of more than 50 miles, Earth motion studies, precise control surveying, and mapping.

Educational Home Computing System

A joint study is being conducted by the Catholic Schools Diocese of Brooklyn and International Business Machines Corporation to see how well high school students can communicate with a computer from their homes by utilizing a push-button telephone. With the push of a button, the students can tell the computer (the IBM 1710, located 50 miles away from the test group) to add, subtract, multiply, divide, or find a square foot. The computer responds by voice, instantly giving answers drawn from its pre-recorded vocabulary. A plastic card placed over the keyboard guides the user in entering problems by showing which buttons are used for special commands, in addition to entering numbers. Also in the educational field, National Cash Register Company is making available to schools an audio tape instruction course in computer programming for its Series 500 computer system. Average time for completion is 60 hours.

(Continued from page 60)

Lee F. Weiler Jr. has joined the staff of Information Sciences Associates.

General Atronics Corp. has announced appointment of **Alfred Stapler** to the new position of Gen. Mgr.

William A. Flood has been named Pacific Southwest District Mgr., Information Systems Marketing, General Electric Computer Dept.

Richard O. Stephenson has been appointed VP/R&D, Digital Development Corp., and **Kenneth L. Giles** has been named Engrg. Mgr.

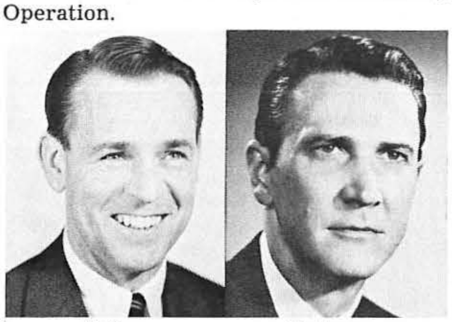
Richard H. Foy has joined Tasker Instruments Corp. as Requirements Analysis Chief.

Melvin Bermat has been appointed Gen. Mgr., Fairchild Hiller Electronics & Information Systems Div.

Bernard D. Loughlin has been named recipient of the Modern Pioneer Scroll Award of the National Association of Manufacturers. He is Exec. VP, Hazeltine Research Laboratories, and inventor of the constant luminance and shunted monochrome systems of transmission of color content of a TV signal, wihch form the basis of the present color TV system. He was the first recipient of the Zworykin TV Prize by the IRE, and has received the David Sarnoff Gold Medal Award of the Society of Motion Picture and Television Engineers.

J. Frank Weatherman has joined Engineered Electronics Co. in the newly-created position of Mgr., Welding Services.

G. William Heath has been appointea to the newly-established post of mgr. of application engrg. for the Schenectady sales office, and **Larry Butkus** has been named San Francisco District Mgr., both of GE's Information Systems Marketing Operation.



Butkus   Harleman

Thomas W. Harleman, former midwestern regional manager, has been named national sales manager for Ampex Corp., Redwood City, Calif., succeeding **Robert R. Owen,** general manager of marketing.

William C. Bennett has joined Precision Instrument Co. as VP/Mktg.

Scientific Data Systems has appointed **Rigdon Currie** as its Eastern Rgnl. Mgr.

Burton A. Yale has joined Data Machines Inc. as Dir., Computer Mktg.

John J. McArdle has joined Servo Corporation of America as Mgr., Infrared/Electro-Optics Div. He is a member of the Optical Society of America and the Infrared Information Symposium.

Systems Engineering Laboratories Inc. has appointed **Marvin L. Bunn Jr.** area manager of its new Huntsville, Ala., office.

Circle Reader Service Card No. 45

ID Correspondence

Hardware Readout Displays Needed

The Weather Bureau has applications for various types of display devices ranging from large dynamic types to small individual high and low speed request/reply types.

The Bureau wishes to survey the display market for equipment which might be suitable for the following applications:

(1) Message Composition, either on or off line to a computer or communications system, with editing capability

(2) Request/reply service, either high or low speed, which would operate in conjunction with remote computers.

I would like to obtain from you a list of manufacturers to whom I can direct inquiries for the above applications. Since the applications mentioned are only two of many, it may be desirable to have other manufacturers' names and addresses for other areas of ID interest to this office. This would enable me to choose companies whose equipment would seem to meet our applications.

