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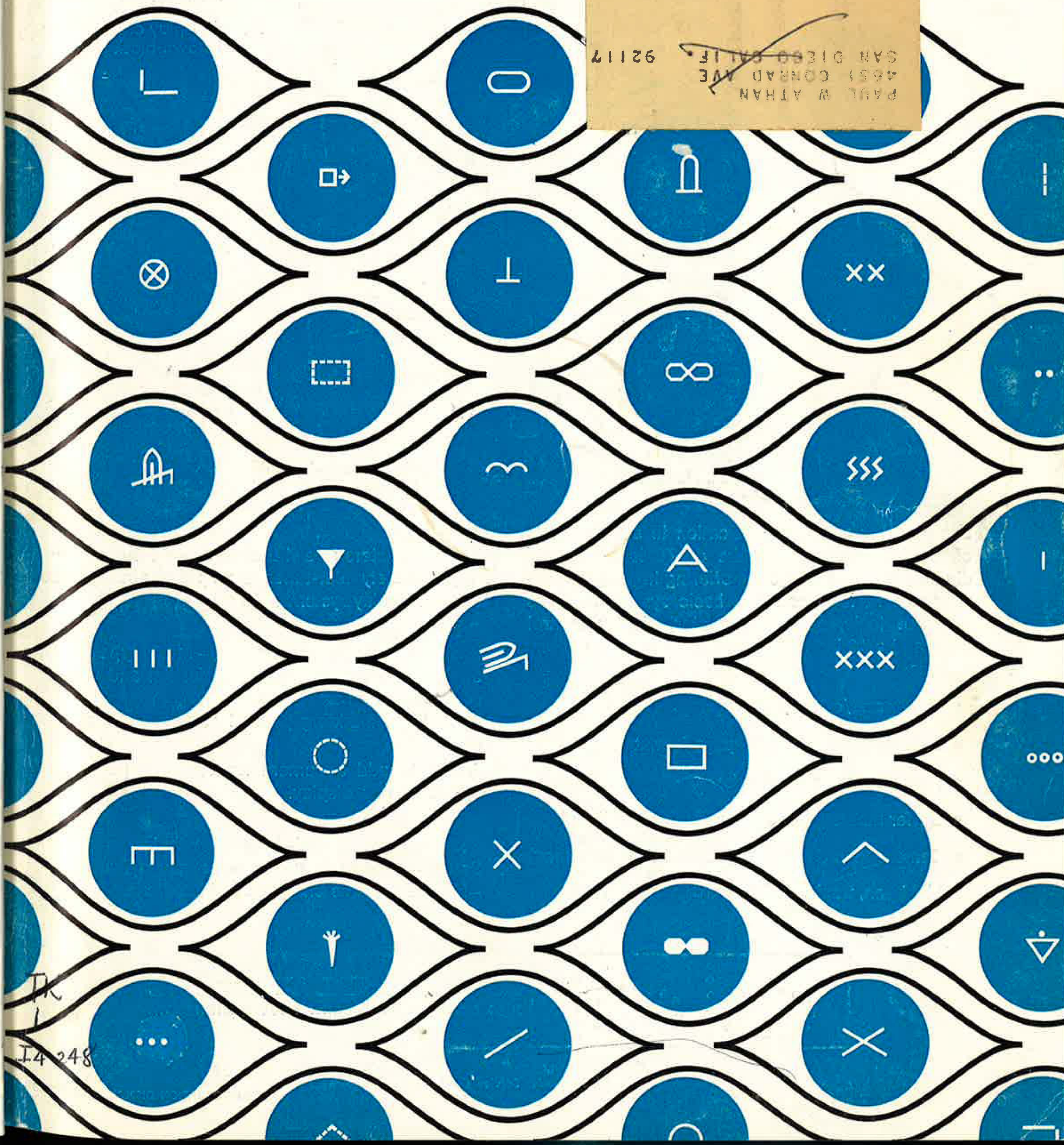
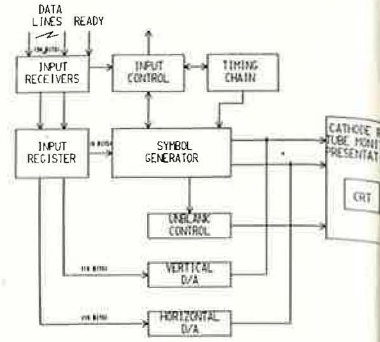
Information Display

Journal of the Society for Information Display





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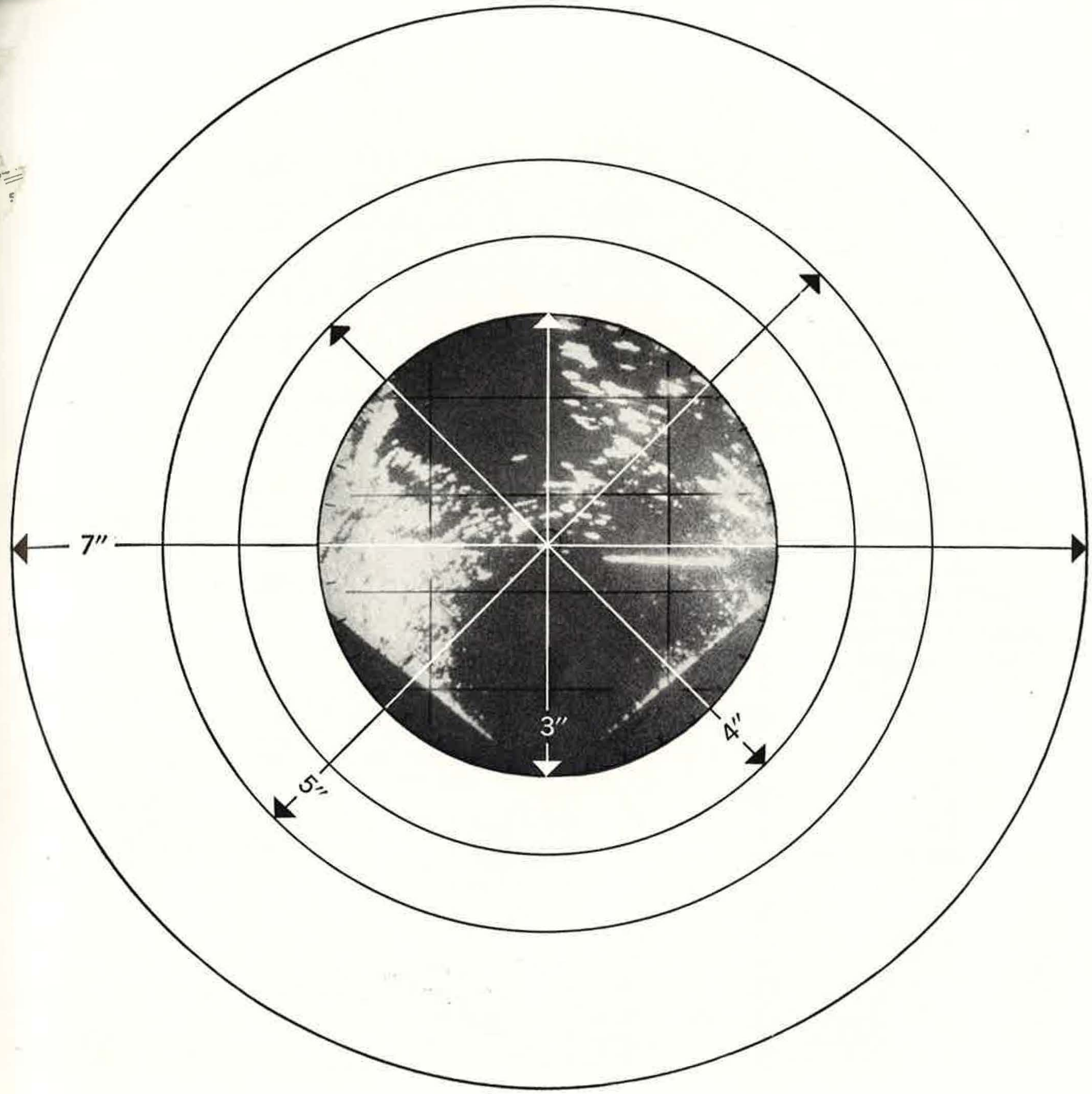
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Information Display

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Information Display

The Journal of the Society for Information Display

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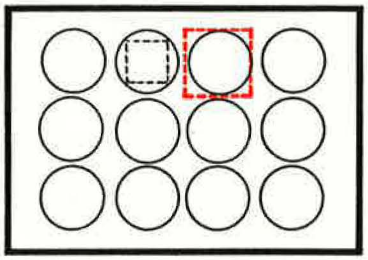
THE COVER

The eyes have it, in artist William Reed's rendition of generally used symbols in military cartographic displays. Graphic characters shown are symbols used to designate elements of military intelligence significance.

WHY A SQUARE THAT'S OUT IS "IN"

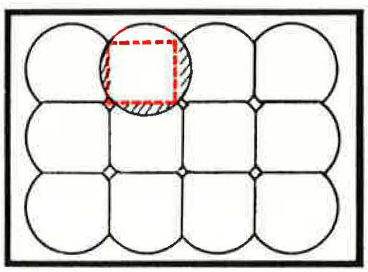
HOW IEE SQUARED THE CIRCLE TO GET 4-TIMES BRIGHTNESS FROM A REAR-PROJECTION READOUT



We're real big in squares and circles this year. Bigger yet in getting our popular Series 10 rear-projection readouts to develop 4-times greater character brightness than ever before (this with conventional MS or commercial lamps operated strictly at rated voltage!). The trick is in the lens.

Above is a horizontal view (actual size) of the old 12-position lens. The dotted square *inside* the circular lens represents the actual usable area that formerly averaged about 20 foot-lamberts with 6.3 v lamps (as bright or brighter than competitive devices). To get even greater brightness while using the same lamps at rated voltage, usable lens area had to be increased. Our problem was limited space. So we put our theoretical square *outside* the circle (shown in red above).

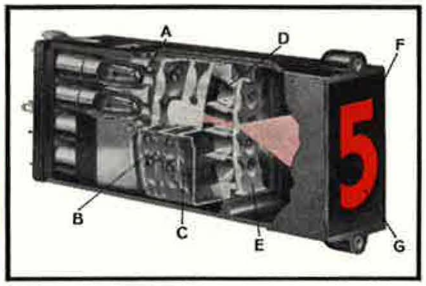
Next, we made the individual lenses larger to encircle the larger square. Now we had an overlap problem. This we solved by squaring the circles to leave off the unused portions, shown below. It's a bit unconventional, or so our lens-maker tells us. The results, however, are most rewarding.



The new Series 10 readout now averages over 75 foot-lamberts of character brightness when used with 6.3 v lamps *at rated voltage*. The increased brightness means visual clarity at wider angles and longer distances, excellent readability even under adverse high ambient light conditions.

And, there's an extra benefit if you're not overly concerned with all this brightness: operate the IEE readout at reduced voltage and you'll get *double brightness plus 10 times the lamp life* (up to 30,000 hours from 6.3 v lamps operated at 5.3 v).

CUT-AWAY SHOWS HOW NEW SERIES 10 READOUT OPERATES:



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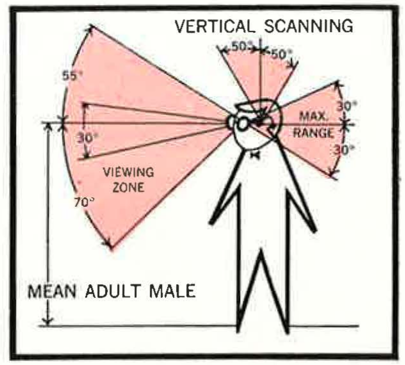

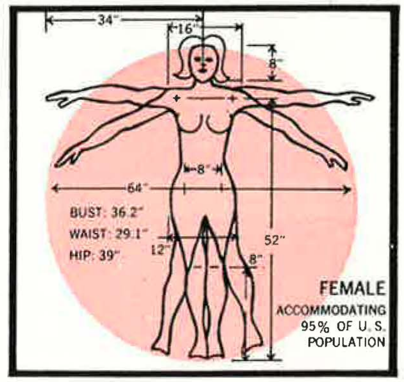

HUMAN FACTORS:

The scanning male & standing female

As builders of display devices for a variety of applications, we are extremely interested in human engineering studies. The July/August, 1963, issue of *Vending Engineer* contained drawings by Walter Koch, Industrial Designer, on which the above illustrations are based (with permission).

The drawings show one of the basic limitations imposed on vertical display areas by physical size of people. Studies show that the effective viewing area of most people is only about 30% of the total of most floor-standing vertical displays. We suspect this data is of interest to readers outside the vending machine industry since human engineering deals in one universal factor: people.

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ANTHONY DEBONS

EDITORIAL

THE INAUGURATION OF INFORMATION DISPLAY .... AND SID GROWTH

The inauguration of *Information Display* as the official publication of the Society is a significant step in the growth and development of our group. The Journal represents the culmination of a concentrated effort by the pioneers of this organization to establish the Society as a technical body in the family of technical societies. In this respect the Journal will add emphasis to the need for the crystallization of our technical role.

The work of the Society seems to me to be cut out for itself. At present the membership of the *Society for Information Display* consists of some of the outstanding display scientists and engineers now in this country. In addition, the growing number of our sustaining subscribers reflects a positive interest by industry in our group. Soon the Society hopes to boast of chapters in Europe and the Far East, bringing into our community scientists and engineers from other countries and nations to compliment our own talents. With this enviable resource we can be in a position to significantly influence the course of information display technology.

I sense, therefore, that for the immediate future our greatest need is to concern ourselves with the nature of our mision. It seems to me that the problems of information display are not sufficiently defined so as to instill in us the quest for debate and inquiry. The division of information display technology into so called "hardware" and "software" has led to camps of interest with inadequate crosstalk and mutual understanding. The focus of attention to the kinds of problems we have been concerned with has been too parochial. Our concerns should be broader. Our interests should branch into education, medicine, news, while maintaining our current focus on the problems of the military. We must not be timid in announcing the possible contribution that we may be in a position to make to these professions. To all of these conditions we must set to work and define the task and outline our plan for accomplishment.

ANTHONY DEBONS

President, SID

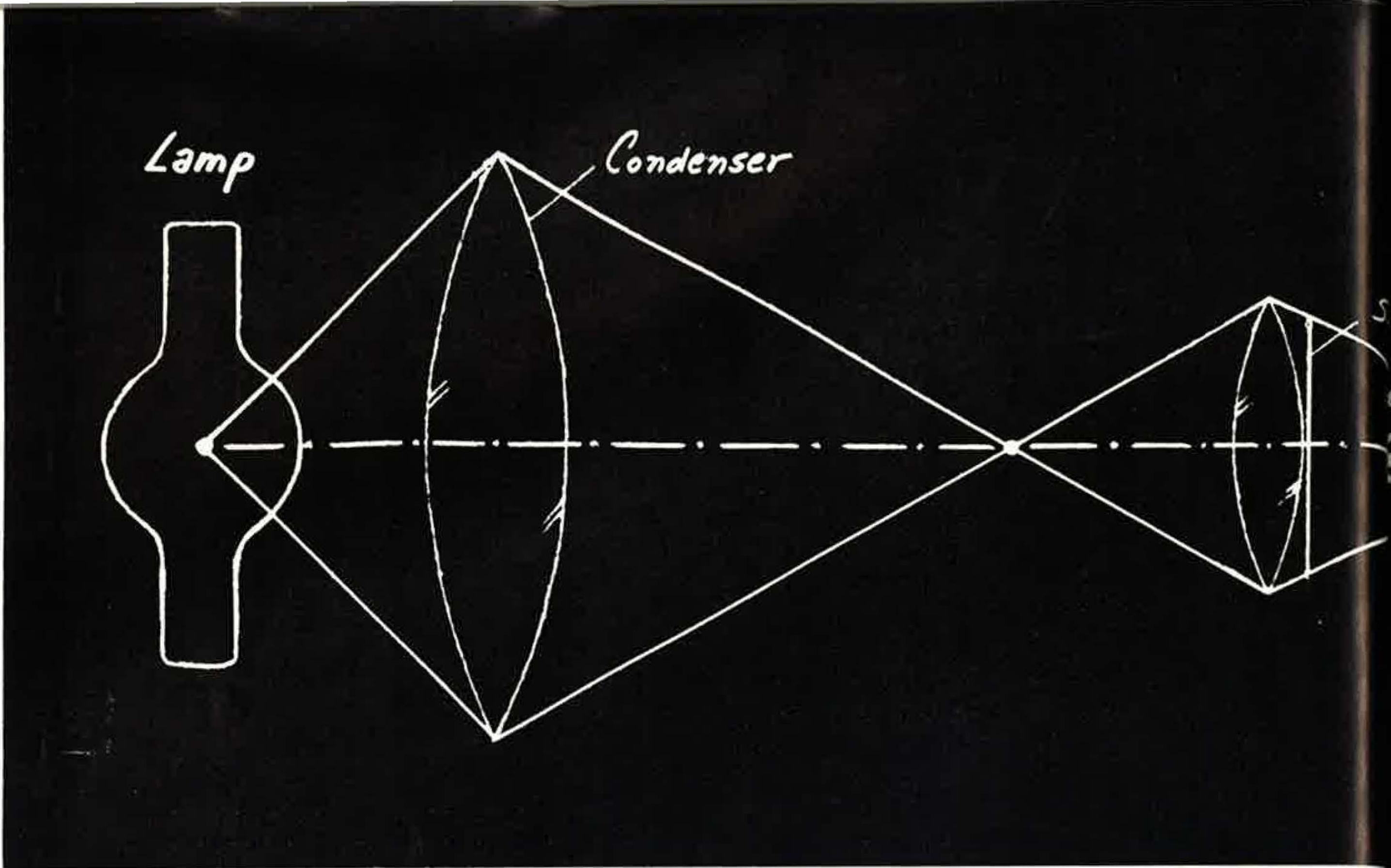
Elected President of the Society for Information Display at the Third National Symposium in San Diego (Feb. 26-27), Anthony Debons is a psychologist at the University of Dayton.

He was affiliated with the Rome Air Development Center from 1957 until last year, initially as Chief of the Human Engineering Laboratory and finally as Director, Directorate of Displays. Col. Debons served as Chief, Visual Displays Section of the Aeromedical Laboratory, Wright Patterson AFB, 1955-1956, following assignment as Research Officer at the facility in 1953.

