

T H E S I S

on

A TRANSLUCENT WRITING SCREEN

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PART I

A NEW TYPE OF WRITING SCREEN

For a great many years group instruction in American schools has been to a considerable extent accomplished through visual methods. The blackboard is the most effective means of advancing visual instruction, and has become so important as to be indispensable in the schoolroom. While blackboards have been in general use for about two centuries, and have increased their useful possibilities, the modern hyloplate does not essentially differ from the blackboards of years ago. The blackboard faults and disadvantages of five decades ago are much the same now.

An analysis of common blackboard faults has shown that certain disadvantages might be avoided by digressing from the rule which seems to require a dark surface and a white crayon. If chalk is retained as a crayon, and it must be admitted that chalk is very desirable for this purpose, contrast can be had only by outlining the chalk mark against a very black or a very bright surface. In the latter case the white chalk would appear dark against the lighter background.

But how can a lighter background be made to retain its contrast with the chalk mark after several erasures? Surely not at all if the background is opaque. A ground glass surface illuminated from behind can be given any degree of brightness. The possibilities of such a screen appear worthy of investigation.

The possible advantages of such a screen are largely comparative. A consideration of the visual and other characteristics of established types of black-board will provide the basis for comparison.

PART II

EXISTING TYPES OF SCREENS AND THEIR CHARACTERISTICS

Crude forms of blackboards were in use as early as the thirteenth century, but the more practical types have been in use only during the last two centuries. Until nearly 1850, blackboards were almost invariably of wood, painted or stained black, and were generally on wood frames, or so fashioned as to be hung on the walls where need dictated. At the present time, four types of blackboards are in more or less common use. These are the cement plaster blackboard, the ground glass blackboard, the slate blackboard, and the hylo-plate.

The cement plaster blackboard is made by thoroughly mixing cement plaster with a dull black coloring matter, and spreading the mixture on wood or metal laths carefully so as to get a level, even surface. Its cheapness, its easy conformity to the walls of a building, its possibilities for any desired coloring, and the readiness with which the component materials may be obtained, are its chief advantages. Its disadvantages are several, including absorption of moisture, tendency to become oily from contact with the hands, liability

to crack or chip, change in color due to washing or uneven use, and the difficulty of getting a surface that will take chalk readily, evenly, and not wastefully.

Ground glass blackboards were introduced in England about 1900, and seem to have proved very satisfactory. Glass is cut into sheets to conform to the dimensions of a specific installation. One side of the glass is ground evenly but lightly, so that it is translucent and yet as smooth as possible. Unless this grinding is done carefully, the surface will be too rough or will not take the chalk evenly, and the writing will be rendered variable and troublesome. This ground glass surface should not feel rough to the fingertips, but should give a hard, smooth, velvety feeling if properly prepared. The opposite unground surface is painted with a dull black paint tinged with any desired color. When the paint has dried, the glass is placed in position with the painted side against the wall. Writing is done upon the ground surface, the latter appearing dark due to the fact that the incident illumination penetrates the glass surface and is absorbed by the black paint at the back. This black paint actually appears to be a part of the glass.

The ground glass surface cuts the crayon sufficiently well to leave a clear even mark, but if proper-

ly ground does not release an undue amount of chalk dust into the room. The color may be made to suit any requirements, for the painted side is wholly out of contact with dirty hands, crayons, erasers, and sponges. If the glass is set solidly and evenly against a carefully constructed back of wood or cement, very little sound results when the chalk is used. The glass blackboard is impervious to moisture; cleaning may be easily done without injury to the surface. No glare is possible from the ground surface. This blackboard lasts indefinitely, and seems to become more satisfactory through use, probably because continual use roughens the surface more uniformly. The surface is said to be almost ideal in the smoothness with which it takes the crayon, and in the lack of noise and scratchy sensations when writing upon it.

Trouble is experienced in joining plates of the glass blackboard, as the joints are noticeable and gather chalk dust. Suitable plates of glass are expensive, and the comparatively high cost retards the use of this type of blackboard. It has been said against the use of the ground glass surface that it does not give an "artistic line" in the teaching of art. For ordinary use, this is not objectionable.

Slate is a natural blackboard material, and possesses many desirable characteristics, both mechanical and visual. The slate blackboard is of uniform composition and lasts indefinitely. Wear is negligible and hard usage does not harm the surface. Washing the blackboard is easy, and does not injure the slate, for moisture is not readily absorbed. The surface takes chalk easily but sparingly, and the result is a sharply defined mark of uniform depth. Slate is pleasant to write upon and is not noisy if set solidly and firmly. Less trouble is experienced in erasing chalk marks from slate than from the hyloplate surface, and a cleaner condition of the board results.

A slate blackboard is relatively more expensive than other types. The slabs commonly used are four feet in length, as greater lengths are difficult to obtain. These short sections result in troublesome joints. Another disadvantage of slate is its absorption of oil from the hands. This oil renders the surface somewhat variable in its reflection factor, and in the readiness with which it takes the chalk. The natural color and texture of the slate cannot be changed, and this at times, makes it difficult to match various sections of a slate blackboard in color and

reflection factor.

Specular reflection is not a prominent fault of slate surfaces. If proper precautions are observed in locating the blackboard with respect to the light source and to the observers, glare does not become objectionable. But if a bright source is reflected to the observer, specular light may become more intense than the light diffused from the chalk mark. Vision then becomes impossible. Such a condition can and does exist if the blackboard is carelessly placed.

The reflection factor of chalk marks on dark surfaces is not the coefficient of reflection of the chalk itself, as the mark is seldom opaque. The uniformity and depth of the mark, therefore, influence its reflection factor. On a particular slate surface the observed reflection factor of the chalk mark was 0.27. On another surface, or by using chalk of a different quality, the reflection factor may differ greatly from this value. The coefficient of reflection of a slate surface is subject to wide variations depending on its quality, on its color, and on its freedom from chalk dust. The coefficient of the surface observed varied from 0.105 to 0.131.

This surface was cleanly erased but not washed. While the difference in the reflection factors for chalk mark and slate surface does not seem great, or even sufficient for good vision, the contrast appeared good and the chalk marks were distinct and clear cut.

In the construction of the hyloplate blackboard several layers of heavy, specially prepared paper are pressed and fastened together so as to make a solid board. It is prepared in large sections; and is later cut to suit any requirements. The outside layers are thoroughly impregnated with a dull black coloring matter which may be tinged with a dark green pigment. The surface is given special treatment to assure smoothness, uniformity of color, and uniformity of abrasive quality.

By virtue of its low first cost, hyloplate is widely used. It is light in weight, convenient to handle or ship, and is not easily broken. Since any length is obtainable, joints may be eliminated, and installation is not troublesome. While the effectiveness of the surface is reduced by wear and rough usage, application of a resurfacing paint will partly restore the qualities of the original surface. The surface of hyloplate is even, and takes the chalk well for a time. On new hyloplate the chalk mark has a uniform depth and

the edges are distinct. The amount of chalk used is not excessive. With a firm backing, this blackboard is not noisy.

The life of the hyloplate is short, and in the long run it is usually economical to use a more permanent type of blackboard. Hyloplate does not wear well, and the surface becomes pitted and rough after two or three years of steady use. Unless done with care, washing contributes greatly to the wear; scrubbing is ruinous to the surface. When badly worn the surface is no longer uniform, and does not take the chalk evenly. Chalk is ground excessively by the worn surface and dust is thrown from the point of contact. Edges of the mark are indistinct. At times wear results in a hard, glazed surface which will not take chalk at all. In general, writing upon a hyloplate surface gives one an unpleasant sensation. Erasing is troublesome, and invariably leaves a dirty surface.

Hyloplate absorbs moisture readily and warping or buckling results. The blackboard then becomes noisy to write upon. Absorption of oil and dirt from the hands results in the surface taking chalk badly.

In considering the visual characteristics of hyloplate, the matter of color is found to be of minor

importance. Two colors are in general use, one a dull black, the other a dull black tinged with green. Neither of the two seems to possess any advantages over the other. Personal opinions often favor one color or the other, but seem not to be founded upon fact.

Glare is generally considered to be one of the unavoidable evils in connection with blackboards and the suggested remedy is to locate the blackboards properly with respect to the light sources and observers. Special attention should be given to the positions of windows. The blackboards should be so located that specularly reflected light cannot reach a pupil at any desk in the room. This restricts the location and reduces the wall space available for blackboards. In many instances more than a half of the clear wall space is useless for mounting blackboards because of conditions resulting in glare. In several class rooms observed, it was found impossible to make use of more than one ten-foot section of hyloplate before the class as a whole. Two other such sections were within easy view of the class, but were made useless by intense specular reflection.

The extent of the glare conditions is partially indicated by measurements made in several of the

observed cases. Observations of surface brightness were taken at an angle from which the specular reflection reached its maximum value. From a badly worn surface the brightness of a chalk mark was only one-eighth the brightness of the hyloplate background. From a highly glazed surface, the ratio of chalk brightness to surface brightness was only 0.09. Another extreme case of glare showed the chalk mark to be only one-fourth as bright as the surrounding blackboard; the chalk appeared dark against the bright background but was not easily visible. Under more representative conditions the chalk mark was from one-half to three-fourths as bright as the specularly reflecting background. In any of these cases, visibility of the chalk mark is destroyed for an observer who is in the path of the specularly reflected light.

Specular reflection from new hyloplate is not usually troublesome. Glare increases as continued use wears down the surface. Specular reflection does exist, however, even though the surface has sufficient roughness to take the chalk well. If the hyloplate becomes glazed, glare reaches its highest value. The only method of reducing specular reflection seems to be in resurfacing, but the result is only temporary. Local

artificial lighting is at times employed as a means of avoiding the effects of specularly reflected light.

Chalk marks give good contrast with a hyloplate background if the surface is clean and not too badly worn. A reduction in the reflection factor of the chalk mark or an increase in that of the blackboard results in a loss of contrast. Both factors are affected by surface wear: nonuniformity of the chalk mark reduces its reflection factor, and wear increases the reflection factor of the blackboard surface. The latter is ordinarily high because of the chalk dust spread over the surface by erasing. In this respect repeated washings have the injurious effect of providing minute cracks and recesses in which the chalk dust becomes embedded.

Measurements were made of the reflection factors of several good hyloplate blackboards in daily use. After washing the surfaces, the average reflection factor from several observations was found to be 0.09. After applying chalk and erasing cleanly, the same hyloplate surfaces showed an average reflection factor of 0.105. Other surfaces, more badly worn and dirty with chalk dust, reflected 0.23 of the incident light. One extremely worn and dusty blackboard showed the high reflection factor of 0.28.

For the chalk marks the reflection factors varied from 0.25 to 0.50 on different surfaces, with a fair average of 0.32.