Sincerely,
G. Stanley Doore
Chief, Presentation & Display Br.,
Weather Bureau,
Environmental Science
Services Admin.,
U.S. Department of Commerce

J. D. Little has been promoted to gen'l mgr. of the Information Systems Div., Planning Research Corp.

Joseph B. Domagala has been appointed dir. of mfg. of Dynasciences Corp.

The appointment of **Dan W. Burns** as pres. and a director of The Electrada Corp. has been announced by the Board of Directors of the firm.

Data Products Corp. has named **Harold Kurth** dir. of engrg., it was announced by **Graham Tyson,** VP.

Richard J. Petschauer has been appointed a VP of Fabri-Tek Inc., and will head the firm's newly-formed Research and Engineering Div., according to **M. F. Mickelson,** pres.

Herbert M. Doherty has been appointed public information mgr., and **Robert S. Knapp** has been appointed advertising mgr. for the Sperry Gyroscope Company Div. of Sperry Rand Corp. Doherty succeeds **Roy E. Wendell** who has resigned to join Republic Aviation Div. of Fairchild Hiller.

Dean W. Davis has joined the scientific staff of The Rauland Corp. (a wholly-owned subsidiary of Zenith Radio Corp.) as Production Mgr., Photoelectric devices.

Radio Corporation of America has named **L. Gillon** to Mgr., Television Picture Tube Mfg. Dept. He will be succeeded in his former post of Plant Mgr., Marion, Ind., by **S. M. Hartman.**

Jerald V. Parker

Jerald Parker is currently engaged as an Engineer with Electro-Optical Systems Inc., conducting investigations of gas laser efficiency and solid-state electro-optical modulators, including theoretical studies of high-power laser amplifiers. He received his BS (1960) and PhD (1964) from California Institute of Technology. Prior to his EOS appointment, he was employed as Research Assistant with Tektronix Inc. devising techniques for fabrication of solid-state diodes, surface passivation, and means to improve switching speed. Prior publications include articles in *Physics and Fluids,* Vol. 6, 1963; and *Physical Review Letters,* Vol. 11, p. 183, 1963.

Rodger Elmo Turnage Jr.

Rodger E. Turnage is Chief, Electronic Design, Stromberg-Carlson, San Diego, with responsibilities for design of CRT displays, microfilm recorders, and electronic hardcopy printers. His prior positions with Stromberg-Carlson have included Project Engineer on USN sea surveillance displays, and Engineering Section Head responsibilities. Earlier, with Hazeltine Electronics, he participated in design of radar PPI and SAGE systems displays. He received his BS/EE from U of Texas (1951) and MS/E from UCLA (1965). He is a charter member and Director-at-Large of *SID,* a Sr. member of IEEE, and a member of Phi Eta Sigma, Eta Kappa Nu, and Tau Beta Pi.

G. T. Nagy

G. T. Nagy is presently engaged in Information System Engineering with Nortronics, a Division of Northrop Corp. He has had extensive R&E experience since receiving his MS/EE from the University of Technical Sciences, Budapest, Hungary. He served in the University's Research Institute (1950-57) before coming to this country, where he became associated with Sylvania Electric Products Inc.; then, with Ampex Corp., Optics Technology Inc., Autonetics Div. of North American, and Electro-Optical Systems Inc., Pasadena. He holds patents on a Stairstep Generator Semiconductor Circuit, and an Electro-Optical Sensing Device.

ID Products

Incremental Curve Follower

California Computer Products Inc., Anaheim, Calif., has developed an incremental curve follower system which provides automatic, precise, incremental tracing and recording, in computer tape format, of analog graphic data for processing by a digital computer.

The system is compatible with both character-oriented and word-oriented computers, according to CalComp, and provides automatic regulation of tape record length and automatic recording of record ID codes. Any standard 500 series CalComp digital incremental plotter, drum, or flatbed may be fitted with the photo-electric tracer head for use with the system. Designated model 471, important applications include digitizing of oscillograms and strip chart recordings, and automated pattern size grading for the apparel industry.

Circle Reader Service Card No. 50

Silicon Logic 6-In. CRT

Systems Engineering Laboratories Inc., Fort Lauderdale, Fla., has introduced a general-purpose 6-in. CRT display with logic designed of silicon monolithic integrated circuits. Termed SEL Model 80-806, the compact electrostatic display is reportedly bright and easily read, ideally suited for uses requiring alphanumeric display, small-screen monitoring for direct computer readout, data display for plotting, bar graph display, vector or dot display, remote monitoring and photorecording display.