Previously, he had established a Psychological Research Department at the Arctic Aeromedical Laboratory in Fairbanks, by request of the Secretary of the Air Force, and had been Research Officer to the Psychological Research Laboratory at Lackland AFB.

He received a B.A. degree at Brooklyn College in 1948, and PhD in Experimental Psychology from Columbia University in 1954.

In addition to SID responsibilities, Dr. Debons is a member of the American Psychological Society, Human Factors Society, Sigma Xi, and the American Physics Society.



by Helmut Weiss

Wide-Angle Slide PROJECTION

How to Beat the Cos⁴ Law of Illumination

Summary

The distribution of screen illuminance from a slide projector does not have to follow the "Cos^4 Law of Illumination" but can be controlled by proper design of the illuminating condenser.

Contents

1. Introduction
2. Light transmission through condenser
3. Effects of objective lens on screen illuminance
4. Paraxial screen illuminance
5. Oblique screen illuminance
6. Illuminance from Lambertian source with aplanatic condenser—Cos^4 Law
7. Illuminance from isotropic source
8. Control of illuminance distribution
9. Uniformity condition for isotropic source
10. Uniformity condition for collimated isotropic source
11. References

1. Introduction

The Cos^4 Law, by its very name, is surrounded with an air of authority. It has, for example, been stated in an AMERICAN STANDARD [1] which deals with photography and projection. Applied to projection with a 90° field, the Cos^4 Law predicts a drop of illuminance from 100% at the center of the screen to 25% at the corners.

While the Cos^4 Law does apply to photography [2], its validity in the case of projection rests on the rather special assumptions of a light source with an overall Lambertian radiation characteristic and of using an aplanatic condenser.

As we shall see, the use of an omnidirectional, or isotropic, light source, represented in good approximation by the modern short-arc lamps, goes a long way in reducing the decline of screen illuminance with increasing projection angle. With any light source, however, the distribution of screen illuminance can be fully controlled by proper condenser design.

The uniformity condition derived in this paper was independently established in 1959 [3] and used in the successful development of a projection display which covered a field of 90°. In subsequent discussions, K. PESTRECOV called the author's attention to earlier approaches to the same problem. Probably the first and most comprehensive discussion was given by STRAUBEL [4] in 1930. A U.S. Patent [5] granted to H. O. OSTERBERG, R. M. MULLER, and R. K. LUNEBURG described control of screen illuminance by appropriate design of the condenser. Some of LUNEBURG's work has more recently been reported by W. WALLIN [6].

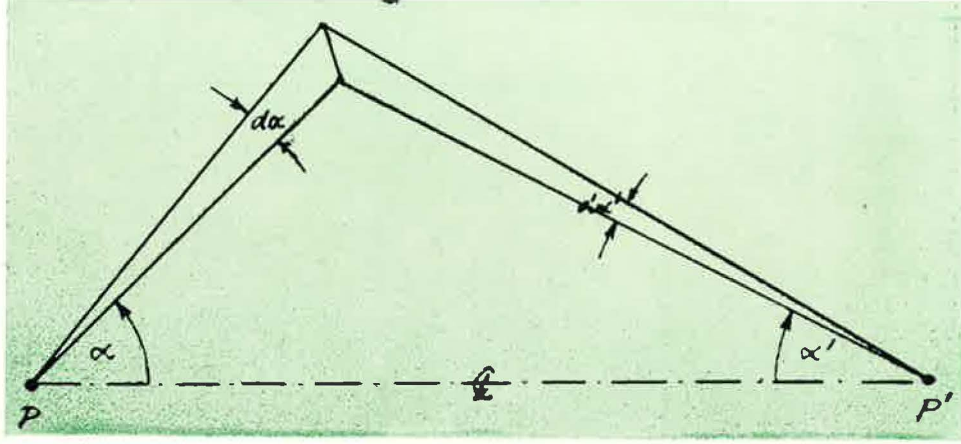
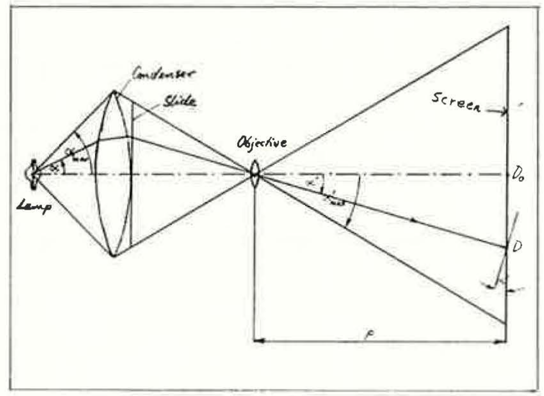


FIGURE 1 (right). Projector schematic showing condenser directing illumination through aperture of the objective.

FIGURE 2 (above). Continuity of light transmission through condenser. Full symmetry of revolution is assumed.

FIGURE 3 (left). Aperture matching by relay. Interposition of an optical transformer results in demagnification of the condenser aperture, matching its image with the frame.



The discussion in this paper is aimed at the problems encountered by the designer of transparency projectors for data display. Examples illustrate how the light distribution on the screen depends upon the directional properties of both the light source and the illuminating condenser. The condition which the condenser must satisfy to provide uniform screen illuminance is derived and geometrically interpreted.

2. Light transmission through condenser

The condenser, which precedes the slide to be projected (Figure 1), directs the illuminating light rays through the aperture of the objective, where they form a more or less well defined image of the light source.

Without being more specific about the imaging properties of the condenser, we assume that the condenser is stigmatic, i.e. that it concentrates all rays originating at the center of the light source in another mathematical point P′.

Assuming further that the angle subtended by the light source at the center of the condenser is very small, we can, with regard to the condenser, consider both the light source and its image as point sources.

Except for reflection and absorption losses in the condenser, which we neglect, a pencil of light centered at P must now carry the same light flux as its conjugate, centered at P′. Assuming full symmetry of revolution, as in Figure 2, we can make an analog statement for the light flux contained between the cones of half-aperature α and $\alpha + d\alpha$ centered at P, and between the cones of half-aperture α' and $\alpha' + d\alpha'$, centered at P′. We have therefore,

$$2\pi \sin \alpha \, d\alpha \, I(\alpha) = 2\pi \sin \alpha' \, d\alpha' \, I'(\alpha'), \qquad (2.1)$$

where $I(\alpha)$ is the intensity of the light source seen under the angle α and $I'(\alpha')$ the intensity of its image seen under the angle α'.

This condition, which expresses the continuity of light flux, applies to any pair of conjugate angles, α in the object space and α' in the image space of the condenser, regardless of the particular lens design. The condenser does not have to be a single lens. It may be a multiplet or even a system of widely spaced relay lenses, provided the assumptions specified above do still hold.

3. Effects of objective lens on screen illuminance

Usually, the objective lens will be designed for negligible image distortion, so that light rays through the center of the lens continue as straight lines. Therefore, when no slide is in the projection gate, the objective lens has no effect on the distribution of screen illuminance, as long as it causes no actual loss of light.

Light losses could be caused by reflection, absorption, and physical obstruction. These effects tend to increase with the angle of obliquity, and affect not just the level but also the distribution of screen illuminance.

Physical obstruction by mechanical apertures or lens mounts is only one form of "vignetting"; the other form is "optical compression or expansion of the beam due to the unsymmetrical refraction of oblique rays at the various lens surfaces."* However, as should be obvious from the foregoing discussion, this second form, purely optical vignetting, can have no effect on the light distribution on the screen if the rays through the center of the objective lens are not broken, i.e. if the lens is free from image distortion.

For the purpose of the following discussion we assume that the objective lens is distortion-free and loss-free, which enables us to disregard its presence entirely.

Quoted from American Standard [1]

4. Paraxial screen illuminance

Regardless of the particular optical design of the condenser (which we only assumed to be stigmatic), its central portion produces a well defined radial magnification,

$$m_o = \lim_{\alpha, \alpha' \to 0} \alpha/\alpha'. \quad (4.1)$$

To calculate the screen illuminance in the vicinity of the axis, for which only the central portion of the condenser is responsible, we let α, $\alpha' \to 0$ and obtain from (2.1) with (4.1)

$$I'(0) = m_o^2 \, I(0). \quad (4.2)$$

Referring to Figure 1, we assume now that the light source image, formed by the condenser in the aperture of the objective, is small compared with the projection distance, p, so that with regard to the screen, it can be treated as a point source. We have then in the vicinity of the point D_o, situated on the axis of the system at the distance p from the objective, the screen illuminance

$$E(0) = I'(0) \,/\, p^2$$

or, with (4.2),

$$\underline{E(0) = m_o^2 \, I(0) \,/\, p^2}. \quad (4.3)$$

This equation shows that the paraxial screen illuminance is proportional to the area magnification of the light source by the condenser, provided the aperture of the objective is wide enough to contain the light source image.

For a given projection angle α'_{max} and condenser aperture, the paraxial light source magnification m_o increases with the half-aperture α_{max} of the light cone intercepted by the condenser. The quantitative relationship depends upon the imaging properties of the condenser, which will be discussed later.

The angle α_{max} is limited only by the radiation pattern of the source. If the physical dimensions of the lamp or the thermal load on the condenser enforce a wide separation between the light source and the condenser, the condenser may become considerably larger than the frame to be projected. In that case, we can interpose an optical transformer in the form of a relay (Figure 3) which demagnifies the condenser aperture so that its image matches the frame. As stated in Section 2, this will not affect the validity of any of our results.

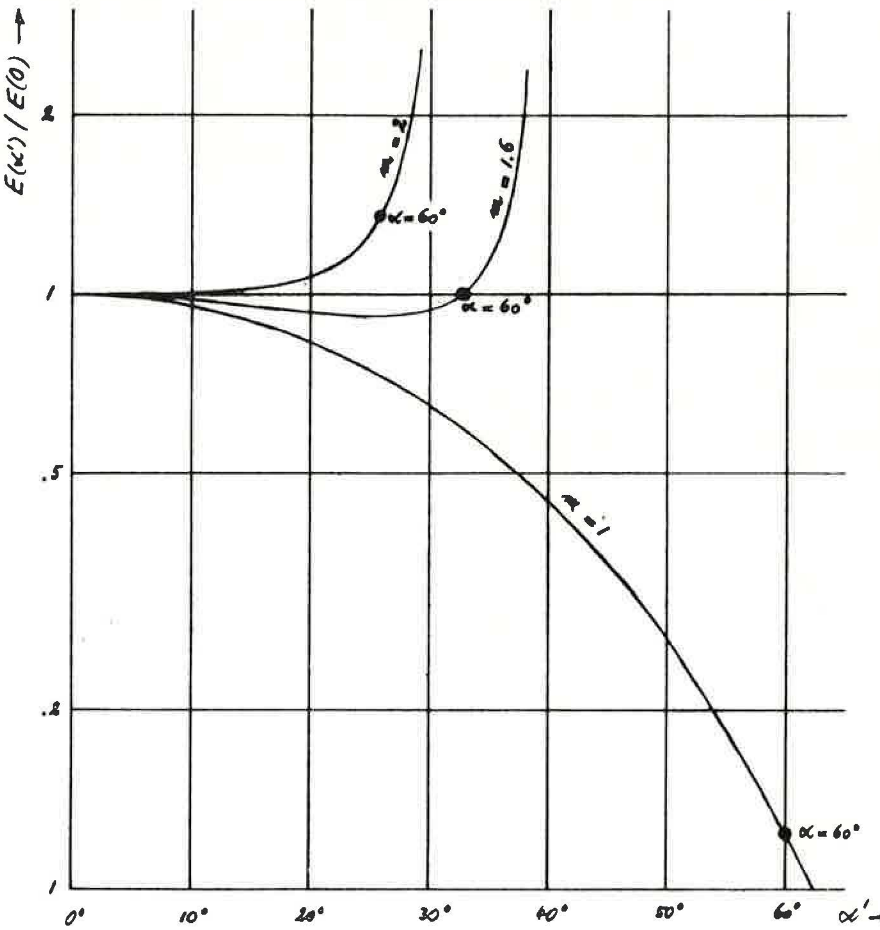


FIGURE 4. Relative screen illuminance from isotropic source with aplanatic condenser. *(Refer to Section 7 on facing page).*

5. Oblique screen illuminance

Referring to Figure 1, we assume again that the light source is small compared with the projection distance p so that it can be treated as a point source of intensity $I'(\alpha')$.

If the screen surface around the point D, which is at the distance $p/\cos\alpha'$ from the objective, were oriented normal to the incident light, it would receive the illuminance

$$E_n(\alpha') = \frac{I'(\alpha')}{p^2} \cos^2\alpha'. \quad (5.1)$$

Actually, it is tilted by the angle α'

which reduces the illuminance to

$$E(\alpha') = E_n(\alpha') \cos\alpha'$$

or, with (5.1)

$$E(\alpha') = \frac{I'(\alpha')}{p^2} \cos^3\alpha'. \qquad (5.2)$$

According to the continuity condition (2.1), the intensity of $I'(\alpha')$ of the light source image depends upon the radiation characteristic of the lamp, $I(\alpha)$, and the imaging properties of the condenser, described by some functional relationship between the conjugate angles α and α'. Using (4.3) to refer intensity and illuminance to their paraxial values, we obtain from (5.2) and (2.1)

$$\frac{E(\alpha')}{E(0)} = \frac{1}{m_o^2} \frac{I(\alpha)}{I(0)} \cos^3\alpha' \frac{\sin\alpha \, d\alpha}{\sin\alpha' \, d\alpha'}, \qquad (5.3)$$

where m_o is the paraxial light source magnification, defined by (4.1).

6. Illuminance from Lambertian source with aplanatic condenser—Cos⁴ Law

The luminance L of a Lambertian source is independent of the viewing angle so that its intensity $I(\alpha)$ varies only with the geometrical projection of the luminous area S. Thus, a flat Lambertian source, seen at the angle α from a distance that is long compared with its diameter, has the intensity

$$I(\alpha) = LS\cos\alpha. \qquad (6.1)$$

In Section 2, we postulated a stigmatic condenser, capable of forming a sharp image of the center point P of the light source. If the source occupies an area element normal to the optical axis, different zones of a stigmatic lens will, in general, produce images of different magnification, depending upon the relationship between the conjugate angles α and α'. According to ABBE, this zonal magnification is

$$m(\alpha, \,') = \sin\alpha / \sin\alpha'^{*} \qquad (6.2)$$

Now, we make the additional assumption that the condenser forms a sharp image of the entire luminous area. As this requires a constant magnification m over the entire lens aperture, the condenser must now be designed so that

$$\sin\alpha / \sin\alpha' = m. \qquad (6.3)$$

This is ABBE's sine condition, which makes the lens "aplanatic."

With the equations (6.1) and (6.3), reflecting the special assumptions made in this section, we obtain from the continuity condition (2.1) the intensity of the light source image,

$$I'(\alpha') = L m^2 S \cos\alpha'. \qquad (6.4)$$

Comparing (6.4) with (6.1), we see that the image of the light source radiates like a Lambertian source with the same luminance as the lamp.

Introducing now (6.1) and (6.3) into (5.3), we have, finally, for the screen illuminance the expression

$$E(\alpha') = E(0)\cos^4\alpha' \qquad (6.5)$$

which is the so-called "Cos⁴ Law of Illumination."

To see the Cos⁴ Law in proper perspective, we have to realize that its validity rests on rather special assumptions, which are not in any way sacred.

**For proof, refer for example, to [7].*

7. Illuminance from isotropic source

Compact arc lamps, which come more and more into use for powerful projectors, have an essentially constant intensity over the angle which is normally utilized. The illuminance from such an isotropic source equipped with an aplanatic condenser does not at all follow the Cos⁴ Law.

Once the light source is a three-dimensional element, however, there is actually no longer any justification for

With a source of constant intensity

$$I(\alpha) = I(0), \qquad (7.1)$$

we obtain from (5.3) with the sine condition (6.3)

$$\frac{E(\alpha')}{E(0)} = \frac{\cos^4\alpha'}{\sqrt{1 - m^2\sin^2\alpha'}} \qquad (7.2)$$

Depending upon the light source magnification m that is employed, the relative screen illuminance $E(\alpha') / E(0)$ may decrease with increasing projection angle (for $m \leq 1$), or go through a minimum (for $1 < m < 2$) or even monotonously increase (for $m \geq 2$). Examples are plotted in Figure 4.

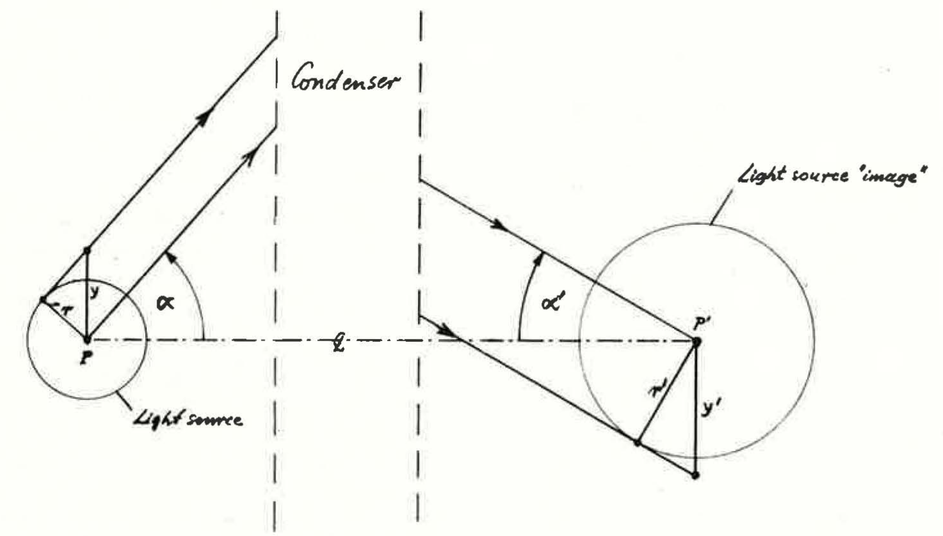


FIGURE 5. Concentration of light from infinitesimal source of spherical shape. ***(Textual reference in Section 7 on following page).***

Once the light source is a three dimensional element, however, there is actually no longer any justification for an aplanatic condenser. To achieve the highest possible concentration of light from a spherical source, for example, all rays should again be directed through a space element of spherical shape, which does not have to be (and cannot even be) a true point-to-point image of the light source. Referring to Figure 5, we have in this case the geometric relations

$$r = y \cos \alpha$$

and

$$r' = y' \cos \alpha'$$

where the ratio y'/y equals the zonal magnification $m(\alpha, \alpha')$ of equation (6.2.) To make not y'/y constant (which would require an aplanatic lens), but

$$r'/r = m = \text{constant},$$

we have to design the condenser so that it satisfies the condition

$$\tan \alpha / \tan \alpha' = m \qquad (7.3)$$

in lieu of the sine condition. With this condition and (7.1), we have from (5.3)

$$\frac{E(\alpha')}{E(0)} = (1 + m^2 \tan^2 \alpha')^{-3/2} \qquad (7.4)$$

Examples are ploted in Figure 5.

