The Motion Picture Theater Its Interior Illumination and the Selection of the Screen

Eastman Kodak Company,
Rochester, N. Y.

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A Booklet for Motion Picture Theater Owners and Managers

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Introduction

THE motion picture theater did not spring at once into popularity, due, in part, to the fact that little attention was given to the comfort of the spectators. In the early days, the pictures were usually exhibited in a stuffy improvised hall and in total darkness. After the arrival of the motion picture theater with its more pleasing and comfortable surroundings, the number of persons attending the theater increased enormously. In the modern theater every detail of decoration, ventilation and temperature regulation has been most carefully worked out.

The public will invariably prefer to patronize the modern theater in which the optical and physical comforts have been looked after. It will fill the up-to-date picture house to capacity and at good prices even when another theater, where the surroundings are not pleasant, is showing the same picture for less money. People may be easily attracted to a theater for the first time by a good picture. They will come again if they viewed the picture in comfort.

When Mr. Eastman, in connection with his gift of a school of music to the people of the City of Rochester, conceived the idea of an endowed motion picture theater, it was found that little attention had been paid in the past to the scientific illumination of the interior of the theater, or to the choice of a suitable projection screen. It was Mr. Eastman's wish that this theater should offer the best surroundings for the exhibition of the pictures and should be a model theater in every detail. Consequently, the problem was turned over to the Kodak Research Laboratory to find the maximum of permissible lighting of the interior of the theater and to choose the screen best suited to the installation.

The results of these tests, it is believed, will be of very great interest to every motion picture theater owner, architect, and engineer. The question of correct lighting of the theater and screen is of as much importance in the motion picture theater as the acoustic properties of the opera house, concert hall or the theater devoted to the spoken drama. This booklet is published in order that the lighting conditions may be raised to the high standard already set in the other details of the theater and in the excellence of the screen offering.

It is as important that theater patrons be relieved from tired eyes as that they should have comfortable seats, good ventilation and satisfying music. They go to see the pictures for rest and relaxation as well as for amusement. If they go home from the theater with all of their senses pleased, they will come back to that theater again and again.

The Kodak Research Laboratory is peculiarly adapted to handling problems connected with light and lighting. It is light that, by affecting the sensitive materials, makes the negative. It is light that prints the positive from the negative. Light is the basis of photography and so our Laboratory men know light as no other group of men in the world know it and they have at their command all the apparatus for conducting the most exhaustive experiments. And when a new problem comes along that requires some hitherto unknown piece of apparatus for its solving, they design and construct whatever may be needed.

There was a work to be accomplished in improving the lighting conditions in motion picture theaters and in providing a more intelligent selection and use of screens. The Kodak Research Laboratory had both the men and the equipment for the work. And so there was turned over to it the task of investigating conditions and carrying out a series of experiments, the results of which should be of definite benefit to the entire motion picture industry.

There was a vast amount of work accomplished and the conclusions that were arrived at as a result of that work are contained in this little book. Even now we do not feel that all of the lighting problems are solved for all time, but we do feel that the subject has been intelligently covered. However, new problems will be constantly arising and we shall gladly use our Laboratory resources in helping you to solve those problems—not merely in a general way but in a specific way if you ask for our help.

EASTMAN KODAK COMPANY,
Rochester, N. Y.

The Illumination of the Interior

IN the early days of the motion picture theater, it was customary to present the pictures in a room containing practically no illumination except what resulted from reflection at the screen. This procedure may have been justified to a certain extent at that time because the light used for projecting the picture was very weak, making it necessary to exclude practically all the light from the room in order that the screen might appear of satisfactory brightness. With improvements in the projection apparatus and in the quality of the photographic materials, the brightness of the picture itself has been increased until it is of relatively high intensity. Following this, there has been some increase in the illumination of the interior of the theater. The higher screen brightness naturally permits more interior illumination without seriously interfering with the picture.