As an alphanumeric display, the unit is capable of displaying up to 512 characters. As a vector or dot display more than 3800 dots or vectors can be displayed. Features include P-31 Phosphor tube, 0° to 55°C temperature operating range, accuracy of ±1% of full scale and a 60-cycle refresh rate for prevention of flicker. CRT shielding permits asynchronous operation with 60-cycle AC line. The unit can be operated remotely up to 1000 feet from a refresh memory. It is designed to fit in a 24 x 19 x 7 in. rack.

Circle Reader Service Card No. 51

Microcircuit Bonding

Hughes Aircraft Co. Welder Dept., Vacuum Products Div., Oceanside, Calif., has announced a compact multi-purpose microcircuit bonding system capable of welding, brazing, parallel-gap soldering and thin-film diffusion bonding. It occupies only 20 in. of bench space, yet includes a power supply, two types of bonding heads, micropositioning apparatus and accessories, and a Bausch & Lomb stereozoom microscope.

Both weld heads feature adjustable-gap electrodes together with the firm's "compliant electrode suspension system" which reputedly assures consistent fit-up of the electrodes to the work. The smaller head, for ultra-fine materials, has successfully bonded wires to termination pads less than 1 square mil in area. The larger head is used for parallel-gap welding or soldering of flat packs, memory plane matrixes and other surface bonding applications.

Circle Reader Service Card No. 52

Laser Beam Expander/Filter

Spectra-Physics Inc., Mountain View, Calif., announces the manufacture of a precision beam-expanding telescope with a built-in spatial filter, for utilization with gas lasers operating at 632.8 nm. Applications for the telescope include long-distance transmission of laser beams, to minimize beam divergence; interferometry and related uses requiring large-diameter collimated beams; and applications such as holography and optical data processing where it is desirable to have a laser source of uniform, noise-free intensity.

The beam-expanding telescope, Model 331, permits expansion of the usual 1 to 2 mm beam size to a 50 mm diameter collimated beam. Optics are highly corrected, producing a plane wave output to within 1/10th wave when properly focused. The spatial filter, a part of Model 331 but optionally available as a Model 332 filter, produces spherical wavefronts between F/30 and F/3.6. Though the beam-expanding telescope and filter are designed to mate with Spectra-Physics' CW gas lasers, they are reported to be adaptable to lasers of other manufacture.

Circle Reader Service Card No. 53

Compact X-Y Recorder

Varian Recorder Division, Palo Alto, Calif., has announced a new Model F-60 compact, solid-state 8½ by 11 in. X-Y recorder which offers a high sensitivity of 100 microvolts/in.; a constant 1 megohm input impedance; accuracy of 0.1% full scale; a floating and guarded input; and a proven vacuum system that permits the operator to position, load, or remove paper while the system is in operation. Features include modular construction and plug-in voltage.

The recorder utilizes a cartridge type pen and enclosed feedback potentiometers. Common mode rejection is over 150 db. Transverse exceeds 60 db. Variable damping is standard. The time sweep provides 8 ranges from 0.5 to 100 secs/in. at an accuracy of 2%.

Circle Reader Service Card No. 54

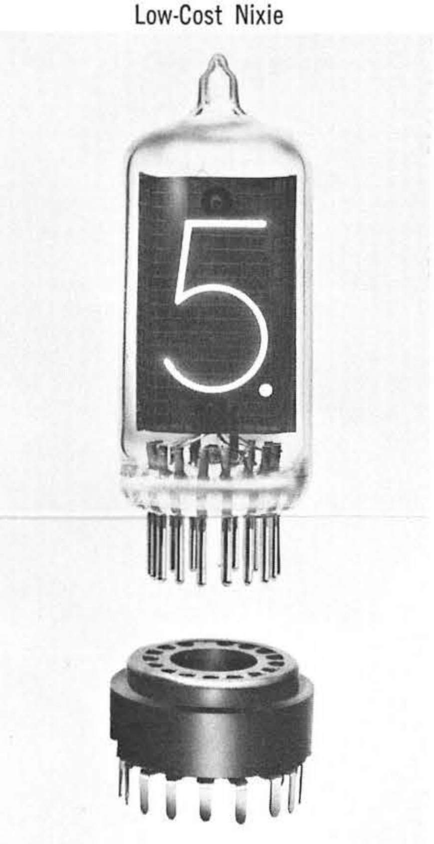
Zero Defect Wiring

Micro Metrics Inc., Paterson, N.J., has announced an unusual series of "rapid systems" electronic production devices which the firm claims offer unusual efficiency and faster methods, with which operators with no prior experience can be rapidly trained (in a matter of hours) to produce zero defect wired assemblies of every description.