With compact light sources, however, the imaging properties of an otherwise stigmatic condenser are not really critical because the available objective aperture will usually allow for some lack of light concentration. The image of a 2000 watt Xenon arc illuminating a 35 mm slide, for example, does not occupy more than about f/5 of the objective aperture. Thus, we need not be too much concerned about the light source image and can, instead, design the condenser so that we gain control of the light distribution on the screen.

8. Control of illuminance distribution

If we make no a-priori assumptions on the imaging properties of the condenser (other than that it shall be stigmatic), we can interpret (5.3) as the condition for obtaining some arbitrary illuminance distribution $E(\alpha')$ from a lamp with a given intensity distribution $I(\alpha)$.

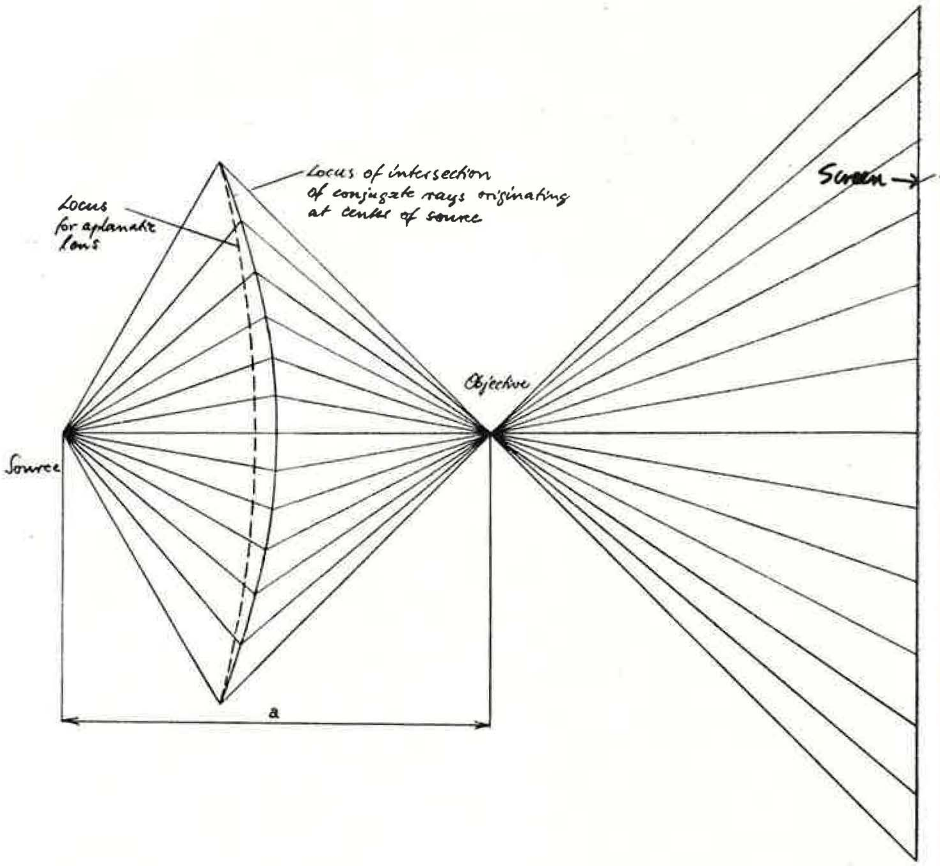


FIGURE 7. Rays through condenser designed to give uniform screen illuminance with isotropic source. *(See Section 9 on facing page).*

Integrated, (5.3) gives the relationship

$$\int_0^{\alpha} \frac{I(\alpha)}{I(0)} \sin \alpha \, d\alpha \doteq m_o^2 \int_0^{\alpha'} \frac{E(\alpha')}{E(0)} \frac{\sin \alpha'}{\cos^3 \alpha'} d\alpha' \qquad (8.1)$$

which the condenser must satisfy. We note that the constant m_o, which is the paraxial light source magnification, is determined by the angles of greatest obliquity, namely the half-apertures α_{max} of the available light cone and α'_{max} of the projecting beam.

Depending upon the form the condition (8.1) assumes under particular conditions, it may or may not be possible to arrive at a lens design that satisfies it.

9. Uniformity condition for isotropic source

If we wish to achieve uniform screen illuminance

$$E(\alpha') = E(0) \qquad (9.1)$$

with an isotropic source, of intensity

$$I(\alpha) = I(0) \qquad (9.2)$$

the general condition (8.1) reduces to the "uniformity condition"

$$2 \sin(\alpha/2) = m_o \tan \alpha' \qquad (9.3)$$

where

$$m_o = \frac{2 \sin (\alpha_{max}/2)}{\tan \alpha'_{max}} \qquad (9.4)$$

is the paraxial magnification.

The uniformity condition (9.3) can be visualized by the shape of the surface on which rays originating at the center of the light source intersect with their conjugates. Figure 7 shows this locus of intersection for a typical case of wide-angle projection with $\alpha_{max} = 60°$ and $\alpha'_{max} = 45°$.

The dotted line included in Figure 7 is the meridian of the spherical surface which, for the same angles, describes the sine condition. It has the radius of curvature

$$A = a \frac{\sin \alpha_{max} \sin \alpha'_{max}}{\sin^2\alpha_{max} - \sin^2\alpha'_{max}} \qquad (9.5)$$

where a is the distance between the light source and its image.

Calculating, for comparison, the corresponding radius of curvature which

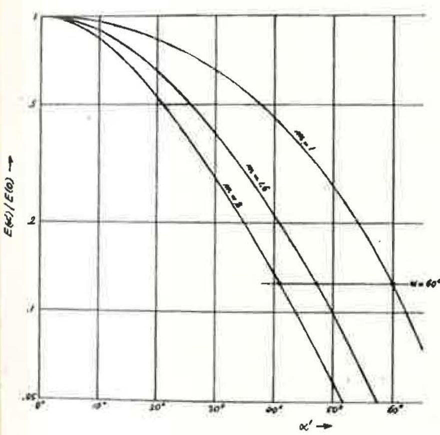


FIGURE 6. Relative screen illuminance from spherical source with condenser designed for maximum light concentration.

applies to the uniformity condition (9.3), we find with (9.4)

$$Q_U = \frac{4a}{3} \frac{\tan \alpha'_{max}}{2 \sin (\alpha_{max}/2)} . \qquad (9.6)$$

As the curvatures $1/Q_A$ and $1/Q_U$ reflect the so-called "bending" of the entire lens, we see that, in the example illustrated in Figure 7, the condenser designed to satisfy the uniformity condition must be more strongly bent than an aplanatic lens.

The ideal stigmatic condenser for uniform screen illuminance, built as a single lens, requires two aspheric surfaces but, in practice, excellent approximations can be achieved by making only the surface facing toward the objective aspherical.

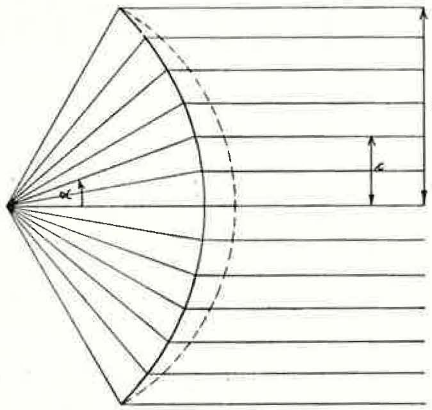


FIGURE 8. Rays through collimator designed to generate beam of uniform illuminance flux density from isotropic source.

10. Uniformity condition for collimated isotropic source

The problem of uniformity is not limited to wide-angle projection. Even at long throw distances, where the projection angle may become comparatively narrow, the utilized light cone will always have a wide aperture to assure efficient light utilization. Therefore, applications with rigid uniformity requirements will still need attention to the problem of light distribution.

In the limit $\alpha' \rightarrow 0$, where the condenser becomes actually a collimator, we have

$$\lim_{\alpha' \rightarrow 0} a \tan \alpha' = c \qquad (10.1)$$

where c is the distance of a given collimated ray from the optical axis. As the result, the uniformity condition (9.3) reduces with m_o from (9.4) to

$$\frac{\sin (\alpha/2)}{\sin (\alpha_{max}/2)} = \frac{c}{C} \qquad (10.2)$$

where C is the radius of the collimator aperture.

Figure 8 shows rays through a collimator designed to satisfy the uniformity condition (10.2). The dotted circle is the locus of intersection for an aplanatic collimator of the same angular aperture. As a comparison with Figure 6 shows, the curvature relationship is now reversed: the collimator designed for uniform flux density requires less bending than the aplanatic condenser.

11. References

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[7] P. Drude, The Theory of Optics, Dover Publ. (1959), p. 59-61.

DISPLAYS, PAR…

The Visual System Com…

In command centers we find for the first time the need to read cathode-ray displays, projection displays, and hard copy under the same level of illumination. Neither the illumination of theatres nor that of offices is suitable, the one being too low for reading papers and the other too high for reading displays.

This paper shows a method for computing the illumination at which both displays and hard copy can be read with equal ease, or conversely for showing the advantage given one data source over the other by the use of a different level of illumination. Properties of displays and hard copy needed in the computation are given, and a sample computation is presented. It is shown that the computed value of illumination is both satisfactory and compatible with the recommendations of the Illuminating Engineering Society. Means for avoiding eye strain and fatigue (applicable to any level of illumination) are restated.

If a command or management center is to be successful, the human decision maker must receive all the assistance from his data sources that the state of the art permits. To this end the display equipment, the hard copy, and the illumination must all be matched to the needs of the user. There is much information on the size, shape, etc. of the symbols that should be presented, a great deal of information on the techniques for producing and presenting the symbols, but very little on the environment in which the displays should operate. This paper is an attempt to fill a major part of this gap—the illumination of the operating area.

One may ask why this should be a serious question, since the subject of illumination has received so much attention in the last fifty years. The reason is that in command centers one finds for the first time that self luminous displays—cathode ray tubes, electroluminescent panels, projection screens, etc. — are combined with reflective displays — messages, maps, operating plans, budgets, schedules, etc. — with the requirement that they be used in close sequence. It follows that the illumination must be at one time suitable for the electronic displays and for the hard copy.

There is an extensive literature on the illumination of rooms for self-luminous displays, beginning with the data gathered by the then Society of Motion Picture Engineers on the lighting of movie theaters. This art was adapted during the war for radar display rooms and other weapons control centers, and extended by use of narrow-band light to take advantage of a color difference. The philosophy of minimum illumination is still seen in rooms where edge-lit, grease-pencil plots are kept. With the advent of brighter displays there came a demand that we "come up out of the caves" into an office atmosphere.

IES Recommendations

The recommendations of the IES (Illuminating Engineering Society) "reflect a consideration of many variables such as visual data, . . . economic factors, convenience, and availability." On examination it is found that their visual data are based on reflective materials — the reading of papers, the performance of shop tasks, etc. It has long been known that when such tasks are difficult because of poor form, extra fine lines, low contrast, etc. a higher level of illumination is helpful. It has been a long time since electric illumination has been expensive, and it is certainly convenient and available. One must conclude that there is no factor in the IES's considerations which exerts a strong influence toward lower illumination, and since they have no control over the quality of material in view, it is quite proper that their recommendations be generous.

Obviously, in a command center a compromise between these extremes is required, and the compromise must be pleasing to persons of high rank. With due attention to the opposite effect of illumination on reflective and self luminous displays, a best illumination can be achieved, and at the present state of the art it will be a very satisfactory illumination if the conditions are met with reasonable care.

The Data

It has long been known that the ease of seeing is related to the illumination, the size of the detail that must be seen, and to the contrast of that detail to the background; and various pairs of these variables have been studied parametrically until the relations are well known. During an eight year research (as of 1959) Dr. H. Richard Blackwell has related these four variables using the same group of observers.

In these experiments the subjects faced a hollow box which covered a wide field of view and which was illuminated evenly with white light. Near a reference mark on the back wall there was a translucent spot of white plastic which appeared the same brightness as the rest of the wall under the front illumination, but which could be back illuminated to a higher level, and the equipment was so built that both brightnesses, the size of the spot, and the duration of its back illumination could be varied over wide ranges.

The observers were thoroughly trained in practice runs not included in the data, to eliminate variation ascribable to learning. They sat before the box for a sufficient time for their eyes to become adapted to the light level to be used; they were then told the limits of a time interval in which the spot might, or might not, have been back illuminated and were asked to decide whether or not they had seen it.

Since the same color light was used for the background and the spot, the contrast could be computed using the simple relation:

$$C = \frac{B_H - B_L}{B_L} \qquad (1)$$

where C is the contrast
B_H is the higher of the two brightnesses
and B_L is the lower of the two brightnesses

This expression for contrast has a value which varies from zero to infinity, and (unlike some) it has the advantage that the zero value conforms to the condition which has no visible contrast.

Over 80,000 observations were made. For each set of conditions the data [illegible]

PARS, and LIGHTING

m Command Centers

by A. C. STOCKER

first corrected for the known percentage of lucky guesses, then were fit to the normal ogive so that the 50% point (the point of maximum slope) could be determined with accuracy. The curves were then smoothed by the use of the known parametric relations between pairs of variables. At the completion of this process it was found that an introduced variation as small as 2% would require an obvious violation of one of the parametric relations.

This work has been reported in various stages of progress, references 1, 2, and 3 being the more important and carrying references to the others. The complete data, without some of the details of how they were gotten, are given in reference 3. Because all the data came from the same basic source, because all four variables are covered, and because of the care used in smoothing, it is felt that the results constitute an unusually useful statement of fact.

To extend these data to the conditions and requirements of practical seeing, Dr. Blackwell uses the concept of field factors by which to multiply the required contrast. A factor to compensate for the difference between skilled observers using forced choice and the ordinary reader facing a new problem was determined experimentally. Factors for off-axis viewing, for the lack of warning, and for the frequency of presentation were determined experimentally. The latter three were checked with reasonable accuracy by use of a task evaluator, an instrument whereby a task and a test spot could both be viewed under conditions of controlled contrast and that contrast reduced to minimum visibility.

The development of the field factor concept is described in reference 3. The overall factor, as determined by the process described above, is in the range from 30 to 37.

While the basic data are felt to be valid beyond doubt, the value of the field factors has been questioned, some workers feeling that the proposed values lead to too low a level of illumination. The author has arbitrarily used an overall value of 40 in making up his human performance curves; however, it will be shown later that the value of the field factor has no bearing on the selected illumination so long as the same value is used in the computations for both hard copy and self-luminous displays.

The author has applied a field factor (40) to the data of reference 3 for detail subtending angles of 1, 2, and 4 minutes of arc, and for illuminations between 0.1 and 100 footcandles and has interpolated for easier use. The resulting curves are given as Figures 1, 2, and 3.

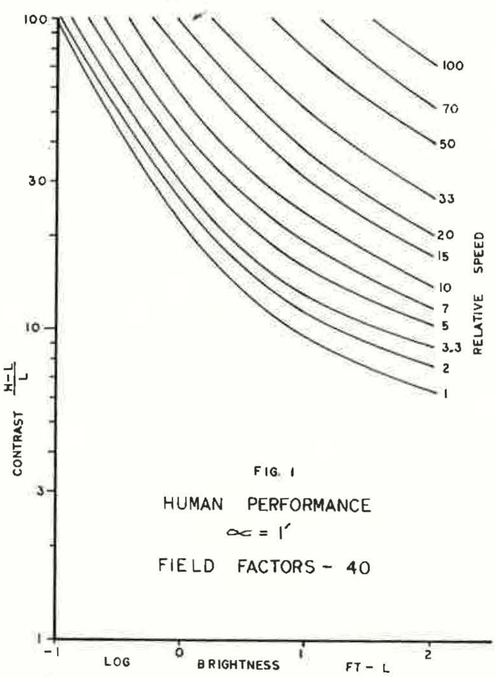


Fig. 1 Human performance when reading symbols with a stroke width (alpha) of one minute of arc.

It must be stressed that the speeds shown in Figures 1, 2, and 3 are not reading speeds, but are the inverse of the times when the spot was back illuminated in the tests. The term "reading ease" was considered for a while, but it is hard to conceive of an ease of 100, so the term "relative perception speed" was finally chosen.

The Selection of an Illumination Level

It is obvious that both the self-luminous and the reflective displays must be readable; lacking other indication it will here be assumed that they should be equally readable. The optimum illumination level is, then, that which gives each the same relative perception speed. This may easily be found once the data are put in the proper form.

The preparation of data for reflective displays (hard copy) is simple. The steps are these:

a) Determine the minimum size of detail that must be easily readable, compute the angle this will subtend at the observer's eyes, and select the curve with this value of alpha.
b) Determine the contrast of the material, and lay a straightedge across the curve at this value.
c) Multiply selected values of illumination by the reflectivity of the paper to establish the background brightness.
d) For each value of brightness, read the relative perception speed.

The preparation of data for the self-luminous type of display is a little more complex. The steps are these:

a) Determine the minimum size of detail that must be easily readable, compute the angle this will subtend at the observer's eyes, and select the curve for this value of alpha.
b) Determine the excitation brightness available at the screen (that supplied by either the electron beam or the projector) and apply factors for the gain and loss of the screen to achieve the visible brightness of the symbols.
c) Apply factors for the reflectivity of the screen, attenuation of its support, the effectiveness of hoods, etc., to selected values of ambient illumination to determine the background brightness.
d) Compute the contrast from item b) and c) above. (These computations are discussed at greater length under Properties of Displays and Hard Copy.)
e) For each value of illumination, lay

a straightedge across the curve at the resultant contrast, and at the corresponding value of background brightness, read the relative perception speed.

To determine the optimum value of illumination, plot relative perception speed vs. illumination for both types of displays. It is obvious that one will have a positive slope and one a negative; the point where they cross is, then, the illumination at which the two types can be read with equal ease.