Various writers and investigators have advised methods of minimizing blackboard faults. Shiny surfaces should be avoided, and blackboards should receive special treatment in order to acquire a dull rather than a glossy surface. Surfaces should be kept clean so as to secure proper contrast when the boards are in use. Recommendations are made that blackboards be carefully placed so that no images of light sources will be reflected toward the audience. Blackboards should never be placed between windows because of direct glare. Several writers advise local artificial lighting for blackboards. The approved method is to install the reflector along the whole length of the board along the top. The lamps should be shaded completely from the audience. These reflectors must not be fixed too closely to the blackboard or the illumination will vary too much from top to bottom.

The suggestion as to local artificial lighting fails to consider the disagreeable effect of the light upon ^{the} one who is lecturing to a class, and must alternately write upon the blackboard and turn to face the pupils. The reflector must be placed well away from

the wall, and one standing between reflector and wall can avoid the glare from the reflector above only by facing the blackboard.

These views represent the extent to which blackboard faults can be reduced. It seems probable that further improvement lies in the substitution of a type of screen which avoids some of the more objectionable blackboard conditions.

PART III

VISUAL CHARACTERISTICS OF CRAYON MARKS ON SCREENS

The visual characteristics of crayon marks on screens are usually dependent on a few important conditions which are more or less variable. The color, intensity, and nature of the incident light have an important bearing on the effectiveness of the screen. The width of crayon marks, the degree of contrast, the mechanical characteristics of screen surface and crayon, and the tendency to produce glare, must receive consideration. Some method must be used to determine the effect on the eye of a change in any of these factors.

An ideal set of conditions is one that permits normal perception of detail with no muscular or retinal strain, a minimum of eye fatigue, and no injury to the eyes. Consequently a system of measurement which tells quantitatively how nearly a given set of conditions approaches this ideal is very desirable. Unfortunately no method is available which makes these determinations. Eye strain and effects tending to permanently injure the eye cannot be ac-

curately measured by any direct method. Measurement of the degree to which fine details can be distinguished can be accurately made, however, and the result gives a good indication of general visual conditions. This factor is termed visual acuity.

Visual acuity is a measure of the perception of detail by the eye. Under favorable conditions of illumination and contrast, the normal eye can easily distinguish details of which the greatest dimension subtends an angle of one minute of arc at the eye. The eye is then said to have a visual acuity of 1.0, which is considered normal. Visual acuity is inversely proportional to the angle subtended at the eye by the smallest perceptible detail.

Just as the visual acuity of any eye can be measured under standard conditions, so different sets of conditions can be compared with one another by their effects upon the normal acuity of a single eye or pair of eyes. The method followed in obtaining the visual acuity of an eye requires a test card or "target," upon which are fine details of equal size and uniformity. The ophthalmologists test card is a white card upon which are printed rows of black capital letters of various sizes. The letters are peculiar in that each is constructed of equal squares. The letters

are five squares high and each line consists of a single row of squares. The normal eye, at a distance of twenty feet can just read that row of letters from which a single square subtends an angle of one minute of arc at the eye.

Since a "target" of this kind is difficult to construct accurately with chalk on a blackboard or screen, a simpler target may be used. Several circles are drawn, the lines forming the circumferences, being uniform and ^{of} known width. From the circumference of each circle, a small section is removed equal in length to its own width so that the missing portion is practically a small square. If the observer is at a fair distance from the chart, the circles appear unbroken. As the observer approaches the chart the breaks become perceptible. When this occurs the small break subtends an angle, which, expressed in minutes of arc, measures the reciprocal of the visual acuity of the observer under this set of conditions. After the first observation, the visual acuity can be computed from its proportionality to the distance at which the detail can be perceived. This method will be used in the visual acuity determinations which are to follow.

Another test that should be made in comparing the merits of writing screens is that of eye fatigue.

Ferree and Rand have proposed to measure this by the length of time for which normal visual acuity can be maintained.

By means of these visual acuity measurements, some general conclusions should be reached as to the best conditions for good vision. However, by considering in detail each of the factors affecting vision, it may be possible to reduce the number of measurements.

On the subject of color, many a prejudice exists without the least foundation. Red is thought to be injurious and fatiguing to the eye; green is popular through its supposed beneficial effect on the eye. Nearly every individual has an aversion to some color or combination of colors. As for experimental facts, there is no evidence to show that one color is more injurious to the eye than another. Nevertheless a popular prejudice must be respected. Without doubt, certain colors have undesirable psychological effects, and their continued presentation to the eye must be avoided. Bright colors are said to be unsuitable for protracted vision.

It has been definitely proven that monochromatic light improves visual acuity by eliminating the effects of chromatic aberration of the eye. Since this re-

sults in an appreciable gain in visual efficiency, monochromatic light is desirable for certain purposes. An advantage possessed by light of the shorter wave lengths, violet, blue, and green, is the fact that at low intensities of illumination these colors have relatively greater effects on the retina than equal intensities of the longer wave lengths. This behavior is known as the Purkinje effect.

Investigations by Ferree and Rand show that the color most favorable to good visual acuity at low intensities is yellow, with yellow-green, orange, green, red, blue-green, and blue following in order. This is not the order to be expected from the Purkinje effect. The order was determined at intensities of 0.075 foot-candles and 0.3116 foot-candles. At 0.3116 foot-candles the Mazda C lamp was found to give better visual acuity than yellow monochromatic light. These results do not serve as an indication of relative visual acuities at the higher intensities.

Ordinarily the intensity of illumination is not critical in its requirements. With good contrast, visual acuity reaches a normal value at about 5 foot-candles illumination, and rises very slightly above this point as the illumination is increased. The kind of light used affects visual acuity only in so far as

color and intensity are concerned. There is no reason why daylight and artificial light should not be used together, one to supplement the other. It is held by certain writers, however, that daylight and artificial light should not be mixed where the color of the artificial light differs greatly from that of daylight.

The respective characteristics of screen and crayon, and the suitability of one to the other, have a decided bearing on the visual effects produced. Unless contrast is to result from a color difference, the reflection factors of crayon and screen surface must differ as much as other considerations will allow. The crayon must be sufficiently soft to produce a line of the desired width. Powder from the crayon is distributed over the screen surface, thereby raising its reflection factor and its diffusion. The crayon mark is usually not uniform and not completely opaque, so that the reflection factor of a crayon mark is far below that of the crayon material. The most desirable combination of screen and crayon is obtained when all crayon marks are clean edged and of uniform depth, and erasure is possible.

A lack of sufficient contrast reduces the visual acuity of the eye below the normal, and makes necessary

a more intense illumination. However, an increase in illumination cannot completely overcome a lack of contrast. Weber's law states that the least perceptible difference in brightness in the two halves of a small field is nearly a constant fraction of the field's brightness, and is normally about one per cent. Cobb found the least perceptible difference in brightness to depend somewhat on the brightness surrounding the test object. With surroundings brighter than the test object, he found the least perceptible difference in brightness to be an increasing fraction of the test object brightness. The same is true for darker surroundings, but to a smaller extent. Evidently the surroundings for a blackboard or writing screen should have a brightness between that of the crayon and that of the screen. A considerable difference in either direction would cause glare.

In case a flat surface is illuminated uniformly by one or more light sources not in the field of vision, contrasts on the flat surface are ordinarily due to the difference between reflection factors. Exceptions are the translucent screen and the opaque screen employing color differences for contrast. On the ordinary opaque screen the best visibility results from the greatest difference between the reflection factors of the screen and of the crayon.

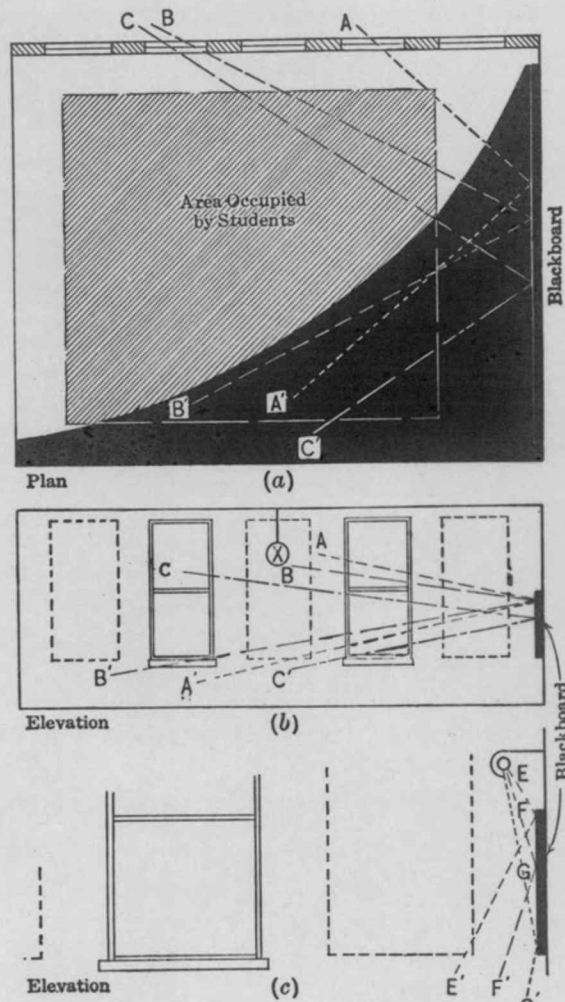


FIG. 1 Diagrammatic Illustration of Glare from Blackboards.

- (a) Showing that occupants of seats in shaded area are subjected to daylight glare from blackboards.
- (b) Showing angles at which glare is experienced from daylight and from artificial light.
- (c) Arrangement of local artificial lighting to minimize glare.

Contrast by differences of color has been designated as hue-contrast to distinguish it from brightness-contrast. In the appearance of adjacent colors it is usually both hue and brightness which are responsible for the contrast.

Glare is probably the most objectionable characteristic of the opaque screens now in use. It is defined as a brightness within the field of view of such an excessive character as to cause discomfort or interference with vision. If there are spots of light in the field of view of very different brightness from their surroundings, the eye suffers considerable strain in adapting itself to one brightness while trying to distinguish detail in the dark part of the field.

The general subject of glare has been investigated, and a classification has been made. That form of glare which is characteristic of the blackboard is called indirect glare, and is a result of specular reflection. The amount of glare depends on the ratio of the quantity of specularly reflected light to quantity of diffused light. This ratio, in turn, depends on the specularly reflecting characteristics of the surface.

The position of a light source influences the quantity of specularly reflected light, the latter becoming greater as the incidence becomes more nearly grazing; but frequently a lamp may be placed in such a

position as to direct the glare on the floor or somewhere else where it will not be troublesome. The amount of glare can be easily determined but such a determination is of little use as a guide to the physiological conditions which it produces in the eye. For the physiological effect of glare, no method of measurement has as yet been devised. Glare is said to produce no retinal injury, and no fatigue to the muscles of the iris; fatigue of the eye is believed to be associated with the muscles of accommodation.

Should contrasts of brightness within the field of view become too great, the visibility of objects diminishes, and direct glare results. But contrast between the object viewed and its background should increase the visibility of the object if both object and background are illuminated equally.