According to MMI, its rapid systems "have proven capable of increasing production rates by two to five times, depending upon the size and complexity of the product." The system reputedly instructs electronic production workers in point-to-point wiring with numeric, alphanumeric, or other illuminated displays. It verifies that punched-tape instructions were carried out before providing new instructions, and provides automatic testing for continuity or shorts.

Circle Reader Service Card No. 55

Low-Cost Nixie



Burroughs Corp., Electronic Components Div., Plainfield, N.J., manufacturer of Nixie® cold-cathode readout tubes, has introduced a Nixie of new design and construction which will sell for under $5 in quantities of 1000. The numeric readout tube, termed Type B-5440, is a side-viewing tube with a 0.750 in. max bulb width for 0.8 in. center-to-center spacing, and a 0.6 in. character height in a bulb only 1.8 in. max height to minimize instrument panel dimensions.

Circle Reader Service Card No. 56

Integrally-Molded Base Lamps

Tung-Sol Industries Inc., Newark, N.J., has introduced a new development in subminiature incandescent lamps – the integrally molded base. The lamps have been designed for the specific requirements of the computer industry. Initial production units have been successfully proven out in pilot installations over the past year, according to Tung-Sol, and a series of standard units for computer use are available.

The integrally-molded base lamp employs a plastic (nylon or other thermoplastic materials) base molded to a solid bulb, replacing not only the separately-attached metal base, but also the mated socket it requires. Since there is no bulb-socket separation, all leads are internally sealed against corrosion, and exposed leads can be of corrosive-resistant material. Color coding is also possible, simplifying replacement procedures.

Circle Reader Service Card No. 57

Submin Display Light

A new SDL Series subminiature display light with separate connector is now available from Transistor Electronics Corp., Minneapolis, Minn. It is just 0.24 in. diam., and lights mount on ¼-in. centers horizontally and vertically. They are designed for use where panel space is limited or where small indications, such as decimal points, are wanted.

A choice of connector hook-up (SDL-A Series) or wire lead (SDL-B Series) is available. Terminals for the SDL-A Series are two 0.018-in.-diam. gold-plated pins for insertion in the connector supplied with the indicator. Solder cups are provided on the connector. The SDL-B Series has 6-in.-long nylon-coated leads stripped 3/16-in. Other wire lead terminations can be provided to fit specific requirements. The SDL Series uses 100,000-hour T-1 incandescent lamps and 13 lens colors are available. Features include its miniature size, full range of lens colors, choice of connector hook-up or wire lead, and low heat dissipation.

Circle Reader Service Card No. 58

Completely Sealed Switch

The Precision Products Div. of Chicago Dynamic Industries Inc., Chicago, has introduced a new completely sealed tab type thumbwheel switch with panel and switching elements separately sealed against hostile environments. Termed Series PS (panel sealed) they are assembled in clean-room atmosphere. According to the manufacturer, the complete sealing not only protects the switch against dust, salt spray, corrosion and other contaminants, but prevents contamination from getting through to relays and other components.

Precision Products recommends the series especially for RFI applications. The series retrofits CDI Series TTS, and can be furnished in both decimal and coded versions. Life is in excess of 100,000 operations; only ⅝-in. panel space is required for each switch module.

Circle Reader Service Card No. 59

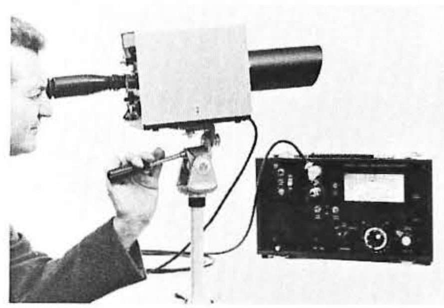
Alphanumeric Input Station Terminal

Control Data Corp., Minneapolis, Minn., is now marketing a Control Data 3020 alphanumeric input station terminal, a keyboard entry console unit capable of composing variable alphanumeric messages for transmission over a data collection system network. Messages are composed in an off-line mode by typing in a conventional manner on the four-row keyboard. A total of 63 characters may be entered by use of the keyboard, which provides the operator with a printed copy of the message format.