Properties of Displays and Hard Copy

Before the design of a command center can be started, it is necessary to have at least an idea of the properties of the display materials that will be used therein. This section will discuss the properties of a representative sample of materials, and will discuss some of the steps that may be taken to assure good legibility.

Hard Copy—Hard Copy will long continue to carry a large and important portion of the information needed in a command center. Yet the information that is available on the properties of hard copy is very limited. The size of type, for instance, is the size of the block on which the face is cut, not the size of the face itself, and there are only very general statements on the reflectivity of papers and inks. For that reason a series of measurements was made.

In these measurements the symbol height was taken as the prependerant height—if the word was in lower case, then the height of a lower case a, e, o, n or similar letter was measured. Some letters have a variable stroke width. However, experience has shown that the intelligence is carried in the heavier portions of the symbol; it is in fact possible to read material in which a faulty reproduction process has eliminated the thin strokes completely. So when a variable stroke width was encountered, the heavier portion of the stroke was measured. These data were taken with a measuring microscope.

The determination of reflectivity presented a problem because of the small area available in the symbol and the known tendency of the human eye to be influenced by the surroundings. A series of paper chips varying from white to black were gotten by selecting from paper stocks where that was possible, and by dyeing to fill the gaps. These chips were placed in a diffuse white illumination measured with a Weston Illuminometer, their brightness was measured with a Spectra Spot Brightness Meter, and their reflectivity was computed. These chips could then be compared directly to the paper of a display. The reflectivity of symbols was determined by placing a chip partially across

TABLE 1

PROPERTIES OF HARD COPY

MATERIAL	HEIGHT Mils	STROKE Mils	STROKE Angle @ 14" Mins	Color	Reflect.	Contrast
Maps						
Army Map Service, NK 18-11						
Paper				white	.65	
Names—large	160	24	5.5	black	.07	8.3
small	40	9	5.2			
Highways		38	9.5	rd & blk		high
Railroads		7	1.7	black		
Creeks		5	1.2	blue	.1	5.5
Contours		5	1.2	tan		fair
Elevations	52	7	1.7			
Sectional Air Chart, Winston Salem						
Paper — Color wash to indicate ground altitude, Est. Avg.					50	
Names—large	110	20	5	black	.1	4
small	44	7	1.7			
Smallest print	40	8	2			
Highways		25	5.5	gray	.3 Est.	.6
Scale tics		8	2			
Contours		9	2	tan		fair
Nautical Chart, H.O. 1290						
Paper				white	.65	
Names—large	144	14	3.5	black	.09	6.2
small	40	10	2.5			
Smallest print	24	5	1.2			
Depth contours		5	1.2			
Soundings	60	9	1.2			
Geological Survey, Redmond, Washington						
Paper				white	.7	
Green overprint for wooded areas						
Names—large	120	15	3.7	black	.1	6
small	60	10	2.5			
Smallest print	45	7	1.7			
Highways		25	5.5	red & blk		high
Roads	dual	6	1.5			
Creeks		8	2	blue		good
Contours		5	1.2	tan		fair
Office Material						
Good pulp paper					.7	
Average pulp paper					.65	
Yellow copy paper					.5	
Typewriter samples						
Paper					.7	
Make A Electric	110	15	3.7	black	.1	6
Make B Elite	110	10	2.5	black	.12	4.8
Make B Pica	114	10	2.5	black	.1	6
Make B Pica—old ribbon	114	7	1.7	gray	.15	3.7
Teletype printer						
Paper				gray	.6	
With new ribbon	105	20	5	black	.1	5
With old ribbon, top		12	2.7	black	.12	4
With old ribbon, bottom		Indef.			.2	2
Computer Printer output						
Make C	95	9	2.2	black	.08	7.9
Make D	100	10	2.5	black	.1	6
Make E	100	17	4.2	black	.08	7.1
As a basis for comparison—						
New York Times						
Paper					.46	
Text	55	10	2.5	black	.1	3.6
Office Copiers						
Make F (translucent material)						
Paper—on dark desk					.45	
Print					.12	2.8
Paper—on white paper					.65	
Print					.12	4.4
Make G (opaque material)						
Paper					.65	
Print					.10	5.5
Pencil						
Pulp paper					.65	
Mechanical pencil, .032" lead, HB		20	5	black	.2	3.3
2H newly sharpened		10	2.5	black	.25	2.3
2H fairly dull		15	3.7			
B newly sharpened		12	2.7	black	.12	4.5
B dull		40	10			

a line of type and examining the type and the edge of the chip through a low power microscope, the microscope magnifying the type to the point where a good comparison could be made. Some materials, pencil as an example, had to be measured under diffuse light to prevent specular reflection.

The data gathered in these tests are given in Table 1. Special attention is invited to the data on office copying machines, pencil copy, and typewriter and teletype output. It will be noted that the contrast can be raised materially, and in some cases the width of the stroke increased by a significant factor, by the proper selection of equipment and materials and the use of fresh ribbons. One must conclude that the legibility of the hard copy is to that extent a function of the interest shown by the members of the staff.

Self-Luminous Displays—Self-luminous displays—cathode ray tubes and projection screens—must combat the ambient illumination, so much of this section will have to do with means for maintaining good contrast. The light in the symbol, the light that carries the useful information, comes from either an electron beam or a projector; we will consider cathode ray tubes first.

Rather than get into a discussion of products, the author will here assume that the tube has a brightness of 50 foot-lamberts available at the phosphor, and offers assurance that this level is within the state of the art using crystalline phosphors. The reflectivity of the phosphor is assumed to be 85%, highly diffusive. The problem, then, is to achieve as good contrast as is possible with this device.

The first step to consider is the use of a gray glass for the face plate of the tube. It is true that such glass reduces the brightness of the symbols by the transmission (filter factor) of the glass. But the ambient illumination must pass through the glass twice, so the contrast is increased by the inverse of the filter factor. This can be a significant amount; RCA lists face plates with filter factors in two groups, one near 0.75 and one near 0.4.

The next step is the use of a cap-bill hood to keep as much as possible of the ambient illumination from falling on the screen. Properly designed, such a hood can easily have a factor of 0.5 without restricting the viewing angle.

The effectiveness of a hood may be increased by limiting the angles at which the light approaches the equipment, as can be done by hanging properly designed honeycomb gratings below the light sources. The light can still come from the major portion of the ceiling, so it is fully diffuse (or indirect); it is merely limited to those angles which will not get under the hood. It is believed that the hood factor can be changed from 0.5 to 0.25 by this means.

After these steps, the direct ambient light will be reduced to the point where the light reflected from the equipment, from white shirts, etc., becomes important. Such secondary sources can be objectionable when they are specularly reflected from the tube face and appear as unwanted images superposed on the data. Glossy finishes should not be used on equipment, furniture, etc.; a medium gray mat surface is much less objectionable. Such light as remains can be rendered innocuous by etching the tube face to a fine mat surface. This is not truly a non-reflecting coating—it merely spreads the reflection over such a large area that the brightness is reduced and the shape of the source obscured. It is, however, a very effective step.

Circular polarizer use

A circular polarizer can be used for the functions of the filter glass and the mat first surface, either for better performance or when the desired properties cannot be had in the available tube. It is not a complete cure, for it itself has bright specular reflection from its front surface. However, it may be used as a plane surface, and the range of incident angles that gives objectionable reflections from a plane surface is much less than the range that gives reflections from a spherical surface.

Projection displays can also take advantage of absorption in the screen support, of a hood, of directive room light, and (in some types) of a mat front surface on the screen. In addition, they can take advantage of directivity.

Directive screens reflect (or transmit) more light in a preferred direction than in other directions. They therefore are said to have "gain", this being the ratio of the brightness in the preferred direction to the brightness of a highly diffusive screen subject to the same illumination. Values between 2 and 10 are common. If the viewers can be located along the preferred axis, the brightness of the data symbols will be increased while that from light sources not near the projector will be decreased, and an increase in contrast will result. This effect reaches its peak in rear projection screens, where the steps which decrease the diffusion of the projected light also decrease the reflectivity to ambient light, and where it is possible to take advantage of a filtering support material.

However, a fundamental characteristic of gain is its sensitivity to changes in angle. Assuming the plane of the screen is correct for the location of the projector and the center of the audience, there will still be a change in brightness due to looking at different portions of the screen or to the viewer's moving about the room. If this change is to be held within acceptable bounds, then directivity must be used with care.

The quantitative relations follow, all based on the fundamental relations that:

$$C = \frac{B_H - B_L}{B_L} \quad (1)$$

$$B = I\ R \quad (2)$$

$$I_p = \frac{L_p}{A} \quad (3)$$

For hard copy:

$$B_H = I_A R_p$$

$$B_L = I_A R_I$$

substituting in (1)

$$C = \frac{R_p - R_I}{R_I} \quad (4)$$

For both cathode-ray tubes and projection screens the brightness of the symbol is the sum of that produced by the intended excitation and that of the background as produced by stray electrons or the transmission of "opaque" parts of the film.

For cathode-ray tubes:

$$B_H = B_{ph} T + B_L$$

$$B_L = I_a R_{ph} T^2 + B_x T$$

substituting in (1)

$$C = \frac{B_{ph}}{I_a R_{ph} T + B_x}$$

For front projection:

$$B_H = \frac{L_p}{A} G + B_L$$

$$B_L = B_a + B_x G$$

Here B_a is the sum of the brightnesses due to the individual room illuminants, each with the value of gain required by its angles. This is so complex that the value is usually determined by measurements on a mockup or on the final assembly.

substituting in (1)

$$C = \frac{L_p G}{A\,(B_a + B_x G)}$$

For rear projection, with the diffusing layer on the projector side of the screen:

$$B_H = \frac{L_p}{A} GT + B_L$$

$$B_L = B_a + B_x GT$$

$$B_a = I_a R_s T^2$$

A single expression for B_a is made possible here by the small difference in reflectivity for the angles of the different room illuminants.

substituting in (1)

$$C = \frac{L_p G}{A(I_a R_s T + B_x G)}$$

In the above:

- A = Area of the projection screen, in square feet.
- B = Brightness, in foot-lamberts.
- B_a = Brightness due to the ambient illumination.
- B_H = The higher of two brightnesses.
- B_L = The lower of two brightnesses.
- B_{ph} = Brightness of a phosphor due

to electron impact or other excitation.

B_x = Brightness due to unintentional excitation, as by stray electrons or transmission through the "opaque" areas of the film.

C = Contrast

G = The gain of a projection screen for the incident and reflected angles involved. Note — commercial values for G usually include the reflectivity, so it is not stated separately.

I = An illumination, in footcandles.

I_a = The ambient illumination.

I_p = The projected illumination.

L_p = The light flux delivered to the screen by the projector, in Lumens.

R = The reflectivity.

R_p = The reflectivity of the paper.

R_I = The reflectivity of the ink.

R_{ph} = The reflectivity of the phosphor.

R_s = The reflectivity of the projection screen.

T = The transmission (filter factor) of the screen support where the support is between the screen and the observer.

Sample Computation

In order to demonstrate the process and to get a feeling for the level of illumination the process will indicate, a sample calculation was carried through using the nearest value of alpha for which there was a curve available (Figures 1, 2, and 3.)

For hard copy, an Army Map Service map, two typewriters with different weight of type face, a teletype machine, and a mechanical pencil were taken as representative of the materials that might be found in a military command center.

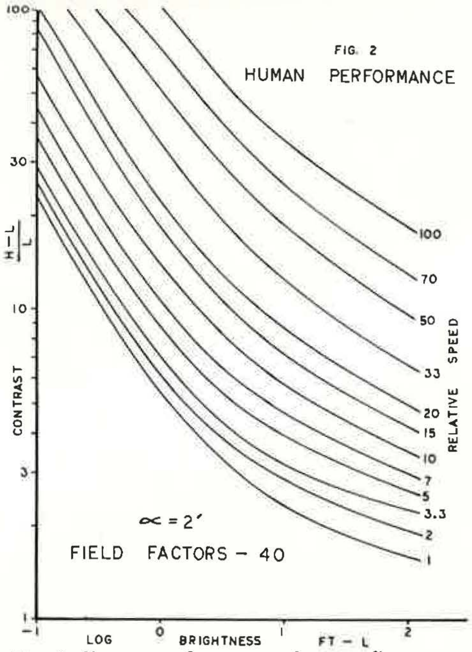


Fig. 2 Human performance when reading symbols with a stroke width (alpha) of two minutes of arc.

The results of the computation are given in Table 2 and plotted in Figure 4.

For the display, a cathode ray tube was chosen and assumed to have a phosphor with a brightness of 50 foot-lamberts and a reflectivity of 0.85. Filter factors of 0.4 or 0.75 were used, alpha was taken as 2′ or 4′, and the hood factor was taken as 0.5 or 0.25. These conditions can also be met in a projection display if the screen size is properly balanced to the available projected light. The results of the calculation are given

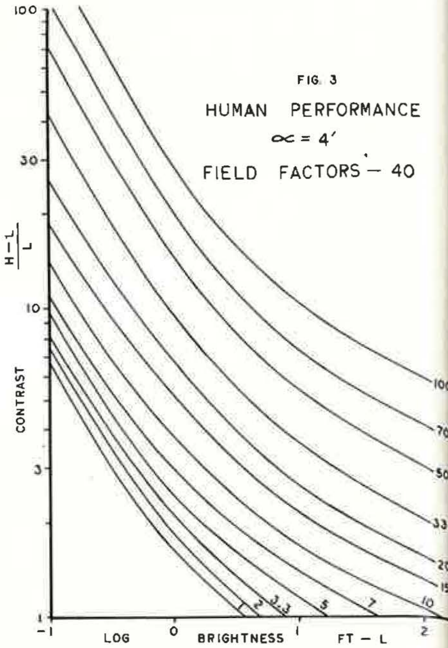


Fig. 3 Human performance when reading sym- bols with a stroke width (alpha) of fou minutes of arc.

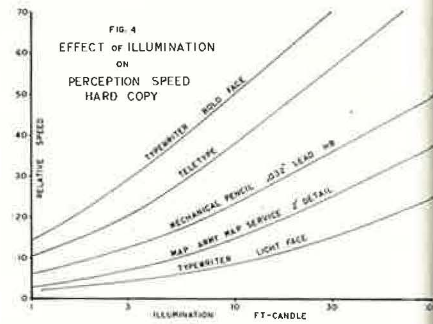


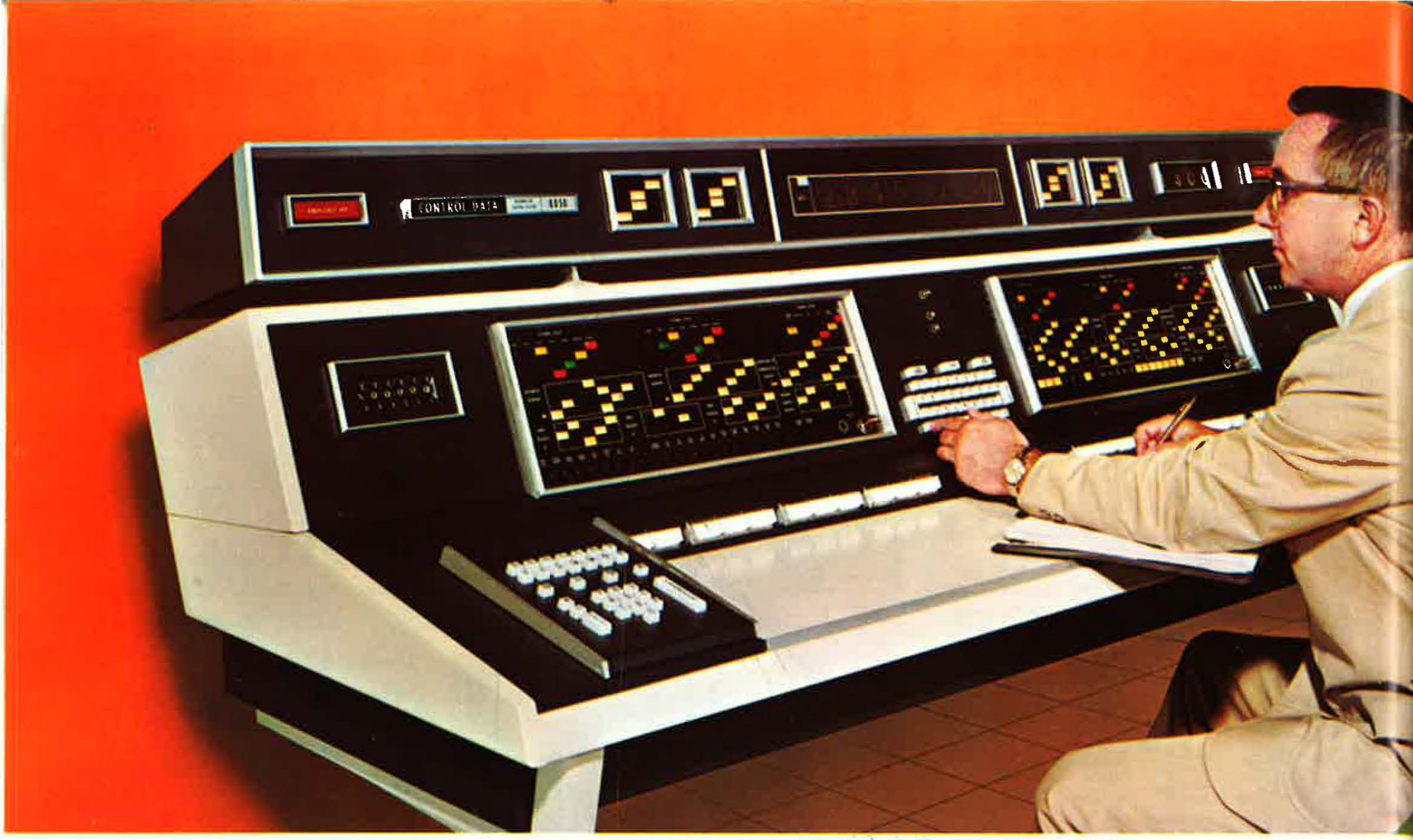
Fig. 4 The effect of illumination on huma perception speed when reading har copy.