PART IV

CONSTRUCTION OF THE TRANSLUCENT WRITING SCREEN

A decided deviation from the common principles of blackboard construction and use is found in the self-illuminated translucent screen. Essentially this screen consists of a sheet of ground plate glass illuminated indirectly from the rear. Ordinary chalk crayons are used for writing, and produce dark lines against the bright illuminated background. In order to make practical comparisons with other types of writing screens, a model has been constructed.

The sheet of plate glass used in the screen is 60 inches long by 40 inches high. It is $5/16$ inch in thickness. The width and length are sufficient to emphasize the importance of securing uniform illumination over the surface. The thickness of the plate is such as to give it sufficient mechanical strength to withstand any ordinary strain to which it may be subjected. A cheaper glass would do if sufficiently strong to withstand ordinary strains, jars, chalk pressure, and heavy tapping.

Unlike the opaque screens, the translucent screen has no backing to assist it in resisting surface blows or pressures.

The glass was ground only on one side. During the grinding process, the glass was laid on a cushion of newspapers spread upon a flat, solid table so as to avoid excessive local strains while grinding. The grinding tool was of lead 48 square inches in area and weighed about 35 pounds. Number 70 carborundum and water were used. The time required was about two hours.

A finer grade of carborundum would perhaps be preferable inasmuch as a few rather wide scratches were made at the beginning of the grinding operation. No real injury to the visual characteristics of the screen is caused by these scratches. When viewed under a microscope of 30 diameters magnification, the surface except for the few wide scratches, appeared uniformly roughened with no trace of fine scratches.

The supporting frame for the translucent screen was constructed of Oregon fir. The pieces used for the two vertical supports and the vertical bracing are planed 2 x 4 stock. All other lumber used in the construction is 2 x 1 stock. Paper composition wall board (Beaver Board) encloses the illuminating compartment.

This compartment extends 18 inches behind the surface of the glass and is framed by the light boards already mentioned. The bottom of the glass is 42 inches above the floor. Four casters are attached to the base in order to permit moving the screen conveniently.

The illumination compartment was constructed with a view to placing the bank of lamps beneath the glass, in such a position as to illuminate the reflecting walls of the compartment evenly. The location of the lamps is such as to prevent entirely any direct illumination of the glass surface. Direct lighting from behind would give the screen a spotted appearance.

Neither the depth of the compartment nor the curvature of the upper reflecting surface were worked out mathematically. The compartment depth of 18 inches was used because it gives plenty of room to mount ordinary electric lamps and also gives space to move them while making adjustments to obtain a uniform illumination upon the reflecting surface. The method of adjusting the illumination consisted in raising or lowering the bank of lamps, and in changing the curvature of the upper part of the back reflecting surface. A horizontal brace near the center of the back holds it in the best curve.

The compartment depth of 18 inches could probably be reduced somewhat. It is likely that the depth could be reduced by half or more if another bank of lamps were placed at the top of the screen.

The entire interior of the compartment, with the exception of the glass surface, was given two coats of a good matt white paint. This painting raised the reflection factor from 0.60 to 0.89, and increased the usefulness of the light by more than two hundred per cent.

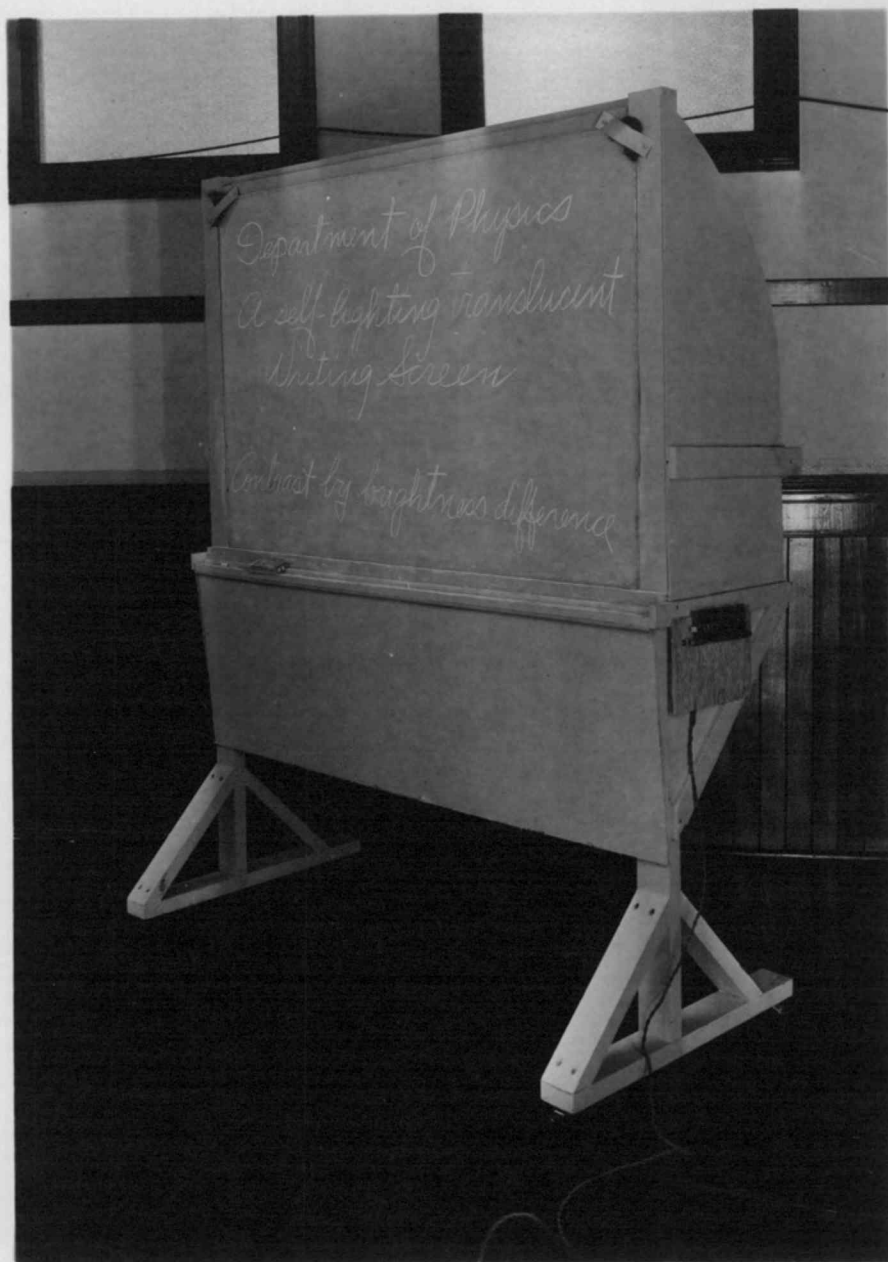
Thirteen lamps are evenly spaced along a narrow board extending between the two main supports and directly beneath the glass surface. This large number of lamps made it possible to perform tests at a comparatively high surface brightness, and yet resulted in an even light distribution when less illumination was used. One to five lamps were usually sufficient. Mazda B were used exclusively in the tests. By lowering and raising the lamp bank until the desired uniformity of illumination resulted, the position was determined in which it was finally mounted.

The board was fastened to the supports at each end by a single screw so as to permit rotation, partly to give another adjustment for even illumination, and partly to make it easy to insert and remove lamps.

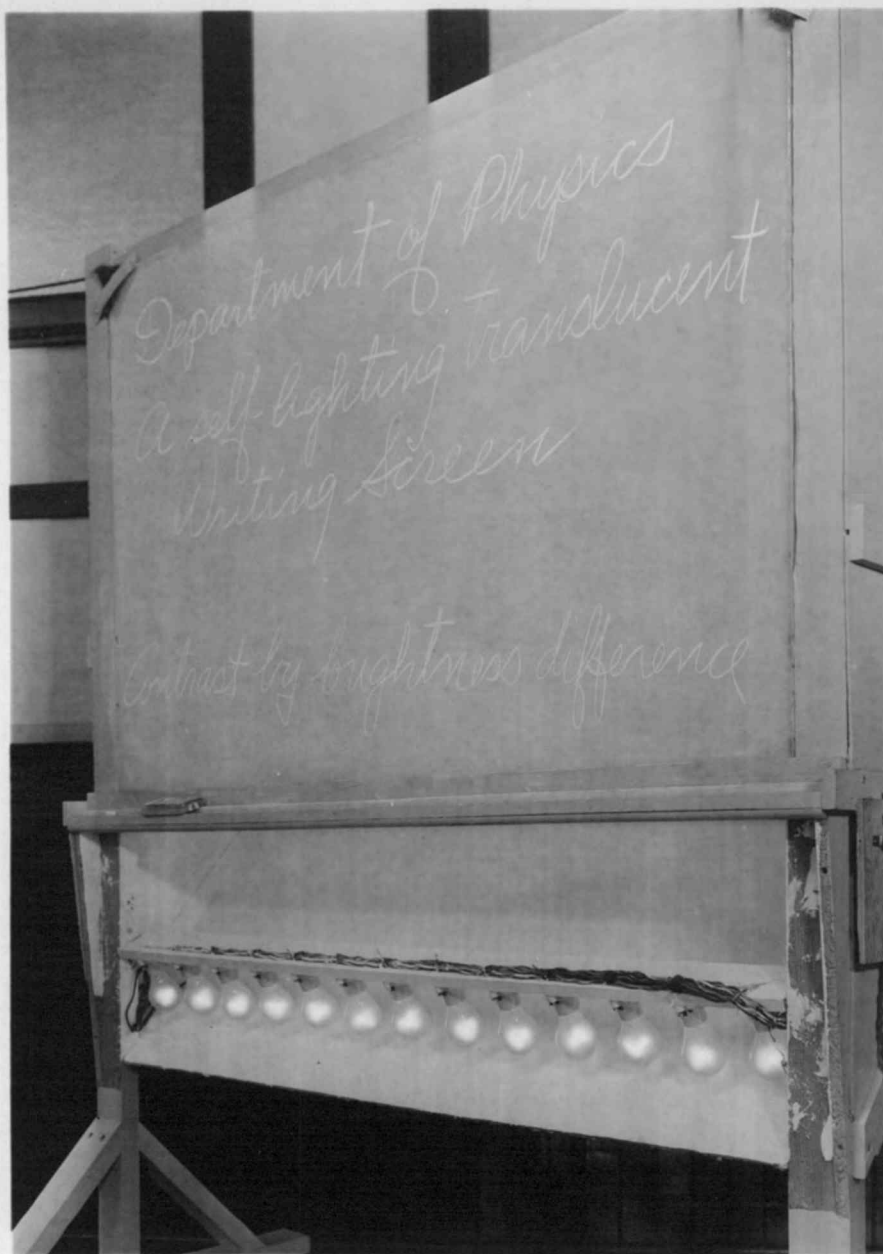
The lamps used were 40 watt Mazda B. A simple 13 pole switch was made for controlling the lamps individually so that any combination of them could be lighted.

After assembling the screen, the outer surface was painted. At the front of the screen cracks and apertures which permitted the light to escape were carefully closed.

The accompanying photographs show the details of the screen construction.