At the same time, the data is recorded on a punched tape, using standard ASC II code. The paper tape, with 8 level code, may be fed directly into the high-speed tape reader in the center of the console. Solid-state logic circuitry controls the input/output devices and provides the data collection trunkline interface. Design of the 3020 terminal permits simultaneous compiling of one message while others are being entered into the data collection system.

Circle Reader Service Card No. 60

High-Resolution Telephotometer



Gamma Scientific Inc., San Diego, Calif., announces the availability of its Model 2000 telephotometer, a high-resolution, high-sensitivity instrument for application in a wide range of photometric measurements. It is a general-purpose instrument for measuring luminance (in foot-lamberts) of small areas at a distance. The Model 2000 may be used for day and night-time visibility studies such as particular target contrast measurement; also, in electron beam diffreaction research, calibration of sattelite photometric instrumentation, and topographic and astrogeolic photometry. It may also be utilized to measure the brightness levels of airport runway and roadway lighting, and to check street lighting luminaries.

Circle Reader Service Card No. 61

High-Voltage Power Supplies

Industrial Laboratories Div., ITT Corp., New York, announces a line of miniature high-voltage power supplies for a variety of applications utilizing special-purpose photoemissive tubes such as ultraviolet and infrared scanning detectors, photometers, and spectrometers – for electro-optical imaging systems, display systems, infrared search and tracking systems, and laser systems. Also for special television devices, flaw detectors and to power special-purpose photo-tubes, star-tracking photomultipliers, and storage CRT's.

The supplies, typically 2.7 in. long by 1 in. in diameter, weigh 4 oz. Standard models take inputs of 1.5 v. at 18 milliamperes or 1.34 v. at 15 milliamperes with outputs of 12 kv and 16 kv at 1 microampere, respectively. Ripple is typically 1% max. Other models in rectangular cases 1 by 4 in. feature inputs of 12, 20, or 28 v. with outputs in 300-v. steps between 1200 and 3000 v. Ripple for these models is 1 v. peak-to-peak. Highher output voltages are available.

Circle Reader Service Card No. 62

Fast Deflection Yoke

CELCO, Mahwah, N.J., is now offering the Dynayoke, an advanced deflection yoke for fast CRT displays. The new yoke offers hitherto unavailable speeds for all pertinent parameters, the manufacturer claims. Typical of the Dynayoke is a zero approach to 0.1% of 6 microseconds max. and a linearity of 0.1%. Delivery 3 weeks ARO.

Circle Reader Service Card No. 63

35-Watt Xenon Lamps

Illumination Industries Inc., Sunnyvale, Calif., announces the availability of a series of Type III 35-w xenon short-arc lamps, with or without starting electrode. Typical applications include airborne or submarine direct-print oscillography, missile flares, secure communications systems, instant-start fault or event recorders, point sources for optical systems, Schlieren flash systems, slit illumination, and infrared devices.

Spectral output, having an efficiency of 17 lumens per watt, approximates, in the visible portion, a color temperature of 6000 K – very close to natural sunlight. The ultraviolet portion extends to about 190 nanometers. Infrared output consists of pressure-broadened xenon lines. Typical operating characteristics are as follows: arc size, 0.010 sq. in.; average luminance, 50,000 candela per square centimeter; minimum starting voltage, 15 kv; and average life, 200 hours.

Circle Reader Service Card No. 66

Compact Numeric Readout

Dialight Corp., Brooklyn, N.Y., offers a compact numeric readout, 710 Series, which displays bold legend characters 1 in. high. Optional decimal point or colon is available for use in any position of the readout. Explanatory captions can be displayed in a compatible module by means of transparencies.

Circle Reader Service Card No. 67

Plug-In Graphic Plotter

Electronic Associates Inc., North Long Branch, N.J., has introduced a Model 12. 1134 ac module which provides the firm's Variplotter (graphic x-y plotter) with the capability of producing plots proportional to the RMS value of an ac sine voltage. This is achieved by converting high-frequency ac signals to proportional dc voltages used to drive the movable arm and pen of the plotters.