TABLE 2

READABILITY OF HARD COPY

Item	AMS Map		Typewriter Make A		Typewriter Make B		Teletype		Pencil HB .032″ lead	
Paper Refl.	.65		.7		.7		.6		.7	
Contrast	8.3		6		6		5		3.3	
Min. Alpha Mins.	2		4		2		4		4	
Illumination ft-candle	B	Speed*	B	Speed*	B	Speed*	B	Speed*	B	Speed*
1	.65	2.7	.7	14.5	.7		.6	10.5	.7	6.2
2	1.3	5.8	1.4	22	1.4	3.2	1.2	16	1.4	10
4	2.6	8.3	2.8	35	2.8	5.5	2.4	25	2.8	14.8
8	5.2	13	5.6	45	5.6	7.7	4.8	35	5.6	21
12	7.8	16.5	8.4	55	8.4	9.7	7.2	42	8.4	26
20	13	21	14	63	14	13	12	48	14	33.3
40	26	28	28	75	28	17	24	62	28	40
80	52	35	56	90	56	23	48	73	56	47
100	65	38	70	96	70	25	60	80	70	50

*See text for meaning.



Two computers are operated from this Control Data Corporation Console which uses six DATA•PANEL Information Displays.

NEW TEC LITE

D A T A • P A N E L

SOLVES FIVE INFORMATION DISPLAY PROBLEMS AT LOW COST!

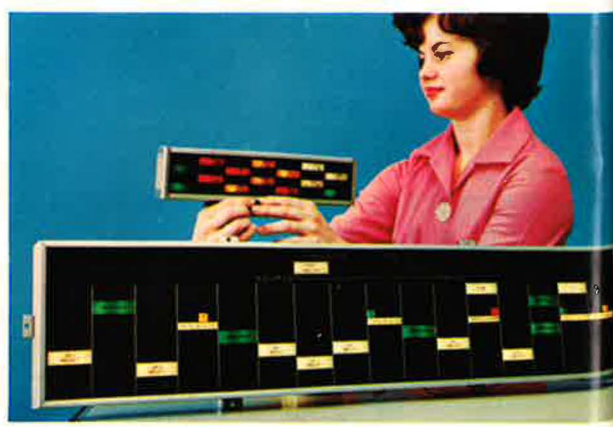
Designers of computer consoles, display panels and status boards now have a strikingly beautiful, yet truly practical way to answer problems of visual impact, operator accuracy, appearance and display versatility. DATA•PANEL offers a totally new approach to custom designing and building information displays at a cost usually far below that for standard panels using conventional individual indicators.

TEC-LITE DATA•PANEL gives the designer almost unlimited freedom in size, style, color and arrangement of messages and indications within the display area. *Only when illuminated* are alpha-numeric messages and symbols visible in color behind planes of glare-free black glass. DATA•PANEL eliminates rows of ever-present individual indicators which restrict design freedom.

Operator accuracy increases sharply with the use of DATA•PANEL because only the important ON indications can be seen and read. OFF indications are invisible until illuminated and the operator is not confused by the presence of non-indicating indicators.

TEC-LITE DATA•PANEL is also electrically and mechanically versatile and is custom designed to fit the particular characteristics of any computing or control system. DATA•PANEL is designed and built by Transistor Electronics Corporation, originator and world's largest manufacturer of transistor controlled indicating devices. Send for 8-page brochure with design specification forms for more information on DATA•PANEL.

1 APPEARANCE—An entirely new look is given computer consoles and display panels by the distinctive and dramatic appearance of DATA•PANEL. Information is displayed with clarity, brilliance and readability never before available to designers. Indications, readouts, complete legends stand out emphatically, in full color behind smooth planes of glare-free black glass. As modern in concept as the systems it serves, DATA•PANEL is the key to clean, handsome console styling.



Status boards can be made in a variety of sizes using the DATA•PANEL Concept.

2 DISPLAY VERSATILITY—There are no restrictions, within practical limits, to the overall size of DATA•PANEL, or to the shape, color, size or arrangement of alpha-numeric messages, indications or digital readouts. Legends (which are photographically reproduced) may be as long or as large as required and unlike methods used with conventional indicator lights, are not limited by size of lens cap or cost of panel engraving. Each legend or symbol appears within a DATA•Module, which may be of many sizes or shapes.

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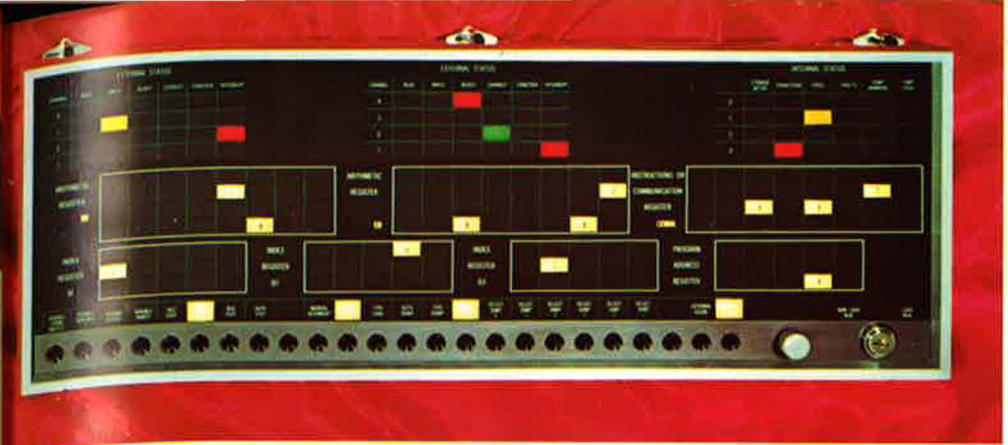
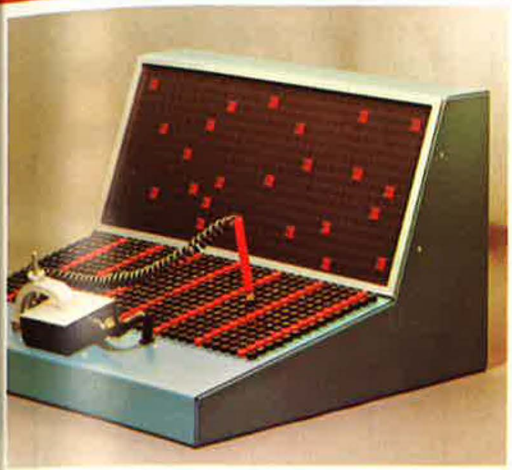


DATA•PANEL indications are visible only when illuminated. Permanently visible legends and grids are provided for operator orientation. Courtesy Control Data Corporation.

3 OPERATOR ACCURACY—DATA•PANEL legends and indications in the OFF condition are totally invisible until illuminated. Operators, therefore, are not distracted or confused by the presence of ambiguous, non-indicating indicators, or, for example, by red lensed indicators that merely turn redder. Permanently visible grid lines and legends can be provided for visual orientation. Operators working with a visually clean panel suffer less fatigue and, consequently, make fewer errors.



DATA•PANEL, with 540 lamp display is used in Module Test Device at Litton Data Systems Division.

DATA•PANEL, 2½" high x 4½" wide, was custom designed for Litton Data Systems Division.

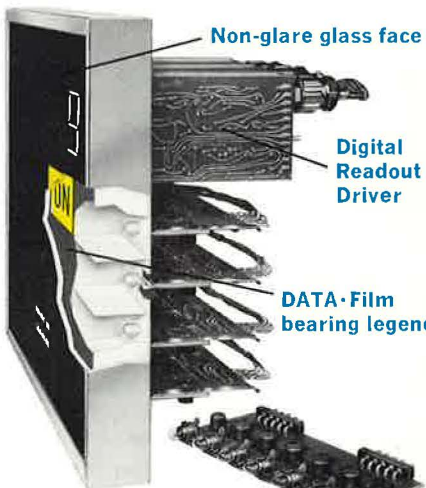
4 CUSTOM DESIGN—Information display areas become an integral, complementary element of console styling when DATA•PANEL is used. Its extremely flexible visual and mechanical parameters give designers freedom never before available in display techniques. Built to designers' specifications, DATA•PANEL is a complete, self-contained display unit ready to mount. If you prefer, TEC-LITE DATA•PANEL industrial designers will provide console styling and display layout based on your requirements.

5 CUTS DISPLAY COSTS—Even though built to your design and offering unequalled appearance, DATA•PANEL usually costs less than conventional display panels using individually mounted indicators. DATA•PANEL costs less because it eliminates these costs: metal panel fabrication and finishing; hot stamping or engraving legends; mounting and wiring of many individual indicators. When transistor controlled lamps are specified, DATA•PANEL costs less because many lamp control circuits are placed on a single printed circuit board, common connections are used and simple lamp mounting devices employed. Eliminated are many expensive parts such as lenses, lamp sockets, nuts, bodies and molded terminal assemblies required for each individual-type indicator. DATA•PANEL production costs are reduced by standard tooling, hardware and component mounting techniques.

CUSTOM SWITCHES—TEC-LITE DATA•Switches extend console design freedom to important control functions, too. They offer a variety of electrical, mechanical and visual options. Buttons may be produced in configurations appropriate to panel design. Conventional or transistor controlled indicators can be incorporated with, but isolated from, the switch to combine indication and control functions for space conservation and operator efficiency.

DATA•PANEL and switches are combined in this display-control assembly built for Control Data Corporation.

DATA•PANEL SOLVES ELECTRICAL-MECHANICAL PROBLEMS
DATA•PANEL is extremely flexible both electrically and mechanically. Replaceable incandescent or neon lamps are used and may be selected to operate from a wide range of supply voltages or controlled by solid state circuitry which is a part of the assembly. High current drain problems encountered with incandescent lamps are solved by transistorized circuitry that switches lamps ON and OFF with low current level signals usually found in solid state systems. High voltage problems inherent in neon lamps are confined to DATA•PANEL by use of self contained circuitry that operates from low level logic signals. Neon display tube, segmented, projection and other alpha-numeric readout devices can be mounted behind the glass panel as an integral part of the assembly. Mechanically, DATA•PANEL and its DATA•Modules may be of any practical size. The self-contained display panel can be mounted flush with adjacent surfaces or recessed below and at angles to surrounding surfaces. Rack mounting is also available.



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FOR IMMEDIATE ASSISTANCE CIRCLE NO. 920

INDICATE 20 ON READER CARD

5-BEAM CRT PROVIDES REAL-TIME DISPLAY WITH SIMULTANEOUS PHOTOGRAPHY OF DATA

Five separate and distinct displays on one tube face-plate together with a rear-view optical window for photographic recording or map projection are two of the features that make the Du Mont type KC 2296 of more than usual interest to design and project engineers. Successfully meeting a number of unusual operating parameters, the KC 2296 is utilized in a military aircraft navigational application, but numerous other uses are possible for this type and other cathode-ray tubes which may be designed around the multi-gun, rear-view window concept.

Time, distance, angular displacement, pressure, acceleration, telemetry... in fact any kind of data that can be translated into voltage format can be displayed and photographed at the same time. With PPI radar, five sets of data can be superimposed on maps projected on the face of the tube through the optical window. The data (e.g., positions of aircraft or other targets) are then viewed in real-time relationships to the map. Any standard or special phosphor, or any graticule configuration, can be supplied.

Actual phosphor used in the KC 2296 is a double layer phosphor with a high efficiency visual component and high energy blue component for maximum results with blue sensitive film.

With KC 2296, information is displayed on the internal graticule, on the inside of the tube face-plate, making both front and rear views free of parallax. A special phosphor deposition technique allows the graticule lines to be essentially free of phosphor and sharply visible from both front and rear. The five electron guns are independently controllable, and each beam is positioned to scan a separate screen area, except for two beams which coincide. The tube can as readily be designed so that each gun sweeps the entire display area, or any selected segment. Each electron gun is electrostatically focused and deflected.

The rear-view optical port includes such design innovations as freedom from distortion, and the internal graticule may be illuminated by a special side-lighting technique for sharp, clear photographic prints.

RECENT DU MONT ADDITIONS TO CATHODE-RAY TUBE TECHNOLOGY

New application requirements in instrumentation, radar, character display, and other display and readout use have seen significant advances by Fairchild's Du Mont Laboratories in essential types and characteristics. Following are several areas which may be of specific interest to systems managers and project engineers concerned with display and readout problems.

Higher Resolution

Newest designs produce tubes with resolutions of 1,000 lines per inch in electrostatic types with electrostatic deflection. Resolution of 2,000 lines per inch is achieved in magnetic deflection tubes. High resolution electrostatic types achieve deflection sensibilities of 15 mv/trace width at writing speeds in excess of 10" trace widths/second.

Deflection Sensitivity

Deflection factors in currently available tubes are 1 volt/cm and 7 volts/cm in the signal and time axis respectively when operating at a screen potential of 15 KV. These types are available with conventional or with fiber optic face-plates.

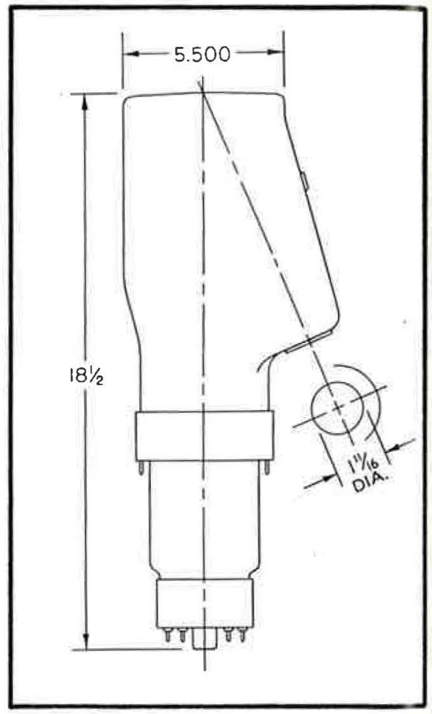
Large Screen Radar Display with High Resolution

Flat face radar display tubes have been produced for high ambient viewing with resolution capabilities of 2,500 lines across the 20-inch useful screen diameter at high display brightness.

Large Diameter All Electrostatic High Writing Speed

For high-speed computer readout, rapid random access and time-sharing radar displays, Du Mont has a complete new line of large diameter electrostatic focus and deflection CRTs with high writing speeds and high deflection sensitivities.

It makes particular sense to look to the leader for cathode-ray tubes – or for **any** other special purpose tube. No other manufacturer is better equipped to design and build special purpose tubes for your specific application demands.



KC 2296 is 18½" overall, has 7" diagonal, 5" square face. Deflection and acceleration electrodes are brought through tube wall to collar base to minimize L and C of leads.

However, this implies a larger symbol and a reduction in the number of symbols that can be presented on a given size screen. The specification writer is faced with a compromise, which he must make with the knowledge that the selection of a too-small symbol will impose a penalty in legibility, and that this penalty will have to be paid day after day by the commander and his staff.

The display plotted in curve "B" of Figure 5 and the Army map were then selected as representing the displays that might be considered the critical pair in some fictitious command center, and their curves were replotted in Figure 6. It is obvious that their crossing point specifies the illumination at which the critical

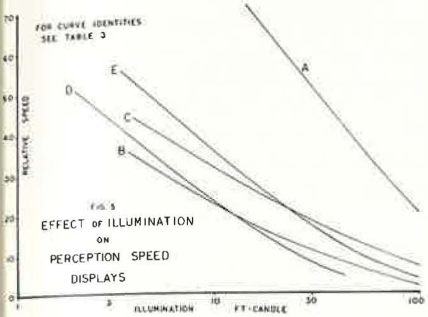


Fig. 5 The effect of illumination on human perception speed when reading self-luminous displays.

hard copy and the critical display can be read with equal ease.

It should be stated again that the speed scale is not the reading speed, but merely a way of achieving comparison.

Several things can be learned from Figure 6. For one, it is possible that either class of display can be improved. The brightness of the cathode ray tube may be increased or the suppression of the ambient illumination improved; the map may be printed on better paper, or its contrast may be increased by a change of ink. The interesting point is that any improvement will raise the curve for that display, and if the value of illumination is adjusted to suit, the ease of reading of *both* displays will be improved.

Second, it must be recognized that it will sometimes not be possible, or perhaps desirable, to use the value of illumination that the computation calls for.

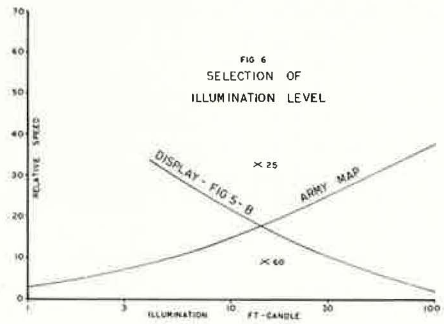


Fig. 6 The selection of an optimum illumination for reading both hard copy and self-luminous displays is accomplished when the relative perception speeds are equal.

On such an occasion the plot offers numerical indication of the advantage given one type of display and the penalty imposed on the other by the required level of illumination.

And third, the small crosses marked 25 and 60 represent the crossing points of two other sets of curves for the same displays but based on human performance curves in which the field factors were taken as 25 and 60. The three crossings indicate the same value of illumination to within the accuracy with which the performance curves can be read and their plot smoothed; it must be concluded that the value of the field factor has no bearing on the computed value of illumination so long as the same factor is used in the computations for both self-luminous displays and hard copy.

Suitability of the Computed Illumination

Since the computed level of illumination is markedly lower than the general recommendations of the Illuminating Engineering Society for offices, it is proper to question whether or not it is suitable. This must be asked in two parts—is it sufficient? and is it pleasing?