FRONT AND SIDE VIEW OF THE TRANSLUCENT
WRITING SCREEN.

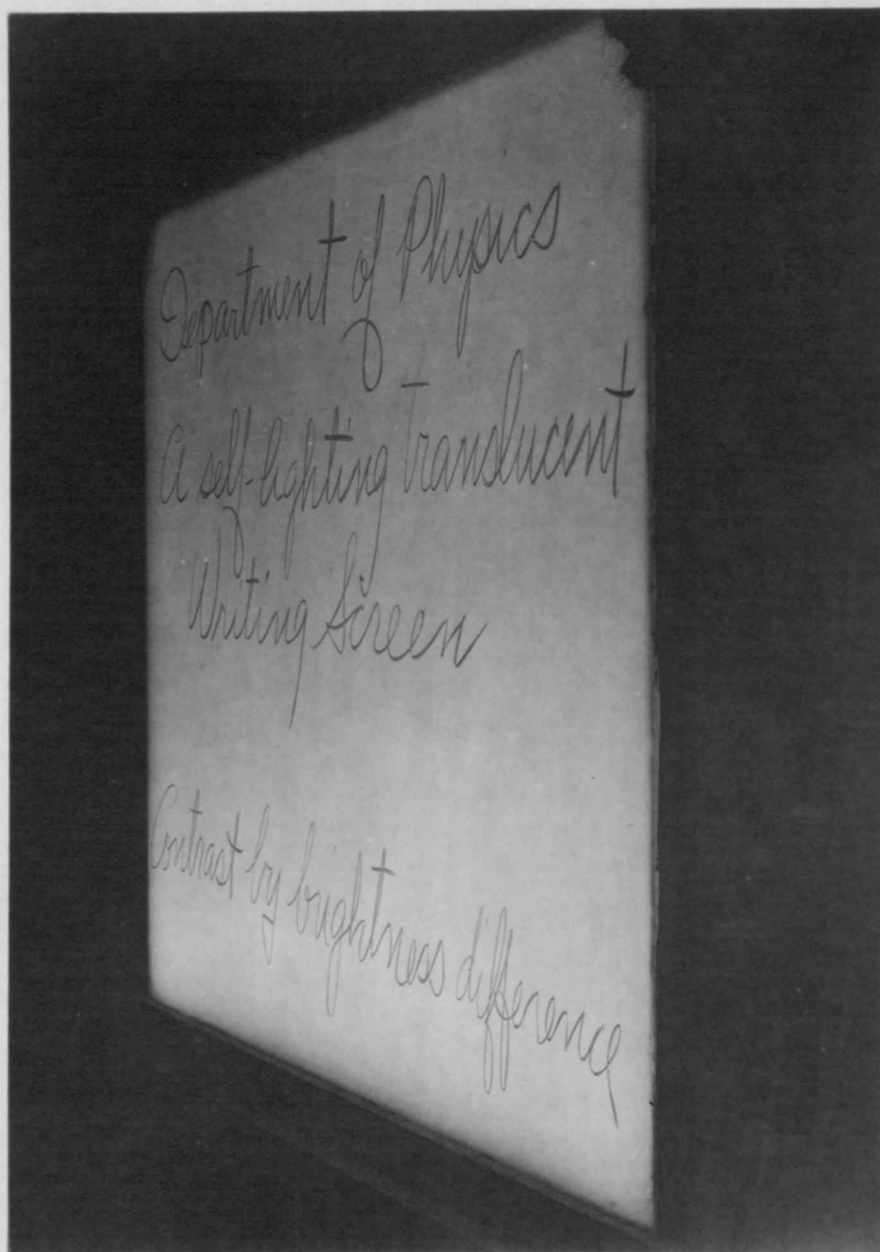


FRONT VIEW OF THE TRANSLUCENT WRITING SCREEN
WITH A SECTION OF THE ILLUMINATION COMPARTMENT
REMOVED TO SHOW LAMP BANK.

Department of Physics
A self-lighting translucent
Writing Screen

Contrast by brightness difference

FRONT VIEW OF THE TRANSLUCENT WRITING SCREEN IN OPERATION.



VIEW OF TRANSLUCENT WRITING SCREEN IN OPERATION
FROM A POINT AT A 15° ANGLE WITH THE SCREEN
SURFACE.

PART V

TESTING THE TRANSLUCENT WRITING SCREEN

Before describing the various tests, certain observations should be stated as to the principles upon which the screen operates. The chief factor in the illumination of the writing surface is not the diffuse transmission of the surface itself but rather the diffuse and uniform illumination of the curved back of the illumination compartment. The chief function of the surface itself is to take the chalk. The general room illumination is not, as a rule, the chief cause of the brightness of the chalk mark, for the screen illumination penetrates both the glass and chalk mark. The transmission factor of the surface alone is considerably more than that for the surface and chalk mark together. As a result the surface appears bright and the chalk mark dull by comparison.

Another peculiarity results from the fact that a chalk mark does not transmit light as well as the surface, but diffusely reflects light much better. If the room illumination is fairly high and a chalk

mark is viewed normally to the illuminated glass surface, the mark appears dark against the light background. Transmission by the glass is greater than the combined transmission and reflection by the chalk mark. But as an observer moves so as to view the screen at more acute angles the diffuse reflection and transmission of the chalk becomes equal to the transmission by the glass, and the two are of equal brightness. Under this condition a chalk mark is invisible. At a still more acute angle a chalk mark appears bright against the darker background due to light diffusely reflected by the chalk.

An attempt to use colored lamps did not yield much of promise. Both red and green lamps were tried, but the available intensities were too low to give good effects. The illumination was striking but gave no real indication of visual possibilities.

A Macbeth Illuminometer was used for making all brightness and intensity measurements and all reflection factor determinations.

Tests were made under all available conditions of screen illumination, and under the intensities of room illumination commonly encountered. In changing the number of lamps to vary the screen illumination the grouping was rearranged to secure the best distribution.

For example, if the thirteen lamps are numbered 1 to 13, and one lamp is required, number 7 is turned on. If two lamps are wanted, numbers 3 and 10 are used; if three, 1, 7, 13; if five, 1, 4, 7, 10, 13. As a method of control the use of a rheostat would be very impractical, because of the waste of power. Furthermore a lamp should be operated at its rated voltage in order to obtain the highest efficiency. In all tests of the translucent screen, the lamps were maintained at their rating of 120 volts.

The reflection factors of the chalk mark and glass surface were measured under ordinary room illumination, with no lights on in the compartment. These reflection factors, with a few others of interest are given in the following table:

TABLE I
REFLECTION FACTORS OF SEVERAL SURFACES

Surface	
Ground Glass	0.69
Chalk Mark on Ground Glass	0.805
Hyloplate (good)	0.09 - 0.105
Chalk Mark on Hyloplate (good)	0.32
Hyloplate (bad)	0.23 - 0.28
Chalk Mark on Hyloplate (bad)	0.30 - 0.40
Slate	0.105 - 0.131
Chalk Mark on Slate	0.27
Chalk (material)	0.85
Reflecting Back of Screen	0.89

With the room in complete darkness the screen was illuminated from within at various degrees of brightness. The brightnesses of screen and chalk mark were measured at each increment of illumination. The following brightness values were taken before the illumination compartment was painted, while its reflection factor was 0.60:

TABLE II

BRIGHTNESS CHARACTERISTICS OF TRANSLUCENT
SCREEN UNDER NO OUTSIDE ILLUMINATION.

(Compartment Reflection Factor 0.6)

Number 40 Watt Lamps	Brightness of Screen Surface-Millilamberts	Brightness of Chalk Mark - Millilamberts
0	0	0
5	12.4	8.15
10	29.4	15.7
13	36.7	22.35

Fig.2. Brightness Curves
Compartment Reflection Factor 0.60
No Room Illumination

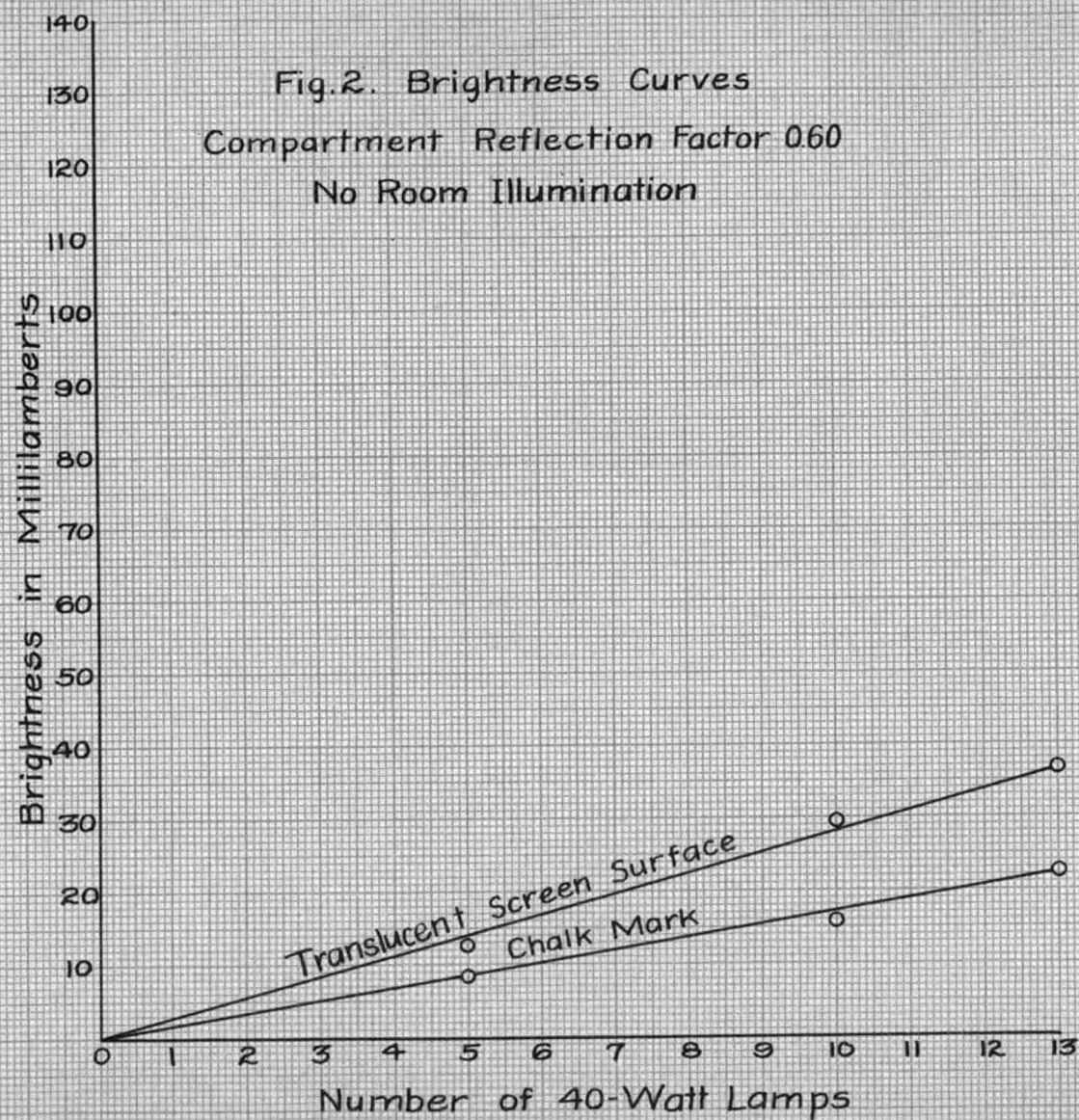


Fig. 2 shows graphically the increase in brightness of the screen surface and the chalk mark as additional lamps are turned on. The brightnesses of surface and chalk mark were individually directly proportional to the number of lamps.