According to EAI, the module can provide permanent high-resolution records of pure sine waves emanating, for example, from ac amplifiers, transducers, audio-measuring devices, and analog computers. The solid-state module may be used for either axis of the plotter. It features nine calibrated voltage ranges from 0.05 to 20 RMS volts/in., with 0 to 100% attenuation over each range, and a 20 cps to 100 kc frequency range, EAI reports.

Circle Reader Service Card No. 68

Submin Incandescent Lamps

Industrial Electronic Engineers Inc., Van Nuys, Calif., announces the introduction of a line of subminiature incandsecent lamps, designated as T1, T1-¼, and T1-¾. In addition to the 3 basic sizes, special configurations are available.

IEE states that major advantages gained include filament stability by an aging process, proper mean spherical candle power by light meter testing, and specially-blown bulbs designed to provide greater accuracy, eliminate distortion and spots and insure centering of filaments.

Circle Reader Service Card No. 69

Illuminated Push-Button Switches

The Ericsson Corp., New York, announces the availability of a line of versatile, compact high-quality locking or non-locking push-button switches, both with two Form C's, telephone-type silver contacts. The switches have separate inputs for two independent miniaturized long-life lamps. Lamps are plug-in telephone-type with standard dc voltages.

Features include a fail-safe lock action, grey Delrin uni-body frame, and optional high-density mounting bar. Legends are environment-protected and change easily with removable plastic cap, clear window, frosted legend insert and tinted filter.

Circle Reader Service Card No. 70

Spiral Accelerator Tube

The Electronic Tube Division, Sylvania Electric Products Inc., Seneca Falls, N.Y., a subsidiary of General Telephone & Electronics Corp., announces the availability of a 19-in. high-brightness tube for use in information data display systems. The SC-4448 tube, a spiral accelerator, provides superior display with minimum pattern distortion, according to Sylvania. It is a direct viewed round tube with an aluminized screen, spiral post accelerator, and electrostatic deflection and focus that provides readout of character and vector information.

The deflection guns are assembled on special mounting jigs accurate to 0.001 in., magnified 10 times on optical comparators and checked for spacing, dimension, and alignment. The tube offers high resolution at high-speed writing rates and incorporates a special geometry control electrode to achieve max. pattern linearity. The helical resistant coating inside the accelerator tube allows accelerating voltage to be uniformly increased along the bulb length between deflection plates and screen, permitting higher ratio of final anode voltage to second anode voltage without pattern distortion.

Circle Reader Service Card No. 71

High-Speed Fiber-Optics CRT

Du Mont Electron Tubes division of Fairchild Camera and Instrument Corp., Clifton, N.J., has developed a high-speed, high-resolution fiber-optics CRT. The unit offers superior line-width and bandwidth capability, according to Du Mont. The KC2427P, a 3 in. CRT with a fiber-optics faceplate bundle made up of 10. micron diam. fibers, has a writing speed of 10^{12} trace widths/sec., 15.0 mv/trace width deflection sensitivity, resolution of 500 traces/in., and a bandwidth capability of 1000 MHz permitting display of nanosecond information. The tube's distributed deflection structure contributes significantly to its ability to display broadband transients for recording purposes, according to the manufacturer.

The unit's faceplate is optically finished to within 1 mil of absolute flatness. The KS2427P is available with a number of phosphor options of varying persistencies. In addition to oscilloscopic applications, it will have wide usage wherever it is desirable to record extremely fast phenomena with good sensitivity and resolution.

Circle Reader Service Card No. 72

Transistorized Digital Readout

Transistor Electronics Corp., Minneapolis, Minn., has designed a completely transistorized digital readout, TNR-50 Series, available in 8 models to handle 8-wire BCD input in 1, 2, 4, 8 code with input signals as small as 3.5 v. Other input codes such as 1, 2, 4, 2; XS-3; Gray cyclic; XS-3 Gray; etc., as well as a variety of signal voltages, may be accommodated on custom basis.

Supply voltage of +180 VCD ± 10 VDC at 2 to 12 ma is confined to the panel area. Elements of the rectangular neon readout tube are controlled by internal all-transistor, decoder-driven circuitry that eliminates diode decoders. All tube elements may be turned off when no indication is required. The readout utilizes a rectangular, ultra-long-life nixie tube with a flat face which brings numerals closer to the front for wide-angle viewing. Numerals are 0.610 high. Life expectancy is 100,000 to 200,000 hours. A TNR-40 Series transistorized digital readout is also available which provides decimal readout from low-level decimal input signals.