Many years ago a number of observers were given control of the illumination and were asked to find the value that was best for reading the *Saturday Evening Post*. The reported values follow:[6]

Available value of illumination, foot candles	10	30	45
Chosen value	5	12	16

The very human tendency to choose a middle value is apparent, and it must be remembered that the observers were accustomed to a lower level of illumina-

TABLE 3
READABILITY OF DISPLAYS

Phosphor — Brightness, 50 ft-L; Reflectivity, 85 %

Filter Factor	0.4			0.4			0.4			0.75			0.75		
Symbol B ft-L	20			20			20			37.5			37.5		
Alpha Minutes	4			2			2			2			2		
Hood Factor	.5			.5			.25			.5			.25		
Illumination ft-candle	Backgd. B ft-L	C	Speed*	Backgd. B ft-L	C	Speed*	Backgd. B ft-L	C	Speed*	Backgd. B ft-L	C	Speed*	Backgd. B ft-L	C	Speed*
1	.068	294		.068	294		.034			0.239	156		0.119	315	
2	0.136	147		0.136	147		.068	294		0.478	78.5	51	0.239	156	
4	0.272	73.6	101	0.272	73.6	33	0.136	147		0.956	39.2	36	0.478	78.5	51
8	0.544	36.8	87	0.544	36.8	25	0.272	73.6	33	1.91	19.6	27	0.956	39.2	36
12	0.816	24.5	76	0.816	24.5	19.5	0.408	49	28	2.87	13	19	1.44	26	31
20	1.36	14.7	60	1.36	14.7	13.5	0.68	29.4	23	4.78	7.85	12	2.39	15.7	23
40	2.72	7.36	42	2.72	7.36	7.9	1.36	14.7	13.5	9.56	3.92	4.8	4.78	7.85	12
80	5.44	3.68	25	5.44	3.68	3.1	2.72	7.36	7.9	19.1	1.96		9.56	3.92	4.8
100	6.8	2.94	19.5	6.8	2.94	1.6	3.4	5.89	6.2	23.9	1.57		11.9	3.15	3.3
Curve in Figure 5		A			B			C			D			E	

*See text for meaning.

tion than are we today. However, it is also apparent that there is no pressing human need for high levels when the contrast is good.

And in their work on the utility of colored illuminants, Feree and Rand[7] tested the eyes of their observers both before and after reading for three hours in Table 3 and plotted in Figure 5.

The difference between curve "A" (four minutes of arc) and the other curves (two minutes) is notable. One is tempted to say that a stroke width of four minutes should always be used. with a colored illumination of only 0.3 ft-candle. There was a measurable loss, but the significant fact is that it was possible to read for that time with an undesirable light and at such a low level.

One must conclude, then, that the computed level of illumination is above the minimum by a factor of at least forty, and that it is in a range that has been selected as optimum in tests where the observer could control the level of illumination.

It is clear from the above data that the computed level of illumination is sufficient, but that does not assure that it will be pleasing. The reason why it may be one and not the other is that the eye does not see illumination—it sees the brightness of the work and its surroundings that result from that illumination.

The sources of illumination should be distributed, but not evenly distributed. Completely diffuse illumination creates a somnolent atmosphere, while the inclusion of some concentration points helps seeing through the formation of the shadows by which form is perceived. And of course no light source whose brightness is materially higher than that of the walls should be within the field of views of the operating people.

The ratio of brightnesses within the field of view should be low. This effect is most easily achieved by using the same finish for similar objects and keeping the illumination reasonably even. Such variation in brightness as exists should follow as closely as possible the rule that the ceiling be brightest, the walls next bright, the furniture and equipment next, and the floors least bright, but not dark. The IES recommends that the reflectivities be walls, 0.5; furniture and equipment, 0.35, and floors, 0.3. It should be noted that hard copy, with a paper reflectivity near 0.7 and ink reflectivity near 0.1, will have good contrast within itself without either the paper or the ink being markedly different from its surroundings.

Wall projection screens present a problem because the symbol brightness is limited and it is necessary to achieve the required contrast by keeping the background dark. Hence, the screen must be carefully screened from all room lights. However, the area immediately around the screen must be as bright as the rest of the wall. This surrounding area can be illuminated by highly directive lights, it can be back lighted, it can be set back of the screen and illuminated by lights behind the screen, it can be made fluorescent and excited by ultraviolet light, etc. When done properly the symbols will be brighter than the walls and the background darker; the presence of the walls will make the screen appear to have a greater contrast than it actually has, and at the same time will maintain the balance of brightness with the rest of the room.

A clear and public example of the effectiveness of balanced brightness is available in the two reading rooms of the Congressional Library in Washington. The old reading room in the main building is equipped with dark furniture. At night the walls are relatively dark, and the darkness of the ceiling is relieved only by an illuminated painting. Lights over the desks illuminate only the writing surface. In the day the walls are much brighter, but the windows to the south and the spots of sunlight to the north make severe glare spots. Study in this room is very tiring, eye strain setting in after an hour or two. The reading room in the Annex is illuminated with artificial sources only, using desk lights similar to those in the old room plus indirect illumination. The ceiling is the brightest part of the room, the walls are next bright, and the furniture is relatively light. There are no glare spots. One can study for hours in this room without fatigue. The comparison is striking proof of the desirability of a low ratio of brightnesses: it is even more striking when one realizes that the illumination on the writing surfaces in the two rooms is the same.

It is clear, then, that the process outlined in this paper provides equal ease of reading for both hard copy and displays, that the resultant illumination is entirely adequate, and that it can be made pleasing. There remains only the problem of those officers who normally work in brightly lit offices and who must move to the command center on the occasion of an alert. Luckily the computed illumination for the command center is less than that to be expected in offices by a factor of only three to six. It is felt that a smooth transition can be made possible by setting the illumination of the intervening halls and anteroom at a value intermediate between those of the offices and the command center.

As in most system studies, this work shows that much can be done by a number of small steps taken together. It must be noted that one of these steps, that of providing a limited range of brightnesses, has long been known but has frequently been overlooked.

There is no easy way to compute th effectiveness of hoods, means for direc ing the illumination, etc. One solutio is to make the display contractor respon sible for the entire installation and t provide time and funds for either mockup or extensive tests in location. A approach that would save the cost c repeated mockups is for the Governme to make the tests, to provide a suitab room, to specify the design of the hood and to relieve the contractor from r sponsibility for the contrast.

Conclusions

a) The described process readily giv the illumination level at which hard co and self-luminous displays are equal readable, or gives a quantitative stat ment of the advantage given one da source over the other when a different i lumination level is used.

b) The current art for cathode-ray di plays permits an adequate level of ill mination if known techniques for mai taining contrast are used. The same true for projection displays if the scre area is reasonable.

c) This level of illumination will b pleasing if the color of the ceiling, wal furniture, equipment, and floors, an the distribution of illumination gives small range of brightness with a prop distribution of brightness.

d) The values for the contrast of ha copy given herein should be re-examine If the listed values are low, then corre values will permit a new selection of i lumination with which both the ha copy and the displays can be read mo easily. If the listed values are corre then similar values can be used in futu display specifications with a financial sa ing for the customer. ⊙

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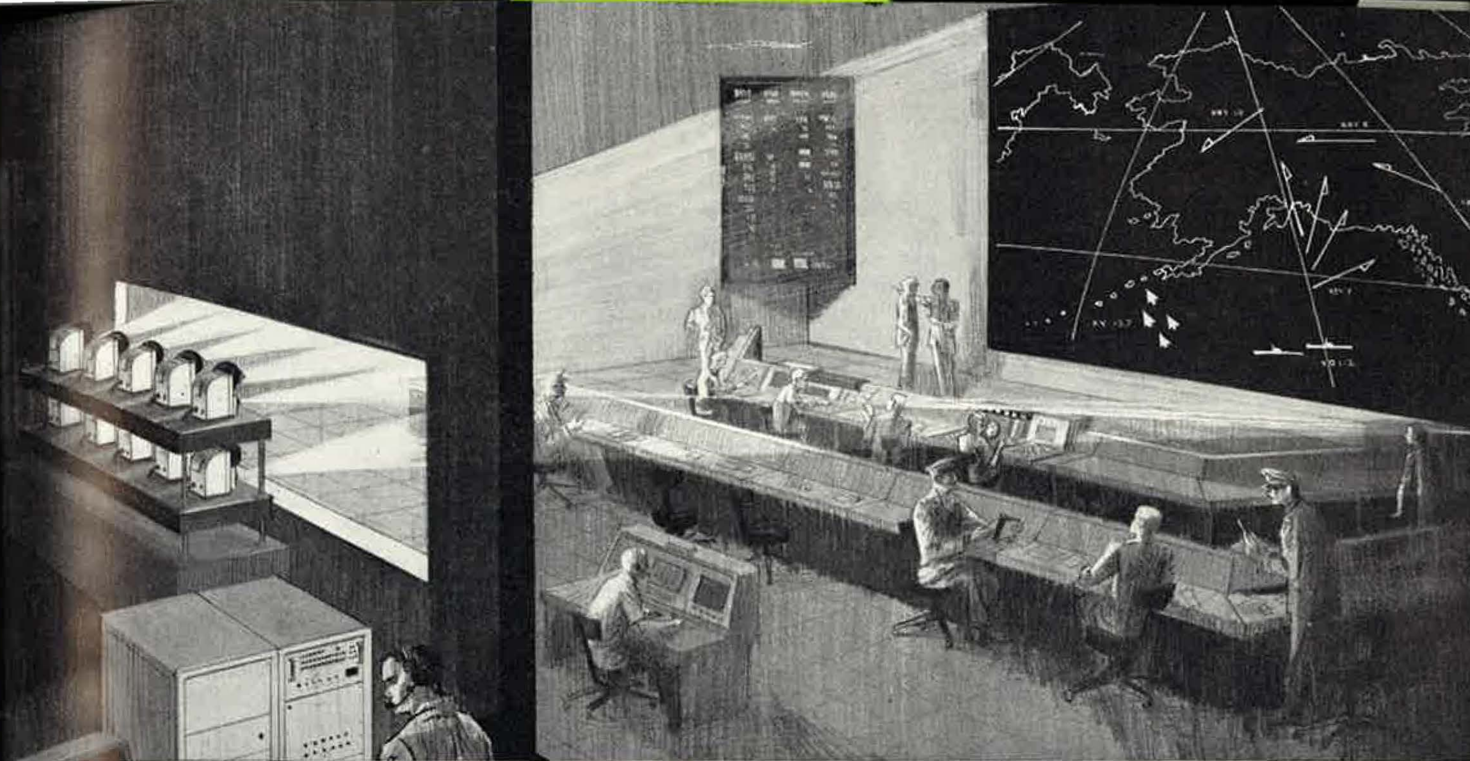

How do you visualize real time computer data . . . continuously, completely, for command decisions?

One Military Command does it with 50 of these.

This is a Kollsman Data Display Projector. It is a modular unit that is built up into systems for displaying real time command or control data from analog or digital computers or manual input sources, on a large screen. The display systems enable commanders to base decisions on visual interpretation of continuously displayed, computer-processed data.

Why was it selected for this important mission? Partly because of its performance—real time response and high contrast ratios . . . plus a repositioning accuracy of 0.03%. Partly because of its rugged construction, dependability and ease of maintenance. And partly because of its proven capability in actual service installations.

For command control or training missions, or for air traffic control, Kollsman Data Display Systems with their solid-state circuitry and advanced electro-mechanical components provide the sure performance their sensitive roles demand.

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Circle Reader Service Card No. 22

THE INFORMATION DI

AS IT EXIST

by
Ruth M. Davis

A good catch-phrase with which to start a discussion on displays might be "There is something in it for everyone." Certainly, the interdisciplinary nature of display development attests to the truth of this phrase. Contributing disciplines include optics, psychology, physiology, engineering, the behavioral sciences and the computing sciences.

Such an interdisciplinary approach is both a strength and a weakness to display development. Its strength lies simply in the multiplicity of disciplines upon which it may feed and expand; its weakness lies in the difficulty of effecting a parallel advance on all the essential fronts typifying any display development.

It would be interesting, in this regard, to survey the membership of the SOCIETY FOR INFORMATION DISPLAY just to determine what the formal scientific backgrounds of its members were. Without dwelling indefinitely on this interesting characteristic of displays, suffice it to say that it reveals the role always played by displays which has been accentuated by the recent development of automated dis- play devices. In particular, the function of information display is a transfer func- tion between the external environment and man's reasoning and decision making capabilities. The effectiveness of the in- formation display function is affected by individual human traits, by the method of display, by the mechanics of display and, of course, by the completeness and representativeness of the information being displayed. It is believed that each of these display characteristics might form the nucleus of a contributing dis- cipline in the information display field.

Currently, it appears that the field of information display, although growing rapidly, is disorganized and relatively ineffectual in its influence upon display development projects. The present state of organization within the field is epit- omized (1) by a standing group within the National Academy of Sciences–Na- tional Research Council known as Work- ing Group VI of the Vision Committee and concerned with displays for control of forces, (2) by a yearly Institute spon- sored by the Center for Technology and Administration of the American Univer- sity, (3) by courses given at the Univer- sity of California at Los Angeles (UCLA) and, (4) by the SOCIETY FOR INFORMA- TION DISPLAY with its local chapters and national conventions. Working Group VI is the oldest of these groups and it date back to about 1959, emphasizing the youthfulness of the field.

This state of affairs merely serves to point up the fact that the information display field is a young and growing one, that it has no solid scientific discipline or academic curriculum to support it as yet and that a tremendous amount of challenging yet essential ground work remains to be done before projects in the field can expect to gain any but accidental success. It is always an interesting exercise when trying to describe a new subject area such as information display to try to establish a hypothetical scholastic discipline which will lead to various degrees of proficiency. Such an exercise here reveals both that a wide range of formal schooling is needed to cover the waterfront of information display design and that no one of the existing standard college specialization fields is sufficient to qualify a graduate as an information display designer.

Contrary to these facts being considered an indictment against college curricula they are instead advanced as an indictment against the current frenzied search to find an individual who typifies a typical information display expert, a standardized set of procedures to follow in information display design, a typical hierarchy of information display systems from which one can derive all information display systems, a single book in which one can cover all aspects of information display system design and a parallel development in all techniques of information display. The railway system was not immediately possible with the invention of the steam engine although a requirement for rapid, reliable transportation between all cities in the Continental United States existed and was frequently stated. Again, the invention of the printing press did not result in a breed of trained individuals capable of developing an optimum reproduction and dissemination system for rapid, controlled, responsive distribution of printed material although, here too, such a requirement existed. Similarly, in our time the development of many new information display devices from individual consoles to large board automated displays, along with an associated requirement for an information system, does not guarantee either the development of the system or the existence of individuals adept in design of such a system.

On the assumption that the process of learning and applying new techniques and theories has not changed over the years, it is probable that most of the state-of-the-art techniques and immediately available skills now utilized in system design are interim measures and that a basic theory covering the varied aspects of system design is already evolving and will supplant many of the mispractices and misues of system design now tolerated and condoned.

Of course, the information display field runs the gamut from grease pencil charts through television displays to computer-run automated large board color displays and each portion of this display spectrum in turn has its own challenges and its own problems. However, it might be interesting at this point to discuss one particular area in which the Department of Defense has had some recent experience.

As is well known, the Department of Defense has pioneered in the design, development and usage of automated display systems. They have been joined in the last several years by NASA and FAA where this trio probably represents almost the entire government support for such systems. The Department of Defense, itself, has sponsored eight major efforts to design, develop and use computer-driven large board display projects. These were intended for automated air defense or command and control type systems.

The initial effort is just now about a decade old and is, of course, that for the SAGE air defense systems. These eight projects cost the Department of Defense more than seventy-five million dollars. Three involved black and white displays and five involved color displays. One black and white display—the SAGE display—and one color display are currently functioning in an operational environment. However, no color display has yet been used by the command for what it was intended for its prescribed purpose.

One display which was installed and declared operational by the developing agency is in the process of being removed less than three years after its operational birth date. Its removal is due simply to the disturbing fact that it was never found useful by its users. It was cumbersome to use and the display system was incapable of being readily modified so as to display information not initially thought of by the users or system developers.

Development of two of the display systems had to be stopped several years after work was initiated but prior to final completion and the project had to be completely reoriented. Stoppage in these cases was due to technical difficulties in the engineering design and occurred before any operational criteria could be applied.

It is interesting to note that for the

PLAY FIELD

TODAY

SAGE System no statistics or data have been compiled on the usefulness or the adequacy of the large board display systems for the command concerned. Succeeding projects have as a result not been based on lessons learned from previous efforts.

Mistakes have been duplicated and unfortunately very little learning has accrued to the intended users since most of the displays run into their technical or philosophical difficulties prior to their being applied to military command users. To the best of my knowledge, only one company has been asked to deliver a second large board display system and this occurred seven to ten years ago. It is difficult to imagine a stronger indictment against the success of display efforts.

One should of course be able to use this decade of experience to draw a number of conclusions concerning both potentials and deficiencies in management, design and usage of display systems. That this is indeed the case will be shown subsequently. However, at this point it is worthwhile to explore another area of display technology where some considerable success is being achieved and where there appears to be considerable potential to exploit.

Presently, the individual display console seems to have proven more useful than has the large group display. It may be because of the distinct correlation between decision modes and electronic display equipment types. First, the following modes of decision may be differentiated on the basis of user roles:

- Decision modes based on user roles
  - (1) *Individual* – here an individual is self-sufficient as a decision-maker and provides a unilateral decision.
  - (2) *Group* – here group participation results in a decision made while the group is in session. The decision has the concurrence of all group members.
  - (3) *Individual within a group* – here the individual although part of a working team makes an individual decision which forms a part of the complete decision required of the group. There is always a dependency between such individual decisions which can be explicitly stated, e.g., time-phased.

Secondly, a division of display equipment types based on engineering or systems roles may be made as follows:

- Electronic display equipment types
  - (1) *Individual console* – the console is designed for use by one to three individuals at a time. Display is non-permanent. (No permanent copy is produced.)
  - (2) *Group display* (or large board display) – a large screen display suitable for viewing and use by a minimum of four people at a given time while they are seated. The size of the display is dependent upon the stated number of viewers. Display is non-permanent.
  - (3) *Intercommunicating individual consoles* – the individual console forms part of an intercommunicating display system such that an operator at any given console may change the display at any other console or have his display so changed. The intercommunications are under operator control. Display is non-permanent.
  - (4) *Hard-copy display unit* – any equipment capable of producing a permanent hard-copy display of any size.

The correlation between the above decision modes and electronic display equipment types is as follows:

- Correlation between decision modes and display equipment types

(1) Individual	(1) Individual Console
(2) Groups	(2) Group Display
(3) Individual with a group	(3) Interconnecting individual console
	(4) Hard-copy display unit

The intended meaning of the linking lines can be illustrated by an example. The solid line from the individual console equipment to the individual decision mode indicates that this is an entirely satisfactory linkage. The dotted line (-•-•-•) from the individual console equipment type to the "individual within a group" decision mode indicates a frequently made correspondence which is not entirely satisfactory.

The contention is made here that individual display consoles have achieved more success because the individual decision mode has been more completely studied than the group mode and because group decisions involve more qualitative factors than individual decisions. It is true that those decisions which are the most difficult to make are those which involve qualitative factors such as judgment, experience and intention.