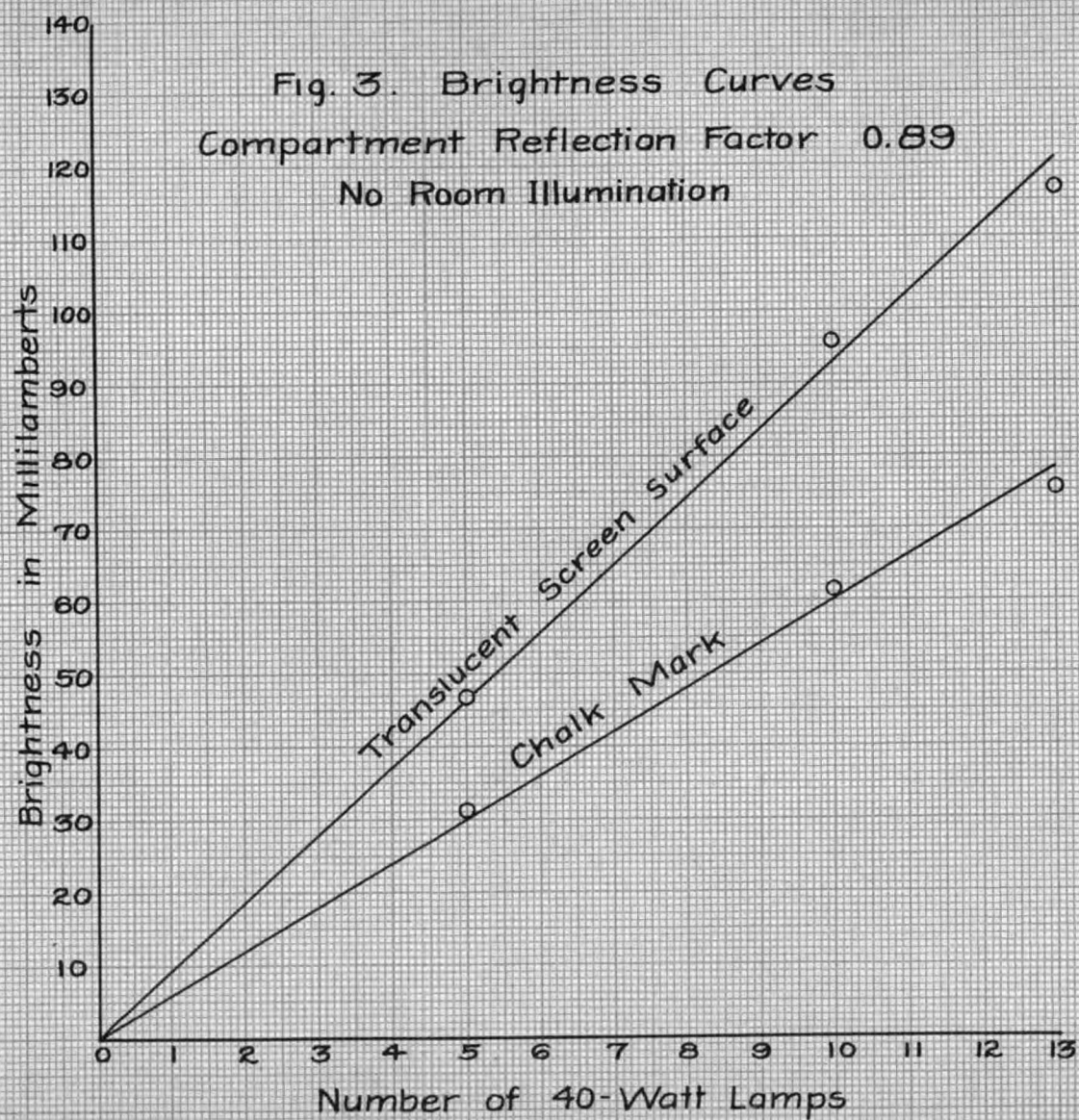
After painting the illumination compartment so as to raise its reflection factor to 0.89, the brightness was again measured and the following results obtained:

TABLE III

BRIGHTNESS CHARACTERISTICS OF TRANSLUCENT SCREEN UNDER NO OUTSIDE ILLUMINATION. COMPARTMENT REFLECTION FACTOR 0.89

Number 40 Watt Lamps	Brightness of Screen Surface-Millilamberts	Brightness of Chalk Mark-Millilamberts
0	0	0
5	46.8	31.0
10	95.6	61.2
13	116.6	75.2

Fig. 3. Brightness Curves
Compartment Reflection Factor 0.89
No Room Illumination



These values are shown graphically in Fig. 3. By increasing the reflection factor of the blackboard of the compartment from 0.6 to 0.89, the screen and chalk brightness became over three times as great as before.

The next measurements were made under conditions of use, with the room illuminated. The visual conditions of the screen and crayon were observed under four intensities of room illumination. In addition to making brightness measurements, an attempt was made to determine the effect of the different illuminations of the front and rear of the writing surface on visual acuity. The data obtained are not to be regarded as being numerically reliable since they were obtained for only one observer. In order to compare the screen with hyloplate, the two were placed side by side and measurements made under the same room illumination. The blackboard used had a reflection factor of 0.146 and its chalk mark reflected 0.385 of the incident light. The following tables show the visual conditions of the translucent screen under room illuminations of 3.25, 5.65, 10.45, and 17.5 foot-candles:

TABLE IV

BRIGHTNESS OF CHALK MARK AND SCREEN AND VISUAL ACUITY
UNDER 3.25 FOOT-CANDLES ROOM ILLUMINATION

Number of 40 Watt Lamps	Bright- ness of screen Surface Millilam- berts	Bright- ness of Chalk Mark Millilam- berts	Visual Acuity Chalk on Trans- lucent Screen	Visual Acuity Chalk on Black- board
0	2.3	2.8	0.75	0.7
1	31.0	---	0.85	
3	31.0	19.7	1.02	
5	---	---	1.10	
6	55.2	37.5	---	
7	---	---	1.14	
10	97.2	61.1	---	
13	122.7	78.2	1.31	

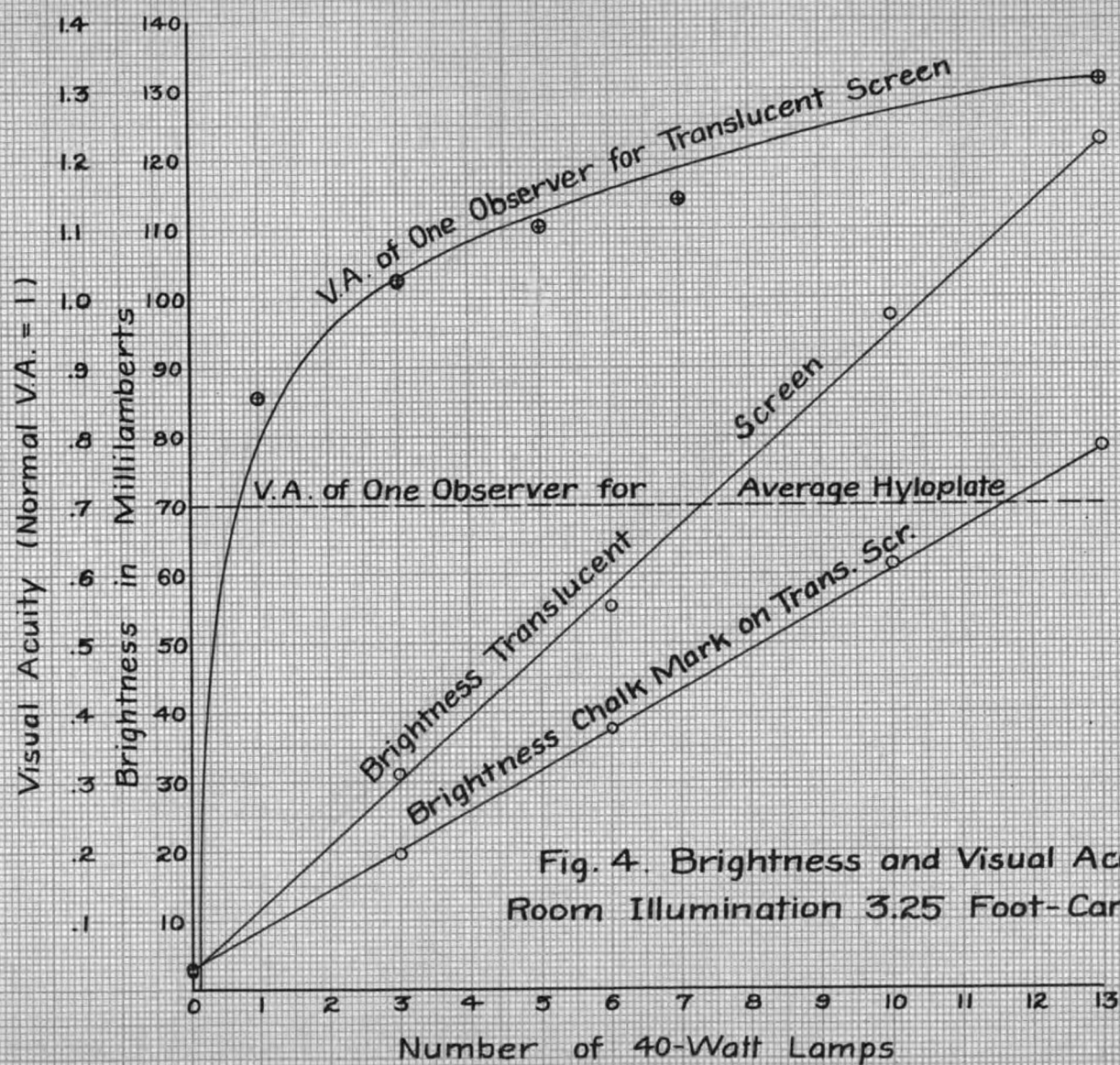


Fig. 4. Brightness and Visual Acuity
Room Illumination 3.25 Foot-Candles

TABLE V

BRIGHTNESS OF CHALK MARK AND SCREEN AND VISUAL ACUITY
UNDER 5.65 FOOT-CANDLES ROOM ILLUMINATION.