Circle Reader Service Card No. 73

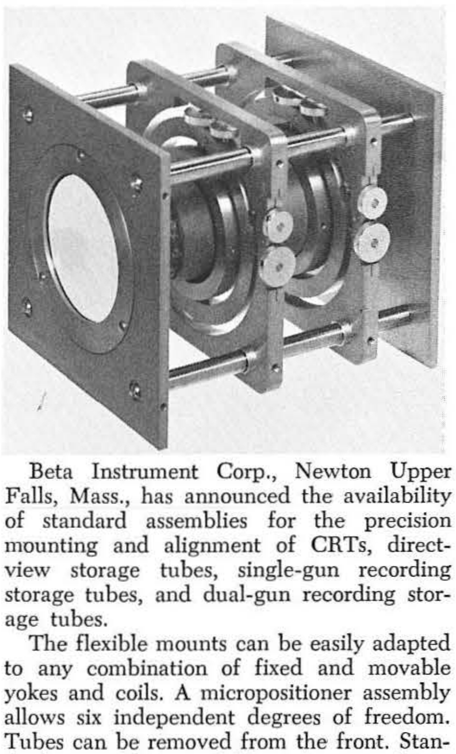
Encapsulated 90° Yoke

Syntronic Instruments Inc., Addison, Ill., has announced a new encapsulated deflection yoke which combines a 90° deflection angle with full 1-in. ID and large flare for excellent fit and elimination of neck shadow. Termed Type C4179, its 1-in. ID eliminates possible tolerance overlapping, and permits proper fit on a large family of CRTs with neck sizes from 7/8 to 1 in. Applications are primarily in closed-circuit mil and industrial TV, or similar fields.

Resonant operation is achieved by using a high Q ferrite core. Flat face pincushion distortion is eliminated by four anti-pincushion magnets which are pre-adjusted and pre-aligned to the customer's requirement. A wide variety of impedances are available for both the horizontal and vertical axes. The single ended coils have a high L to R ratio for good linearity and efficient operation.

Circle Reader Service Card No. 74

Tube & Coil Mounts



Beta Instrument Corp., Newton Upper Falls, Mass., has announced the availability of standard assemblies for the precision mounting and alignment of CRTs, direct-view storage tubes, single-gun recording storage tubes, and dual-gun recording storage tubes.

The flexible mounts can be easily adapted to any combination of fixed and movable yokes and coils. A micropositioner assembly allows six independent degrees of freedom. Tubes can be removed from the front. Standard assemblies available in any combination specified include basic CRT mount, basic dual-gun recording storage tube mount, micropositioning coil mount, fixed-yoke mount, and centering and alignment coil mount.

Circle Reader Service Card No. 75

Bright Readout Lamp

Los Angeles Miniature Products, Gardena, Calif., has made available a 4-v numerical readout lamp which yields 4000-ft.-lambert filament brightness, readable in direct sunlight. Termed Numeralamp No. 109, it provides segmented numbers 0 through 9, 0.7 in. high and 0.4 in. wide; the decimal point is included. White numbers are read directly from the filament, permitting a wide viewing angle.

The 4-v ac/dc design (5 v ac/dc max) permits operation directly from a transistor without intervening circuitry. The configuration is a standard T-6½ lamp with standard 9-pin base. The firm claims life of 200,000 hrs. at 4 v, with cyclic life in excess of 10 million.

Circle Reader Service Card No. 76

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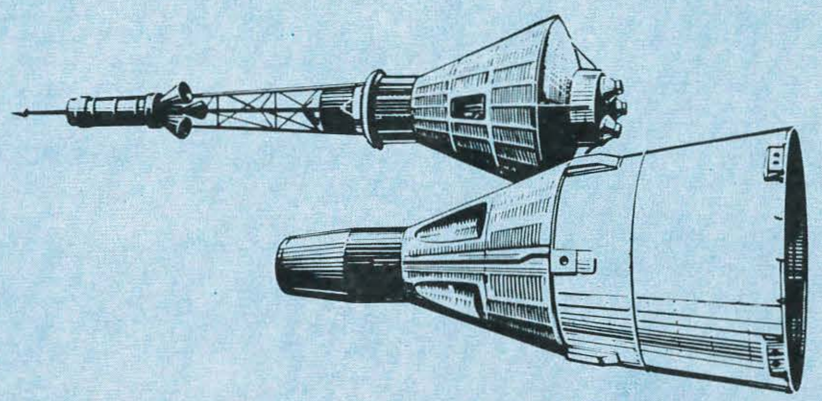