A decision which involves quantitative factors only may be completely described in terms of successive steps and may be assigned to an individual to make. More than one individual is normally consulted where qualitative judgments are required. Also, as one might expect, it is more difficult to determine how to use displays to aid in decisions involving qualitative factors or to aid group decisions.

It is interesting to list some of the areas for which automated individual consoles are being used or investigated in the Department of Defense if one first notes that large automated group displays are normally suggested as group briefing aids or as aids in viewing large geographical areas on which changing information is being displayed.

Some of the areas of interest for application of automated individual consoles include:

(1) On-line solution of numeric problems.
(2) Query of automated data base
(3) Automated programming aids.
(4) Graphical problem solution.
(5) Tactical command and problem such as air defense.
(6) Input analysis
(7) Textual editing, extracting and indexing.
(8) Monitoring of system status, say as for secure ADP system
(9) Presentation of changing force status and/or disposition.
(10) Rapid modification of automated data bases.
(11) Photo interpretation.
(12) Pattern recognition.
(13) Geographical contouring.

There are projects in each of these areas, either already funded or in the process of being funded in the Department of Defense and one can certainly expect the number to be increasing as our knowledge of display technology and usage becomes more precise and scientifically-grounded.

On the basis of experience gained during the last decade and as a result of the research done in government laboratories and by private industries it now appears possible to formulate a management approach to development of automated display systems and of orienting future developments so that they do improve the capability of the military commander. The main subject areas proposed for this management approach are:

(1) Keying of displays to specific functional requirements of user groups.
(2) Analysis of the correlation between display types, information structure and behavioral characteristics of the user groups.
(3) Improvement of system design techniques to permit shorter design lead times.
(4) Development of more varied and simple display hardware.
(5) Development of improved computer-to-display techniques and hardware.
(6) Advancement of human factors research and application.

All of you are encouraged to discuss these topics and advance ideas which you may have with us in DDR&E who are interested in the science of information display.

ID Readout

News from SID Chapters

— Los Angeles/San Diego —

The Los Angeles and San Diego chapters joined, in their first fall meeting, for a visit to March AFB, Riverside, Calif., to see the *WS 456-L* installation. The Los Angeles chapters of SID and SPIE recently presented a joint 2-day symposium on new technologies for data recording and display.

— Washington —

Regular monthly technical meetings held this year have included the following presentations: "Vigicon Displays", by Nortronics; "FAA Bright Display Systems Demonstrations Used in En-Route Air Traffic Control", arranged by E. Storrs; dual presentations of "Multiple Station Display Systems", by The Johns Hopkins University Applied Physics Lab, and "Signal Distribution for Matrix Displays", by Wetinghouse; "Generalized Display Language and System", by Datatrol Corp.; and Air Force Systems Command displays. A joint visit was arranged with the Mid-Atlantic chapter to the Rome Air Development Center in New York. Average attendance at meetings is nearly 70% of membership.

Debons Presides at International Meet

Anthony Debons, President of the *Society for Information Display*, presided as chairman of a group of U.S., French, and German scientists in Bonn, Germany last June. The meeting was sponsored by the Mutual Weapons Development Information Exchange program of the Department of Defense. The group reviewed the state-of-the-art in man-computer information transfer, with particular attention to the present research and development resources of member countries in visual display technology that could meet the needs of the NATO community.

Dalto Receives NASA "LOLA" Contract

NASA has awarded a $1 million contract to Dalto Electronics Corp. to build the lunar navigation display system for the Lunar Orbit and Landing Approach Simulator (LOLA). The simulator, a research tool to develop techniques and test operational hardware for the nation's over-all lunar program, will be installed at NASA's Langley Research Center. It will provide scenes of the moon and stars, as seen through the four viewing ports during simulated spacecraft maneuvers. Four models of the lunar surface furnish the scenery, showing how the moon will look to the astronauts at distances varying from 200 miles out down to 200 ft. from touchdown.

Multichannel Pulse-Height Analyzer/Printer

Optikon, a new data output printer for multichannel pulse height analyzers, has been announced by Nuclear Data, Inc. Optikon uses photographic techniques that the manufacturer claims are 20 times faster than computer readout typewriters. The Opikon printer presents data in row and column format on either a 3 x 4 inch or 4 x 5 inch Polaroid print requiring only 10-second development. A complete readout of 1024 six-digit numbers can be printed in approximately one minue. The new printer has only two moving parts. It is slaved to the controlling instrument.

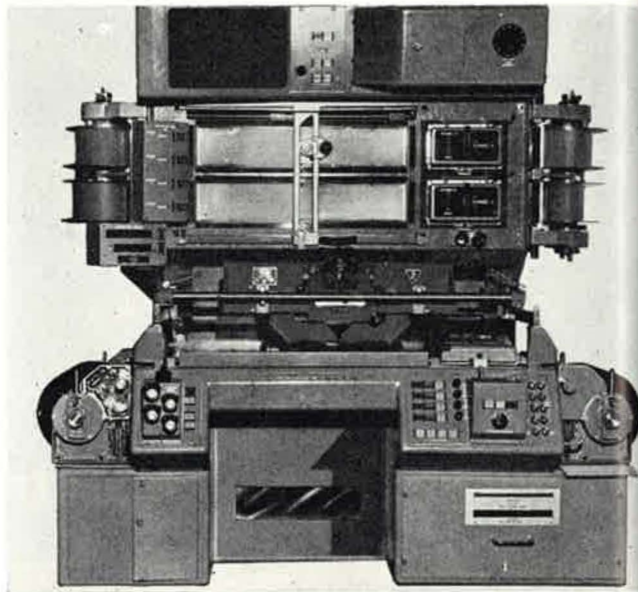
Call for Papers

The Fifth National Symposium of the Society for Information Display, February 25-26, 1965, Los Angeles, is now calling for papers dealing with display systems and related technology. Submit 500-word abstracts to Rudolph Kuehn, Papers Chairman, 1831 Seadrift Drive, Corona del Mar, Calif., by November 16, 1964.

Spacecraft TV Data System for JPL

JPL has ordered a Spacecraft Television Ground and Da Handling System (STGDHS) for its space flight operatio complex to support NASA scientific investigations of the mo and planets by providing visual observations of their surfac The new system, to be built by Link Group, General Pre sion, Inc., will record spacecraft television data and produ accurate image material for the scientific community from t transmissions. Included in the over-all Link system will the following subsystems: data acquisition and recordin data recovery, on-site film recording, media conversion, di play and analysis, and storage retrieval and photoprocessing

Reconnaissance Data Reduction Shelters



Fairchild's new multi-sensor, viewer-printer display console.

Rome Air Development Center has begun accepting d livery of new reconnaissance data reduction shelters fro Fairchild Space & Defense Systems under a $7.6 million co tract to furnish Air Force commanders with split-second int ligence information on tactical enemy targets. Part of a limit war intelligence reduction complex designed by Rome AD AFSC, three of the image interpretation cells can be airlift in a four-engined C-130 Hercules transport to any milit theater within 24 hours. Key element in the cells' semiau mated photo-interpretation systems is a new multi-sen viewer-printer console (see photo) for simultaneous displ of panoramic and frame photography as well as side-looki radar and infrared imagery. A digital computer and telety writer equipment speed preparation and transmission of i telligence reports.

Charactron Tube Versatility Increased 50%

A new matrix containing 96 different characters and sy bols instead of the usual 64 available in the Charact Shaped Beam Tube is being incorporated into new compu display systems produced by Stromberg-Carlson div., Gene Dynamics, the firm has announced. The newly-develop matrix is capable of presenting both upper and lower c letters, plus a variety of symbols and Greek letters. The tu also has a spot writing capability, producing an 0.008-in spot at four microamps. Character size is variable at a ra of 5:1, ranging from 0.200 inches down to 0.040 inches. Sy bols are typically repeated at a 30-times-per-second flick free rate.

Electroluminescent Display Panel Contracts

Sigmatron, Inc., has been awarded two major Navy contracts in the area of high-resolution electroluminescent display panels. One contract, from ONR, is for a research program sponsored jointly by the Army, Navy, and Aircraft Instrumentation Research Committee seeking significant performance improvements in vacuum-deposited thin-film electroluminescent display devices. The second contract, from NADC, Johnsville, Pa., is for the development of a prototype electroluminescent panel which requires extremely high resolution of 256 orthogonal elements over an active surface area of less than 100 square inches. Guidelines indicate brightness of each of the 65,536 individual electroluminescent lamps in the panel will not vary more than 5% over the entire display. Minimum intensity of light output from each lamp is expected to exceed 100 ft. lamberts.

Printers for 416L BUIC Ordered by USAF

The Air Force has ordered more than $1 million in printer systems for its Back-up Interceptor Control (BUIC) program. Anelex Corp., the prime contractor, will supply standard 120-column, 600-lines-per-minute printers, with special cabinetry to combat radio frequency interference. The BUIC semi-automatic command-control system has been designed to provide backup-weapons control capability to SAGE direction centers in this country and in Canada. It will furnish Air Force commanders all possible information, electronically computed and collated, on which to base decision-making in directing air battle. The system, which includes solid-state computers, printers and communications and display equipment, will be installed in existing buildings.

Photochromic Micro-Image Technology

A recent development in information processing has been reported by the Electronics Div., The National Cash Register Co., with its announcement of Photochromic Micro-Image (PCMI) technology. In a recent demonstration of the process, the entire contents of the Bible were reduced, stored, and mass-produced as a film chip of less than two inches square. The basic process can reportedly photograph and store as a reproducible microscopic image almost any record that can be photographed. NCR claims PCMI is the first process which makes it practical to record and disseminate a great quantity of micro-images with very high packing density. Various materials have been successfully recorded and reproduced at reductions ranging up to 50,000:1 in area.

New On-Line Displays at NOTS/Pasadena

Naval Ordnance Test Station, Pasadena, Calif., is currently installing three new display systems at its Simulation and Computer Center. Acquired on an estimated $240,000 contract from Data Display, Inc., the units are basically cathode-tube-type displays, equipped with memories and other refinements. These will be operated "on-line" with both digital and analog equipment utilized in scientific and weapons system analysis. Display of information to a technician will permit him to insert corrections and changes in the computer system.

Bunker-Ramo CRT Flight Information Display

A CRT flight information board recently introduced by Bunker-Ramo Corp. is fed information from a central processor. Bits are displayed on green phosphorescent CRTs, and the presentation is programmed so that size and sequence of characters can be arranged as desired.

Editorial material intended for publication in this column should be addressed to: ID Readout Editor, Information Display, 160 S. Robertson Blvd., Beverly Hills, Calif.

Gen. Gibbs to Speak, 18 Papers Offered At 4th Meeting

Maj. Gen. Gibbs

Maj. Gen. David P. Gibbs, Chief of Communications/Electronics, U.S. Army, is delivering the keynote address at the Fourthe National Symposium of the Society for Information Display, Oct. 1-2, in the Shoreham Hotel, Washington, D.C.

Formerly the Army's Chief Signal Officer, Gen. Gibbs draws on an extensive background in electronics, command and control, and display. This includes a period of activity in the senior command staff, North American Air Defense system (NORAD).

A wide variety of technical papers have been selected stressing information display advances in the fields of medicine, management, education, communications, command and control. Ernest N. Storrs is symposium program chairman.

General Chairman is Lewis R. Blair, Jr., assisted by Vice Chairman Arthur N. Peters. Show Manager is Frank Masters.

In addition to the technical programs, a broad range of the most modern information display equipment available will be exhibited.

Technical papers to be presented include:

The JPL Space Flight Operations Facility Display and Control System —Present Experience and Future Requirements — A. S. Goldstein, JPL.

On-Line Querying Via A Display Console—Harold S. Corbin, Informatics, Inc.

Display Requirements of the Integrated Management Information System of 1968-70 — Peter James, The Diebold Group, Inc.

General Purpose Display System — Stanley L. Kameny, System Development Corp.

Voice Response and Visual Displa Techniques for On-Line Informatio Handling Systems—F. Walter Jeniso The Teleregister Corp.

Psychology of Color Experience- Anthony Debons, University of Dayton.

Narrow-Band Video Communica tions System:—Glenn Southworth, Ba Brothers Research Corp.

Air Traffic Control Simulatio Using Digital Alpha-Numeric Di plays—T. K. Wright, Radiation Me bourne, div. of Radiation Inc.

A Method for Generating Telev sion Mosaic Displays—John W. Conwa and Charles A. Berner, Raytheon Co.

Signal Distribution for A Larg Scale Display—William C. Roberso Advanced Development Engrg. Surfac div., Westinghouse.

Digital Television Message Ge erator—Vernon E. Hupp, Weather Sy tem Center, United Aircraft Corp.

Utilization of Lenticular Fil for Full-Color Display Systems- Daniel J. Morrison, Computer System Section, BuShips, U.S. Navy.

Matrix Controlled Display—A. Orimenko, Data Recording and Displ Electronics Lab, General Electric Co .

An X-Y-Z Plotter—Martin Ruderfe Dimensions, Inc.

Photocromatic Materials In I formation Display Applications—R W. Roth, American Cyanamid Co.

Real-Time CRT Photochromic Pr jection Display — K. J. Stetten, T Budd Co.

A Thin Magnetic Film Techniq for Wall Panel Display—Mr. Full Laboratory for Electronics, Boston.

Displays for Control Cent Management—B. E. Acton, Space & I formation Systems div., North Americ Aviation, Inc.

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ID Authors

Dr. Ruth M. Davis

Staff Assistant to the Special Asst. for Intelligence and Reconnaissance, Office of Director of Defense Research & Eng., Dept. of Defense, Ruth M. Davis received a B.A. in Mathematics from American University and a B.A. and PhD in Applied Mathematics from the University of Maryland.

Dr. Davis has worked with military intelligence branches of the Navy since 1957. She has published several articles on military information display systems and currently serves as Chairman of SID's Honors & Awards Committee.

Dr. Helmut Weiss

Manager of Ford/Philco Aeronutronic's Electro-Optics Dept., Helmut Weiss directed the development of one of the first fully automated display system for the Army.

After studying physics and mathematics in Berlin and at the Universities of Goettingen and Tuebingen, Mr. Weiss received a PhD in physics in 1939.

In addition to work in wide-angle projection, Dr. Weiss has specialized in many areas of information display techniques and authored several papers in the field. He is a charter member of SID.

Mr. A. C. Stocker

Mr. Stocker is the specialist in displays with the Systems Engineering, Evaluation and Research Group of RCA's Defense Electronic Products Division.

He has experience in the early phases of system development, from television in 1930 to reconnaissance satellites in 1956. He is versed in CRT techniques, photography, optics, and photometry.

Mr. Stocker received a BEE at Ohio State University in 1928. He has worked for RCA since then, except during his service with the Navy in World War II. His interest in the problems of command and control originated during the invasions of Africa and Sicily. He holds 32 patents, and is a member of SID.

EDITORIAL ADVISORY BOARD

A technical Society journal is always a difficult publication for which to provide meaningful editorial material. Within an interdisciplinary field such as information display may be found specialists ranging from psychologists to electronic engineers, psychophysicists, equipment designers, systems analysts, optical and solid-state physicists and engineers. Obviously, there must be an underlying thread of common interest in such a diverse assemblage of disciplines, yet there is also a basic difference in academic training, problem approach, and terminology.

In order to establish and maintain a dynamic editorial policy, a distinguished team of consultants has been brought together to form the Editorial Advisory Board for **Information Display**, the Official Journal of the **Society for Information Display.** By means of this Board, the SID will be assured of continuing review at the highest professional level of papers to be published and areas to be covered.

Members of the Editorial Advisory Board represent the dominant disciplines active in the field of information display, both in private industry and in government agencies. Some are introduced below, in this first issue of **Information Display.**

Dr. H. R. Luxenberg

Charter member and first president of the Society for Information Display, Dr. H. R. Luxenberg is currently a member of the technical staff at the Bunker-Ramo Corporation, Canoga Park, Calif.

Previously, he was Vice President and Dir. of Engineering at Houston-Fearless Corp.; Manager, Display Dept., Ramo-Wooldridge Corp.; Manager, Computing Center, Litton Industries; Head Simulation and Analysis Group, Remington-Rand UNIVAC Division; and (1951-52) Research Physicist, Hughes Aircraft Co.

From 1942-45, Dr. Luxenberg served as Weather Officer and Instructor in Meteorology, in the Aleutian Islands.

His computer experience ranges from operation, checkout and maintenance of the Natn'l Bureau of Standards Western Automatic Computer to programming, logical design, system analysis and simulation for many command and control systems. He has recently been concentrating on problems of image enhancement, data display and data storage and retrieval.

Mr. Petro Vlahos

Mr. Vlahos holds an EE degree from the University of California. He is currently on the Special Studies Staff, Defense Systems Division, at System Development Corp. He initially worked with displays as an engineering group head at Douglas in 1941, and later with radar displays at Western Electric in 1944.

From 1946-60, Mr. Vlahos was engaged in R&D 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. This work resulted in several patents, including three widely used systems for traveling matte photography. He joined SDC in 1960.

Mr. Vlahos has lectured on information display at UCLA, and on television recording techniques at USC.

In addition to membership in other professional societies, Mr. Vlahos is Western Regional Director of SID and Chairman of the Los Angeles Chapter.

Dr. Carlo P. Crocetti

Dr. Carlo P. Crocetti has been employed at Rome Air Development Center from 1953 to the present time. He has served in various capacities ranging from Project Engineer, Chief Human Engineering Laboratory, to his current position as Chief, Display Techniques Branch. He is responsible for R&D on new information presentation techniques and technical support to Air Force project offices in acquiring display subsystems.

Carlo Crocetti was born March 12, 1928. His higher education was acquired at Columbia University, where he received an A. B. degree in 1948, A. M. in 1949, and PhD in 1951. From 1951-53 he was on active duty with the AF.

His fields of specialization include photometry and colorimetry, systems and human factors in displays.

He is a member of the American Association for Advancement of Science, Sigma Xi, Psychonomic Society, American Psychological Association, Armed Forces Vision Committee, and SID.

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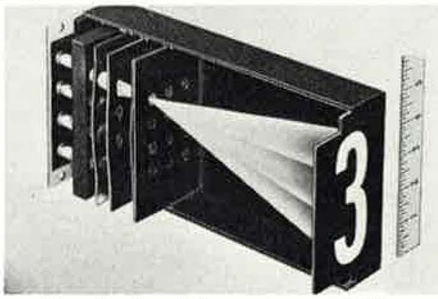

For further information on IEE rear-projection readouts, write Robert Burtner, Industrial Electronic Engineers, 7720 Lemona Ave., Van Nuys, Calif., or phone A. C. 213 877-1144.