Number of 40 Watt Lamps	Bright- ness of screen Surface Millilam- berts	Bright- ness of Chalk Mark Millilam- berts	Visual Acuity Chalk Mark on Trans- lucent screen	Visual Acuity Chalk Mark on Black- board
0	3.8	4.4	---	0.89
1	---	---	0.555	
3	32.1	21.7	0.87	
5	51.0	34.1	0.958	
7	---	---	1.00	
10	99.4	66.5	---	
13	126.4	81.2	1.292	

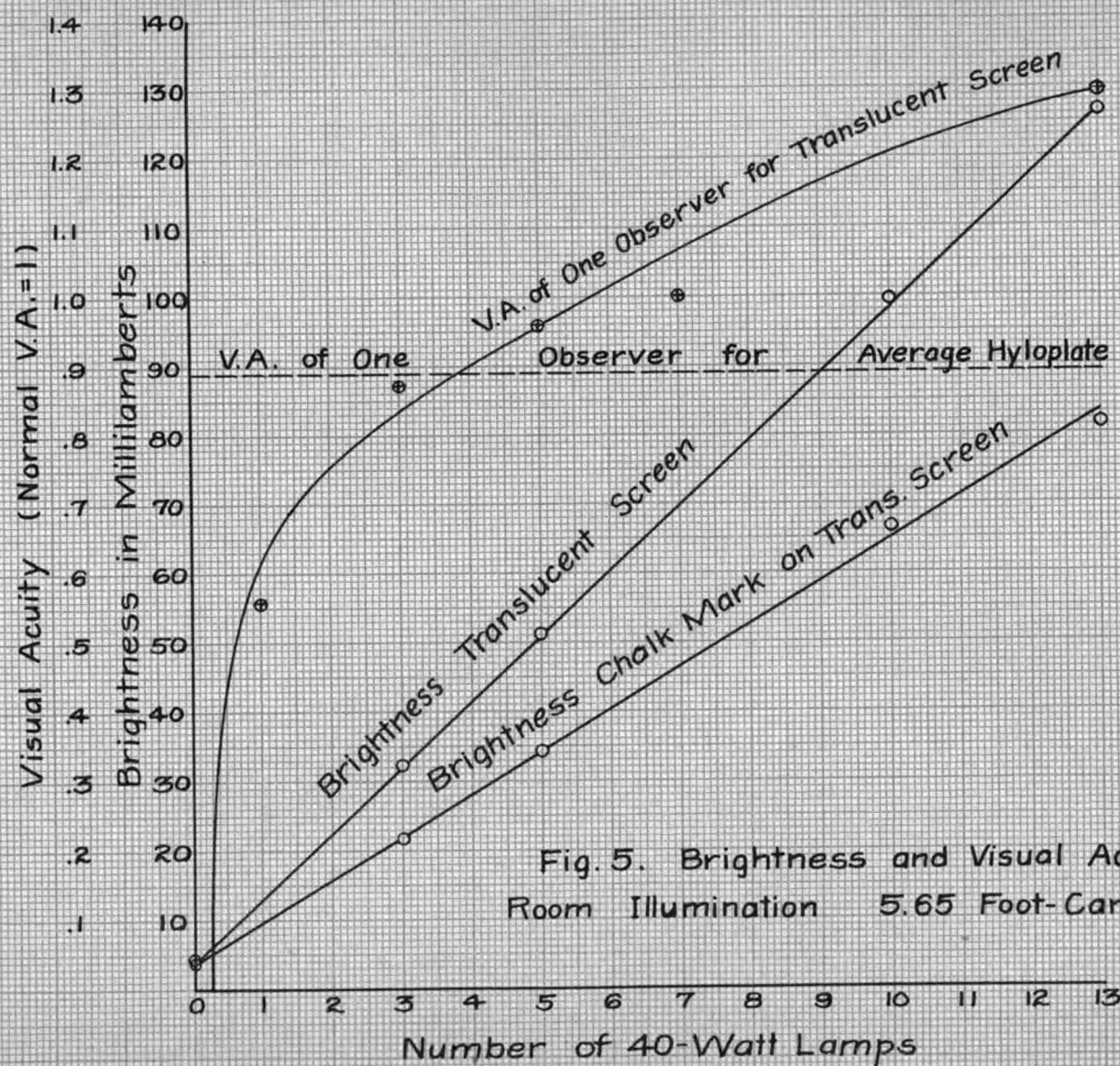


Fig. 5. Brightness and Visual Acuity
Room Illumination 5.65 Foot-Candles

TABLE VI

BRIGHTNESS OF CHALK MARK AND SCREEN AND VISUAL ACUITY
UNDER 10.45 FOOT-CANDLES ROOM ILLUMINATION.

Number of 40 Watt Lamps	Bright- ness of screen Surface Millilam- berts	Bright- ness of Chalk Mark Millilam- berts	Visual Acuity Chalk Mark on Trans- lucent Screen	Visual Acuity Chalk Mark on Black- board
0	7.4	8.6	---	1.16
1	---	---	0.48	
3	36.2	26.0	0.695	
5	54.0	38.2	0.89	
7	---	---	1.07	
10	102.5	66.2	---	
13	131.2	83.5	1.29	

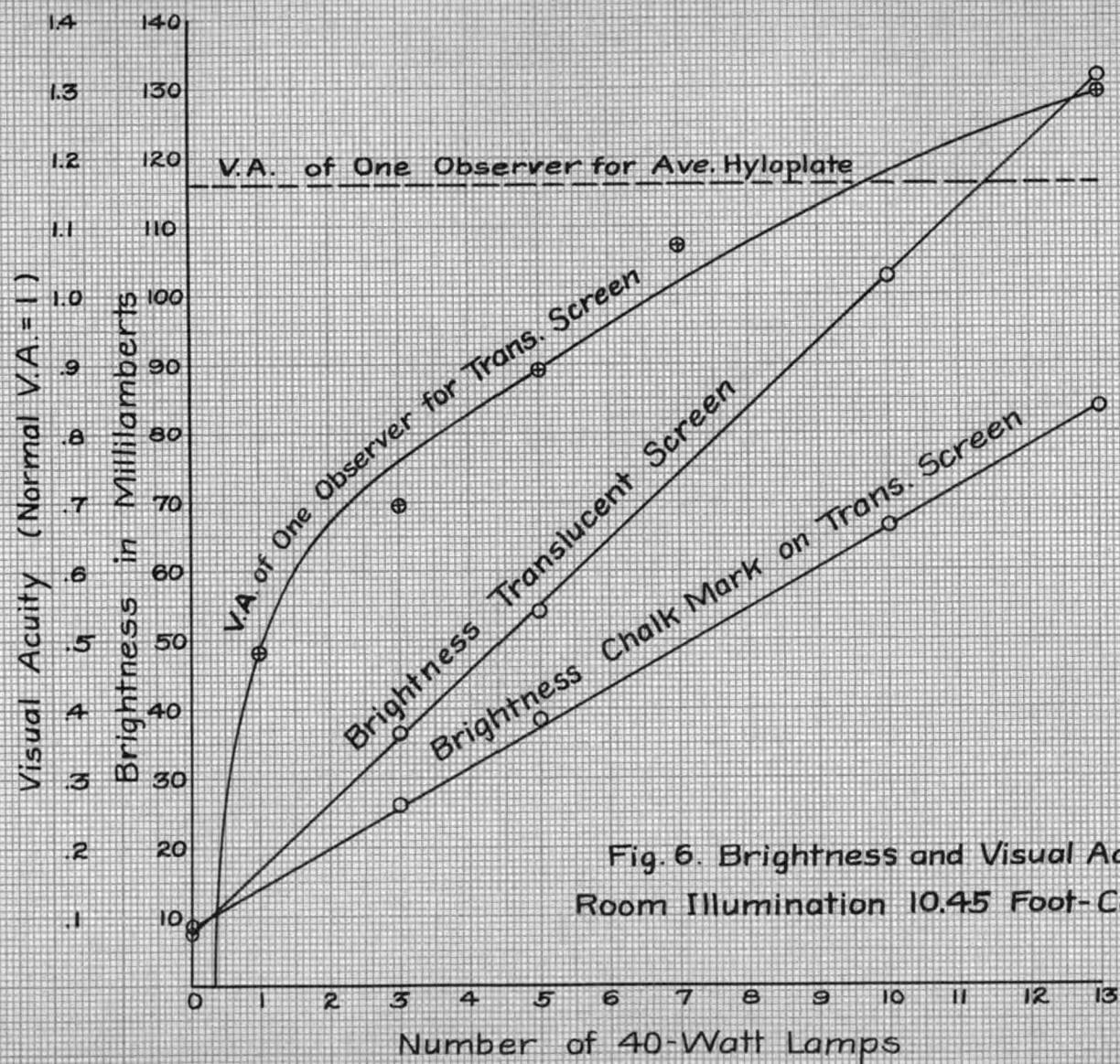


Fig. 6. Brightness and Visual Acuity
Room Illumination 10.45 Foot-Candles

TABLE VII

BRIGHTNESS OF CHALK MARK AND SCREEN AND VISUAL ACUITY
UNDER 17.5 FOOT-CANDLES ROOM ILLUMINATION

Number of 40 Watt Lamps	Bright- ness of screen Surface Millilam- berts	Bright- ness of Chalk Mark Millilam- berts	Visual Acuity Chalk Marks on Trans- lucent Screen	Visual Acuity Chalk Marks on Black- board
0	13.6	15.2	---	1.31
1	---	---	0.513	
3	41.5	31.0	0.685	
5	61.0	41.0	0.77	
7	---	---	1.02	
10	106.8	70.0	---	
13	136.1	87.0	1.28	