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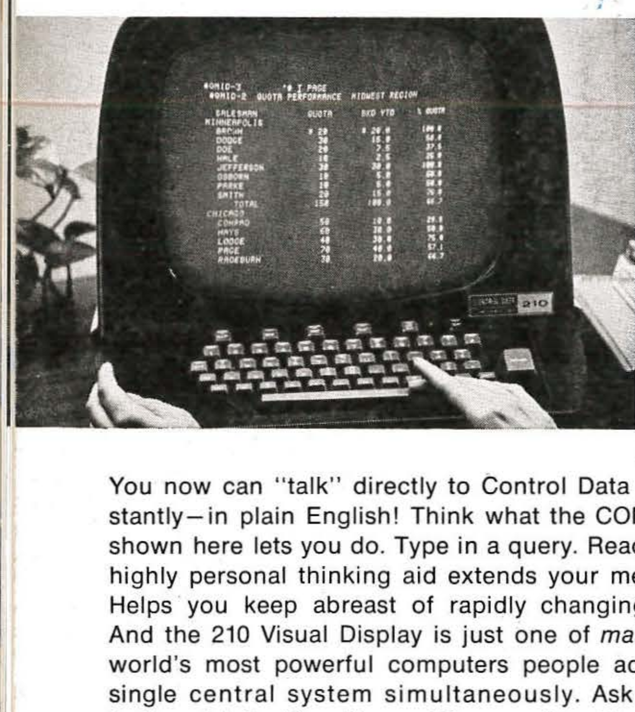

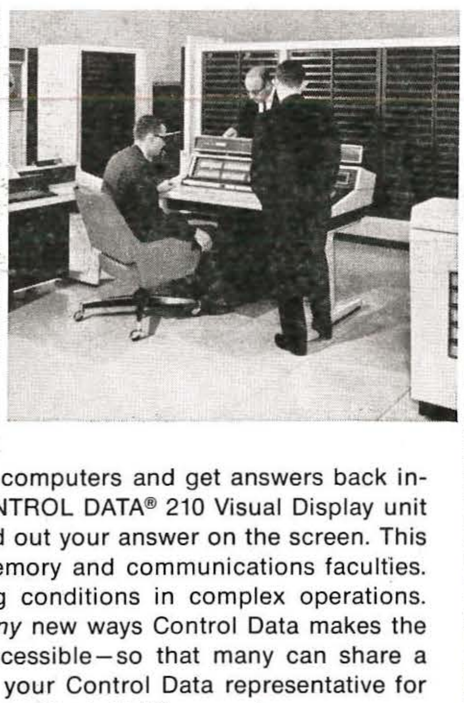

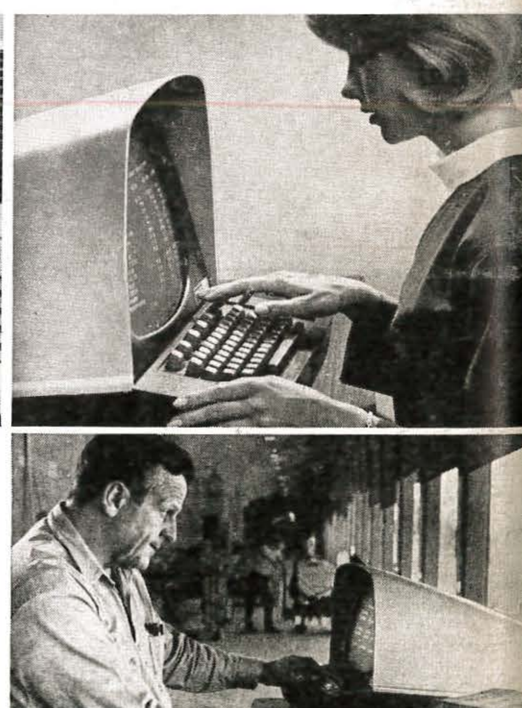

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Circle Reader Service Card No. 79