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Data Display Oscilloscope

MS-3 Data Display Oscilloscope presents a 17-inch CRT display of data for quick-look monitoring. The all-solid-state unit is self-contained with sweep circuitry and power supply in 17½ inches of rack space.

Specifications include a true differential input, 60 lines per inch resolution, 1% linearity, sensitivity ranges from 5 millivolts per centimeter to 50 volts per centimenter, ±2% input attenuator accuracy, 30-second warm-up with drift of less than 0.5 centimeters in 8 hours, and internal sweep ranges from 10 microseconds per centimeter to 0.1 seconds per centimeter. Power requirement is 115V AC, 50 to 60 cps, 100 watts nominal.

Contact Kauke and Compnay, subsidiary Applied Development Corp., 1161 Monterey Pass Road, Monterey Park, California. Telephone: 213-264-2962, att: John Kauke.

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New Cathode Ray Tube

CRT featuring high resolution at ultra-high brightness over a large viewing area, originally developed for use in astronaut training by General Atronics Corp., is now available for industrial applicaitons in character writing systems and for TV monitor displays.

Designated the ETC M1192, the CRT has a round, 7" optically flat face-plate with a useful scan area of 6½". The single gun tube is magnetically focused and deflected.

Makers of the new tube claim it has been operated at 13.5 KV for high light output of 160 foot lamberts over the total useful scan area with a center spot diameter of 2 mils. At lower level brightness, spot size diameter approaches five mils or less. The tube may be operated up to 18 KV with attendant higher brightness and better spot size at higher voltages. Contact Ray Koebert, Sales Manager, Electronic Tube Div., General Atronics Corp., 1200 E. Mermaid Lane, Philadelphia. Phone: A. C. 215 CH 8-3700.

Circle Reader Service Card No. 34

New Projector Has Varied Uses

New series of SCOPUS-II projectors for information display systems by Belock Instrument Corp., are designed as plotting reference or spotting projectors. Projector which uses mylar film to provide stable and unbreakable plotting medium, is available in wide range of outputs and can be used as a single unit or in multiple combinations to suit any system complexity desired. Input data can be received from digital and analog computers or manually operated control units.

For prices and delivery dates contact Bernhard A. Bullwinkel, Belock Instrument Corp., 112-03 14th Avenue, College Point, New York, or phone A. C. 212 HI 5-4200.

Circle Reader Service Card No. 35

Electro-optical Photo Pen

New electro-optical pen from Sanders Associates controls the generation of digital pulses to read, edit, and transmit information from PPI and character generating CRTs. The triggered pulse coincides with the leading edge of the CRT writing pulse. Linking to the computer is accomplished by gating with proper voltage and impedance values.

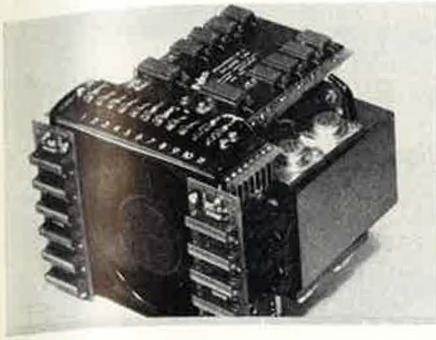
To identify the area on the tube face being sampled, a ring of light is projected from the outer bundle of the coaxial optical fiber light pipe. Variance in the sampling area is achieved by moving the pen closer or further from the tube face.

The complete unit is comprised of a pen unit and a detector-electronics package including a 40-inch flexible cable. Contact Paul M. Leavy, Applied Physics Dept., Sanders Assocs., 95 Canal Street, Nashua, New Hampshire, or phone A. C. 603 TU 3-332

Circle Reader Service Card No. 36

Celco Deflection Amplifier

A new voltage-to-current converter to drive deflection yokes, the Celco Ultra-Linear Deflection Amplifier, is currently available on three weeks delivery. A dc-coupled amplifier, the unit can drive a variety of inductances and claims unrestricted input wave forms. Output current through the yoke is ±3 amps. Input impedance is one megohm.



The dc linearity is ±.05% of full output current. Absolute error is less than 5 mv; offset for zero input is zero; drift 0.1 mv per degree C from 0 to 50° C.

Contact Bob Reese, Celco Pacific, 1150 E. 8th St., Upland, California or phone A. C. 714 YU 2-0215 for complete details.

Circle Reader Service Card No. 37

Alphanumeric Display Generator

Display of computer teletype data on standard home-type television receivers is available through development of an alphanumeric display generator by Norden div., United Aircraft Corp.

Norden's generator is capable of accepting six teletype messages of up to 180 characters each and displaying two messages simultaneously. The all-micro-electronic system can be used for information systems for military command and control; weather forecast reporting, airline schedule reporting, stock quotation displays, and factory data reporting and other applications.

Write Norden Div., UAC, Helen St., Norwalk, Conn., or phone George Flynn, A. C. 203 838-4471.

Circle Reader Service Card No. 38

Illuminated Push Button Switch

Master Specialties Tellite is a two lamp, flush mounted illuminated push button switch. Rectangular front lens evenly illuminates across entire lens face when lamps are energized. Lamp replacement is accomplished from panel without use of any tools. Front lens, which may be engraved for identification of the function being monitored, is securely held to the light capsule by mating slides and may be removed by sliding the two apart.

Easy to mount by simply turning the screws hidden in the unit housing with a screwdriver, the mounting sleeves are drawn into position behind the front panel.

For completet product line data contact Master Specialties, 15020 S. Figueroa, Gardena, California, att: Bill Franklin or phone A. C. 213 321-8450.

Circle Reader Service Card No. 39

Hi-speed Projection Plotter

High-speed projection plotter from LTV Military Electronics Div., Ling-Temco-Vought, writes and simultaneously displays information as rapidly as 1200 alphanumeric characters per minute.

To obtain this speed, the plotter utilizes high-resolution d-c torque motors in place of conventional servo devices. Two of the motors—one for the X axis and one for the Y axis—position a stylus directly, without backlash, gear trains, or complex mechanical linkages. The stylus scribes, with essentially infinite resolution, through an opaque coating on a thin glass plate, and through which a lens system projects high intensity light to a large display screen. The torque motors position the stylus in response to analog voltages or from the output of a computer.

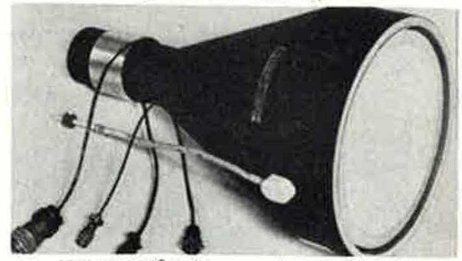
Magnetic Technology makes the torque motors. For more details on the plotter, contact LTV Military Electronics Div., P. O. Box 6118, Dallas, Texas, att: Roland Fribourghouse or phone A. C. 214-BR 6-7111.

Circle Reader Service Card No. 40

Eleven-Inch Direct-View Storage Tubes

Direct-view storage tube for varied display applications is the Du Mont type KS2329—an 11⅞ inch maximum diameter flat-face tube with single write-gun. The new tube was developed by Du Mont Laboratories Div., of Fairchild Camera and Instrument Corp.

The tube was designed with electrostatic deflection for use in radar systems having a wide variety of sweep rates. The improved design overcomes limitations to writing unifromity under conditions of dynamic erasure, providing high detection sensitivity of remote weak targets without overwriting any portion of the display. Useful screen area of the KS2329 is 9 inches.



For specifications, prices, and delivery dates, write Electronic Tube Sales, Du Mont Laboratories, Clifton, New Jersey, or phone Robert Deutsch, Sales Manager, A. C. 201 PR 3-2000.

Circle Reader Servic Card No. 41

Plastic Fixed Neon Indicator Light

Sub-miniature fixed neon indicator light with 2 fixed terminals, Model 862, from The Sloan Company, features streamlined tapered lens design, is of plastic, utilizes high brightness neon bulbs and mounts in 5/16" diameter hole. Overall length is 13/16". Company states all material and processes meet or exceed applicable mil-specs. Lenses available in red, white, amber or clear. In addition, the 862 series is also available with incandescent bulbs. Contact The Sloan Company, P.O. Box 367, Sun Valley, California, att: C. S. Sloan, or phone A. C. 213 TR 7-1123 for immediate assistance.

Circle Reader Service Card No. 42

Circle Reader Service Card No. 28

SID Sustaining Members

Aeronutronic Division
Philco Corporation
A Subsidiary of Ford Motor Company
Newport, California

Aerospace Corporation
San Bernardino, California

General Dynamics/Electronics
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Seneca Falls, New York

Bunker-Ramo Corporation
TRW/Ramo Wooldridge Division
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ITT Federal Laboratories
A Division of International Telephone and Telegraph Corporation
Nutley, New Jersey

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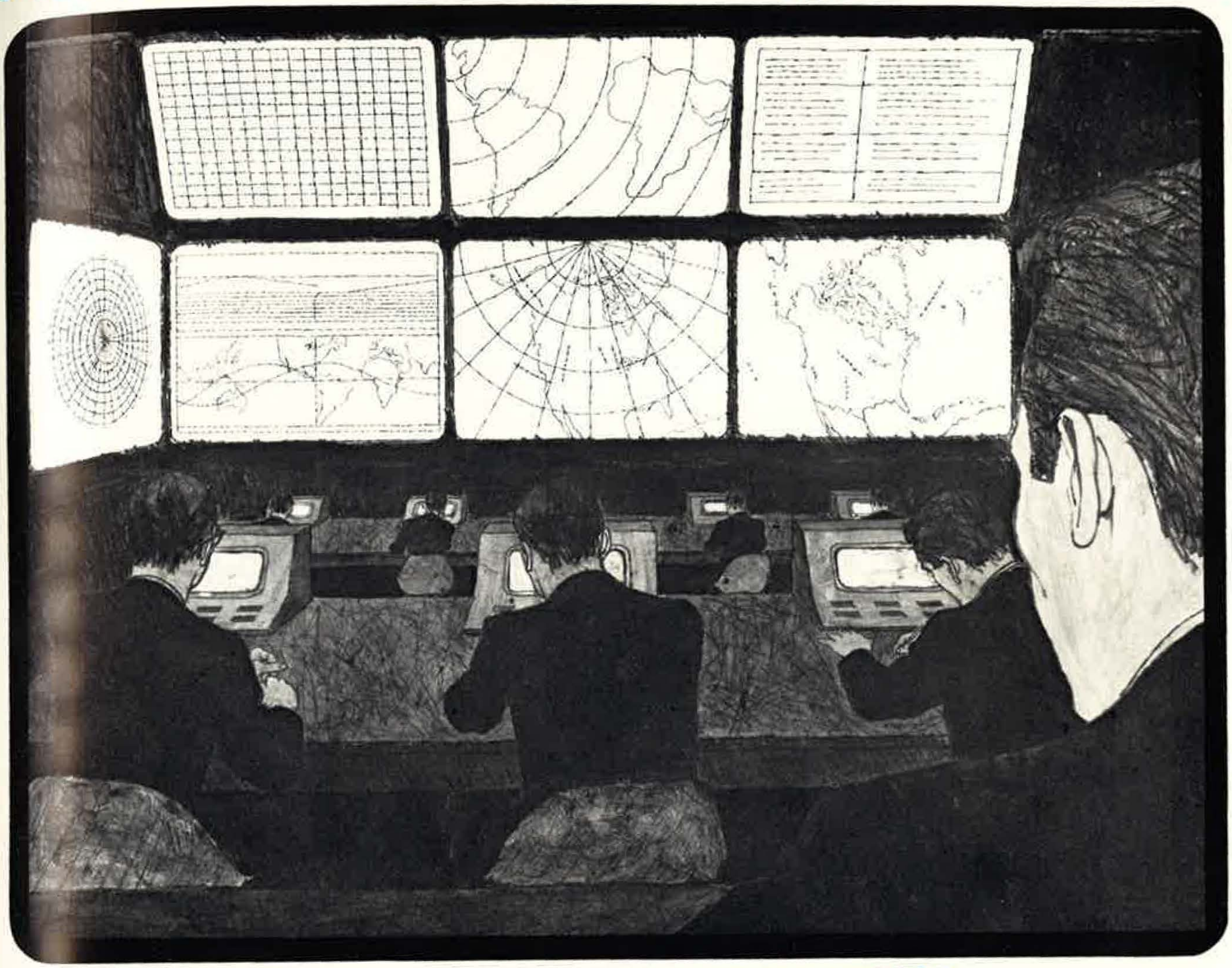
FOR THOSE IN COMMAND OF THE SITUATION...



...AN LTV DISPLAY SYSTEM...

To provide fresh, vital . . . two and three dimensional tracking data projected against any reference background . . . in color . . . with wide range choice of symbology . . . at the near real time speed now possible with the new LTV 7000 electro-mechanical projectors*. . .

This is a brief insight into an LTV display system . . . indispensable *FOR THOSE IN COMMAND OF THE SITUATION . . .*

More than 70 versatile LTV display systems are in operation for missiles, satellite and space tracking, shipboard CIC, air defense and battlefield command.

Contact LTV today for information about complete "Dynamic Plotting Projection Displays" in all sizes for air, sea or land installations. LTV Military Electronics Division, P. O. Box 6118, Dallas, Texas 75222.

***THE NEW LTV 7000 HIGH SPEED DISPLAY SYSTEM PROJECTOR PLOTTER**
Full-scale excursion time 60 milliseconds
Adjacent symbols per sec. 20
Random symbols per sec. 10
Dimensions: 12″ long 7″ wide 11¾″ high

LTV MILITARY ELECTRONICS
A DIVISION OF LING-TEMCO-VOUGHT, INC.

On Exhibit at Society for Information Display Show, October 1 & 2, Shoreham Hotel, Washington, D.C. & Association of U.S. Army Show, November 16-18, Sheraton-Park Hotel, Washington, D.C.

Circle Reader Service Card No. 30

Some of the DDI Display Systems Currently in Use

Model	System Description
dd 10	Multi-Station remote data entry and retrieval system
dd 13	Command and control system design console with internal graphic scanning capability
dd 13B	Range safety officer impact prediction display console and camera recorder
dd 16	High speed electronic point plotter
dd 19	Multi-monitor command and control display system for computer time sharing evaluation
dd 20	Display plotter for telemetry data reduction and processing
dd 26	Computer output point plotter and numeric display console
dd 36	Computer output numeric display indicator
dd 39	Semi-automatic message composer and data entry console
dd 40	General purpose modular computer input/output display system
dd 55	Digital radar indicator and computer input/output console
dd 51	General purpose alphanumeric display system
dd 51/m2	Special purpose data storage and retrieval system
dd 52	Special purpose computer control console
dd 60	Large scale computer console
dd 65	Experimental digital radar indicator and computer input/output system
dd 68	Multi-monitor digital radar indicator and weapons system simulator
dd 73	Multi-console command and control system
dd 74	Multi-monitor data storage and retrieval system
dd 79	Military command and control console
dd 80	High speed microfilm recorder
dd 81	Very large scale data reduction and display system

computer display specialists

At DATA DISPLAY, INC., the entire field of digital CRT displays is served—not just one or two segments of the field. DDI systems **in use today** cover the spectrum of graphic and alphanumeric displays. From dd 10 (multi-station information entry and retrieval system) through dd 40 (on-line, soft-copy information display) to dd 80 (microfilm or full-size sheet form graphic recorder), DDI consoles serve the broadest range of computer display requirements.

For complete details on which **currently available** DDI model is best suited to your information display needs, contact DATA DISPLAY, INC., today.

DATA DISPLAY INCORPORATED

1820 COMO AVENUE
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Area 612 646-6371

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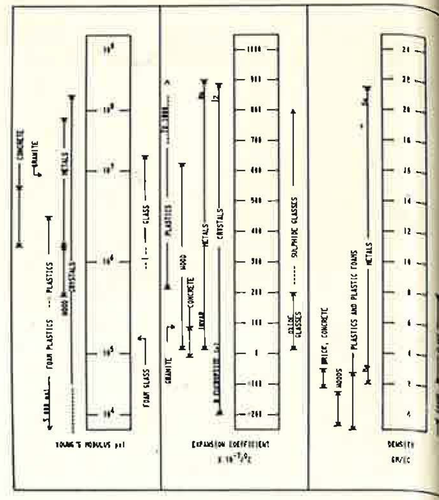
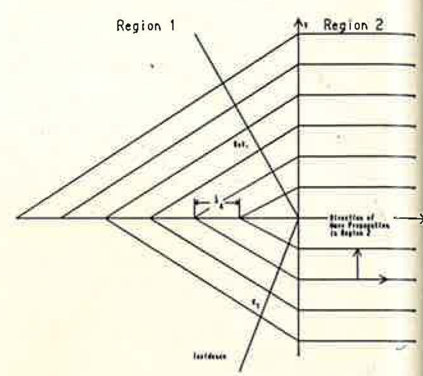


Microfilm Recorder*

Records alphanumeric and graphic computer outpu on-line speeds of 110,000 characters, 170,000 ve and 220,000 points per second in page-at-a-time fo on 35mm microfilm.



Command and Control*

Real time monitoring of military and business sur ance inputs. Man-to-computer communication device cluding typewriter keyboard, light pencil, and trac are available.

dd 40 -- MODULAR DATA DISPLAY SYSTEM

TECHNICAL DESCRIPTION

The dd 40 is a modular digitally driven display system de signed for effective application to a wide range of display re quirements. To achieve this flexibility at low cost, the dd design features a minimum, or basic, system which may be ex panded by including optional modular features.

The basic dd 40 system is a 19-inch CRT monitor presentati designed to operate directly on-line to a digital computer. includes interface logic, symbol generator, display control logic, and the CRT display. The basic system can display 3,0 symbols at random positions on a 12.5 inch square area at a 40 cps repetition rate.

Normally used with the basic dd 40 system would be some co bination of the available options including:

Vector and/or line drawing capability,

Tabular (typewriter-like) word format,

Parallel remote monitor(s),

Buffer memory (for off-line display repetition),

Camera recorder (for high speed data recording).

Information Retrieval*

Typewriter keyboard input to a buffer memory; o verification; block transmission and receipt of data phone subset compatability.

**Reproduction of unretouched photo showing inf tion being displayed on DDI display systems.*