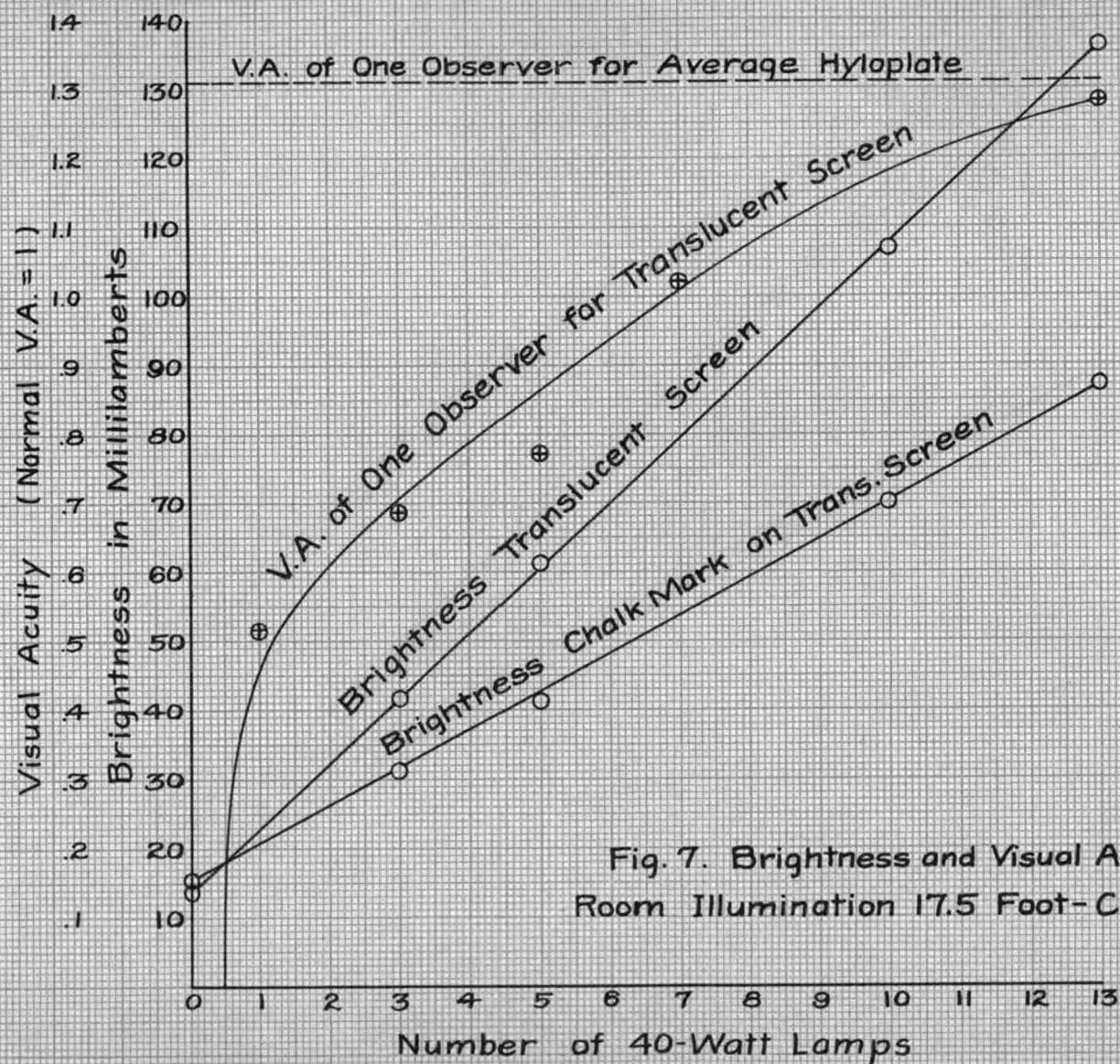


Fig. 7. Brightness and Visual Acuity
Room Illumination 17.5 Foot-Candles

The data of Table IV serves as the basis of Fig.

4. The brightness of screen and crayon mark is slightly increased by the room illumination. The visual acuity curve indicates that three lamps behind the screen under this room illumination (3.25 foot-candles) produces the same visual acuity for the translucent screen as for the hyloplate. With more than one lamp, the translucent screen has the better visual characteristics.

The brightness values and visual acuities under the conditions of Tables V, VI, and VII are represented by the curves of Fig. 5, 6, and 7. Fig. V shows that the increased room illumination has supplied a small increment to the brightness values. The visual acuity, using the translucent screen, is somewhat less than it was under the lower room illumination, whereas the visual acuity, using the blackboard, was a little greater. Under this room illumination (5.65 foot-candles) five lamps were sufficient.

Fig. VI and VII show slight gains in the screen brightness. The intersections of the brightness curves indicates a condition of equal brightness of translucent surface and crayon mark. Before this point is reached the chalk appears bright and contrasts with the darker surface.

At the intersection point the chalk mark becomes invisible. At the lower values of screen illumination the visual acuity of the translucent screen became less as the room illumination became higher. At the conditions of greater screen brightness the visual acuity was not greatly affected by changes in room illumination. The visual acuity in the case of the blackboard became higher as the room illumination was increased. To obtain equal visual characteristics from the translucent screen, a larger number of lamps must be used.

Usually three lamps are sufficient for the screen illumination. Since this screen has a surface of slightly more than 15 square feet, it is likely that to illuminate a surface of this type only 8 watts per square foot need be allowed ordinarily, and 15 watts per square foot at the highest room illumination.

In practically all the brightness determinations, the ratio of chalk mark brightness to screen brightness was approximately 0.64. This ratio is evidently a constant visual characteristic of crayon and screen surface.

Mention has been made of the sudden dropping off of the brightness of both screen and chalk mark when

viewed in a direction making a small angle with the surface of the screen. The difference in brightness was not measured, but observations were taken of visual acuity changes. These observations are shown in the following tables, under three sets of illumination conditions.

TABLE VIII

VISUAL ACUITY FOR CHALK MARKS ON TRANSLUCENT SCREEN VIEWED AT VARIOUS ANGLES TO SCREEN SURFACE. ROOM ILLUMINATION 17.5 FOOT-CANDLES; SCREEN ILLUMINATION 13 LAMPS.

Angle with Normal to Screen Surface	Visual Acuity
0°	1.28
15°	1.28
30°	1.28
45°	1.28
60°	1.28
75°	1.28
90°	0

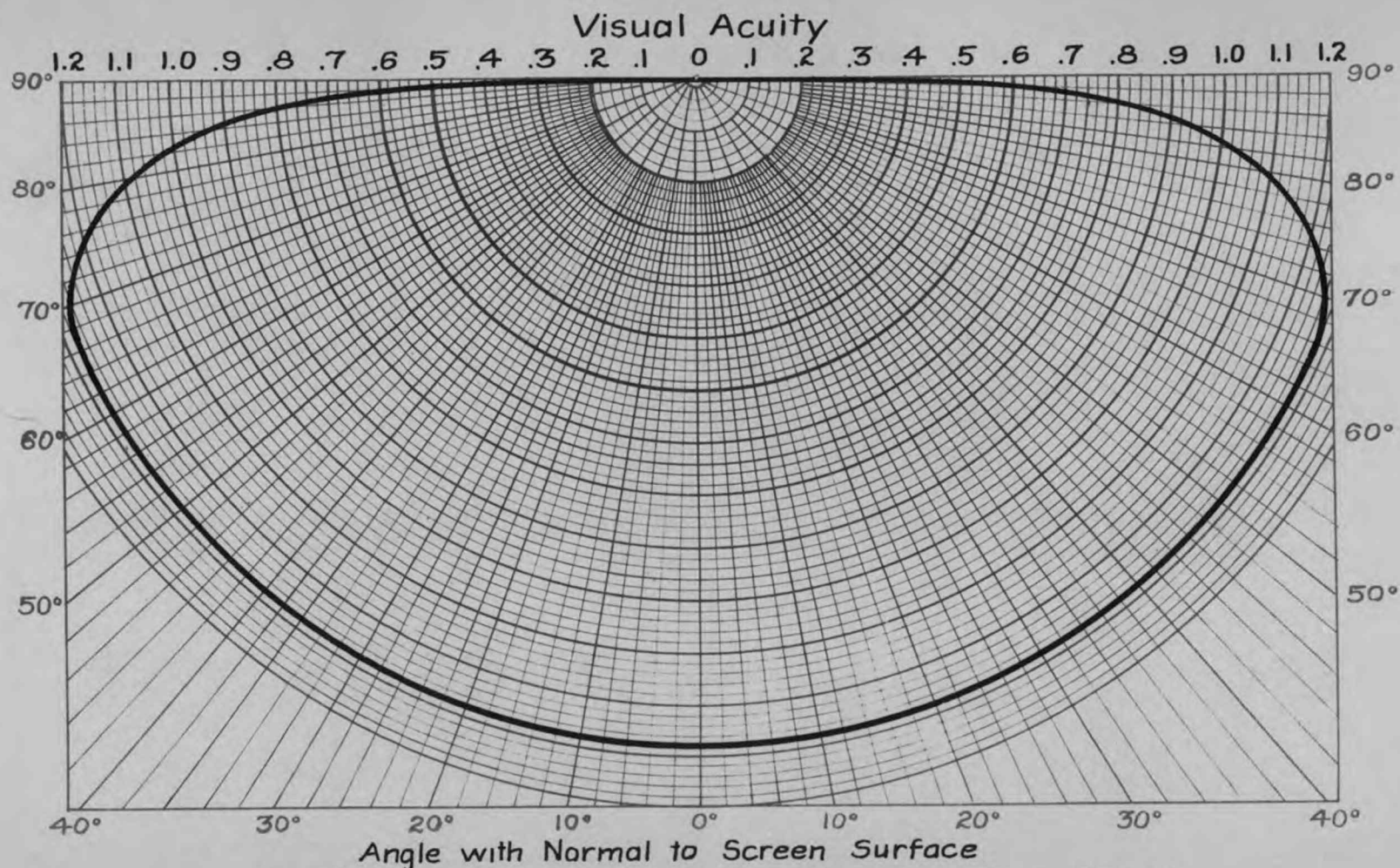


Fig. 8. Visual Acuity for Chalk Mark on Trans. Screen.
 Room Illum. 17.5 Foot-Candles; Screen Illum. 13 Lamps.

TABLE IX

VISUAL ACUITY FOR CHALK MARKS ON TRANSLUCENT SCREEN VIEWED AT VARIOUS ANGLES TO SCREEN SURFACE. ROOM ILLUMINATION 17.5 FOOT-CANDLES; SCREEN ILLUMINATION 3 LAMPS.

Angle with Normal to Screen Surface	Visual Acuity
0°	0.685
30°	0.68
71½°	0

TABLE X

VISUAL ACUITY FOR CHALK MARKS ON TRANSLUCENT SCREEN VIEWED AT VARIOUS ANGLES TO SCREEN SURFACE. ROOM ILLUMINATION 17.5 FOOT-CANDLES; SCREEN ILLUMINATION 1 LAMP.

Angle With Normal to Screen Surface	Visual Acuity
0°	0.513
30°	0.45
46°	0

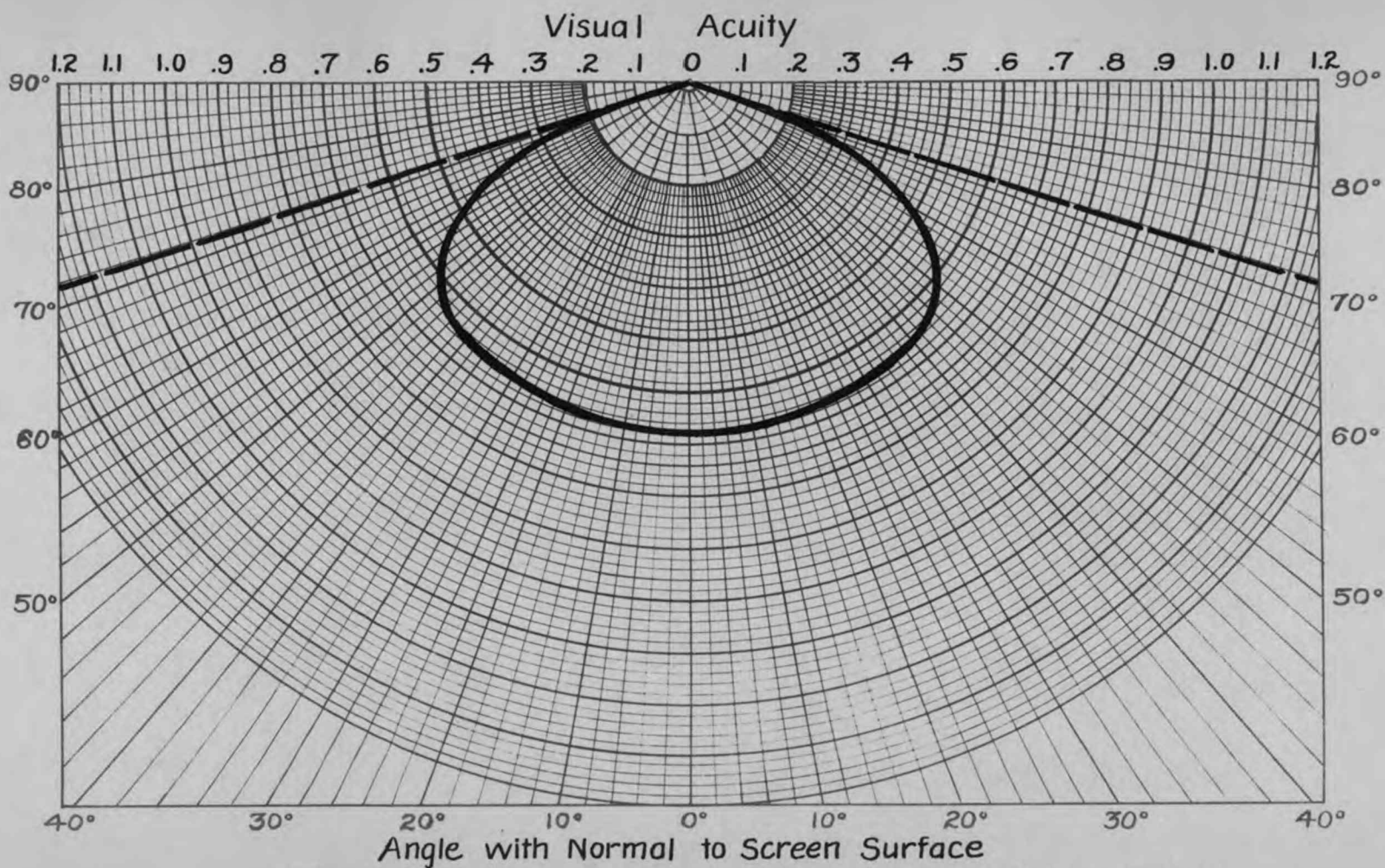


Fig.9. Visual Acuity for Chalk Mark on Trans. Screen.
Room Illum. 17.5 Foot-Candles; Screen Illum. 3 Lamps.

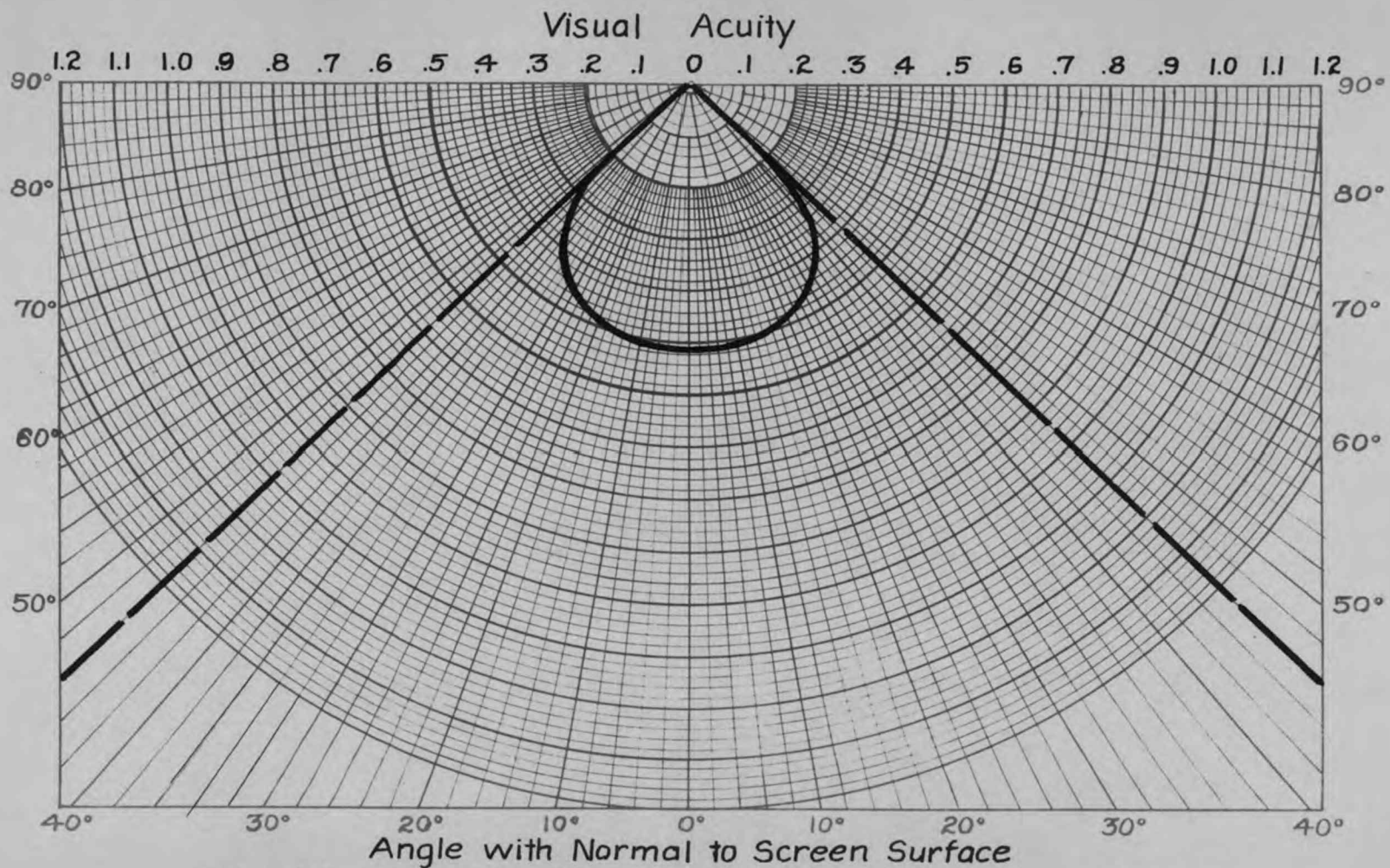


Fig. 10. Visual Acuity for Chalk Mark on Trans. Screen.
 Room Illum. 17.5 Foot-Candles; Screen Illum. 1 Lamp.

The conditions of the foregoing tables are graphically represented in Fig. 8, 9, and 10. The disappearance of the chalk marks is a characteristic observed only when the room illumination is high, and the screen brightness is low. With a sufficient number of lamps in use, the point of chalk mark invisibility can be made 90° to the normal to screen surface.

Several mechanical characteristics of the translucent screen surface were noted in connection with the use of chalk. The surface takes the chalk well and a clear uniform line results. The width of chalk marks varies from 0.15 cm. to 0.60 cm., or about the same as for chalk marks on hyloplate. The chalk is not ground excessively by the ground glass surface, and no dust is given off by the crayon in writing.

Erasures of chalk marks are very easily made and a clean surface results. The diffusion of the screen surface seems actually to be improved by erasures due to the spreading of fine chalk dust. When necessary, washing can be done very rapidly and without any particular care as to the surface. An excess of water should not be used as it seeps around the edges of the glass and leaves stains in the illumination compartment.

The noise accompanying writing is somewhat objectionable and is doubtless due to the fact that the glass is not pressed tightly against a backing. At times a high-pitched sound results from passing the chalk over the ground glass surface. This does not occur ordinarily, and probably is caused by a lack of uniformity in the quality of the chalk.

PART VI

COMPARISON OF THE TRANSLUCENT WRITING
SCREEN WITH EXISTING TYPES OF WRITING
SCREENS

A comparison of the translucent writing screen with screens now in use shows that the former is in many respects a decided improvement.

The life of the translucent writing screen is independent of the amount of normal use and may last indefinitely. In this respect it is similar to slate and much superior to hyloplate.

Writing upon the ground glass surface leaves a mark which is as clean and distinct as a mark upon slate, or even more so. Hyloplate is much inferior in its way of taking the chalk.

Erasures which detract from the effectiveness of hyloplate and slate improve the visual qualities of the translucent screen.

Washing of the ground glass surface is seldom necessary and is easily accomplished. Other types of screens require almost daily washing when in active use.

The translucent writing screen is more noisy than the other types of screens which are backed against board or plaster.

The translucent writing screen is self-lighting, and, unlike other screens, is independent of external lighting except at high values of room illuminations and to these it can be adjusted easily by simply turning on more lamps.

Glare, which provides such a serious objection to the use of blackboards in general, is entirely absent from the translucent ground glass surface.

The contrast of chalk marks to screen surface is less in the case of the translucent screen but this does not seem to affect vision noticeably.

Although the visual acuity measurements were not numerous enough to be reliable, the results obtained indicate that the translucent screen at proper brightnesses is superior to hyloplate. The fact that the contrast is better between chalk mark and hyloplate surface than between chalk mark and illuminated screen surface, throws some doubt upon the acuity measurements. It can be said, however, that the comparison is not as might be expected from a consideration of contrasts.

The appearance of the translucent screen with its ground glass surface is much better than the dusty black

surface of hyloplate or slate. With no inside illumination the reflection factor of the ground glass surface and reflecting back is 0.69 compared to about 0.10 for slate or hyloplate.

The depth of the translucent screen puts it at a disadvantage when compared with other types of screens. The thickness of blackboard is negligible and allows it to be attached to a wall with no waste of space; whereas, the translucent screen in its present form requires 18 inches of space behind it for illumination. A good installation involves many detailed adjustments, with the illumination and electric wiring to complicate matters. A reduction of the distance appears to be entirely feasible and will be tried in the near future.

The cost of the translucent screen is considerably more than any of the opaque screens. A higher fixed cost results from the greater investment required in installation. To the fixed cost must be added the operating cost, which is not excessive if the screen is properly used. The operating costs consist of the lamp replacements and the cost of electric energy. The rate of using electricity may be assumed as 15 watts per square foot of surface while the screen is in use.

In conclusion several suggested applications of the translucent writing screen will be listed. The screen can be used to advantage in rooms in which blackboards have proven unsatisfactory. It may be very effectively used in stock exchanges, in railway stations, and for display advertising. It may be put to various unusual uses; a diagram can be projected upon the screen and lines added as required. Coordinates and other forms such as outline maps can be drawn on tracing cloth, mounted upon rollers, and when needed drawn down behind the ground glass so as to cast a shadow upon the screen. In fact, it is felt that many difficult and unusual problems of visual instruction can be solved by its aid.

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