The desirability of comfortably lighting the theater is at once apparent provided it can be done without loss of quality in the picture. It is hardly necessary to enumerate the objections to the use of poorly lighted theaters. The difficulty encountered by persons entering the theater in finding their way to unoccupied seats, and the strain placed upon the eyes by the sudden transition from the dark interior to the brightly lighted exterior when leaving, are familiar to everyone. Furthermore, in a poorly lighted theater, it is quite impossible for the management to supervise adequately the conduct of individuals; a fact which has lead to no little criticism of the motion picture theater. More serious than any of these, however, is the tax placed upon the eyes when viewing a bright screen in a dark theater. The eyes become adjusted to brightness conditions just as a runner gets his second wind when his pace has become adjusted to his physical ability. The ideal condition for viewing the motion picture screen occurs when the eyes have become adapted to the average brightness of the screen. This is usually impossible since the screen fills only a small fraction of the whole field of view and the remainder of the field is very dark. Because of this, the eyes are forced to view a bright screen to which they can never become adapted. In other words, the eyes under the above conditions are in the same state of distress as the runner before he gets his second-wind, but in the case of the eyes the condition continues indefinitely. The remedy is, of course, to increase the illumination of the interior of the theater. The first phase of the problem undertaken by the Kodak Research Laboratory was the determination of the conditions of interior illumination which would afford the maximum of comfort for the audience without impairing the quality of the picture.

In order to make practical tests of illumination, a projection booth and a projection machine were installed in a room in the laboratory. A projection screen of an ordinary type was placed at one end of the room. The room was about forty-two feet long and the ceiling of the room was white, while the walls were a medium tone of buff. A lighting fixture was suspended from the ceiling from brackets in such a way that the position of the fixture in the room, the angle of inclination and the distance from the ceiling could be varied in almost every conceivable manner. The fixture itself was of the indirect type so arranged that the direct rays from the lamps could strike only on the ceiling and rear wall of the room. The electric current in the arc of the projection machine was adjusted so that the brightness of the screen with the machine running, but without a film, was 20 apparent foot-candles* which is slightly

*Just as the candle power is the unit of light intensity, the foot-candle is the unit of the illumination produced. Thus, a 16 candle-power lamp one foot away from the screen would produce an illumination of 16 foot-candles. A 32 candle-power lamp would produce an illumination of 32 foot-candles. By the 20-ft. candles given above is meant that the light coming from the projection machine illuminates the screen to the same brightness as a 20 candle-power lamp would illuminate a portion of the screen placed one foot from the lamp.

higher than an average brightness as measured in a number of motion picture theaters.

With conditions established which were similar to those in a motion picture theater, the research laboratory made many trials to determine the most suitable lighting arrangement. The number of lights in the fixture and the position of the fixture in the room were altered in every way possible. At last, a condition was found where the illumination seemed to be better than any other. The general room illumination was such that a person entering the room from the bright sunshine could see immediately all details of furniture about the room and after a period of not more than one or two minutes, could read ordinary printed matter. *Indeed, the facility with which print could be read would make it entirely feasible to sell advertising space on programs.*

To be sure that the quality of the picture was not impaired by this scheme of lighting, several persons experienced in the judging of the photographic quality were asked to express their opinions. These observers were unanimous in the decision that, not only was the photographic quality of the picture fully as good, but that the effect was more pleasing and resulted in greater visual comfort. An important point noted was that much less shock was experienced by the eyes when the screen brightness was suddenly changed by the appearance of a title, and further, that the slight flicker due to a lack of precise shutter adjustment was less noticeable. On the whole, the arrangement was considered satisfactory by all the spectators.

Having found what seemed to be the best lighting conditions, the illumination was measured at many different points in the room. This can be done by means of a small portable instrument* which can be used to measure the

*The instrument used in this work was a Macbeth Illuminometer made by the Leeds & Northup Company, Philadelphia, Pa. It is essentially a portable photometer which is calibrated to measure illumination. In use, an opal glass test plate is placed at the point where the illumination is to be measured. The instrument is then pointed illumination at as many different places as desired. From the values obtained, an illumination engineer is able to duplicate this condition in any theater. Obviously, specific instructions for theater lighting can not be laid down because every theater is more or less a problem in itself. Such factors as the size, the architectural details, use of cornices and arches, the reflecting power of various ceiling and wall surfaces have to be taken into any computation. Certain decorative schemes, especially of ceiling, may also have to be worked out in order to make the lighting most effective. Since the lamps must in general be placed close to the ceiling, certain regions require a low reflecting power and others a high reflecting power. All of these factors may be taken into account, however, and with close co-operation between the lighting engineer and the designer of the decorative scheme, a highly satisfactory arrangement may be chosen.

To show the improvement which might be brought about in a theater in which the lighting system was already installed, the Kodak experts designed a scheme of illumination for a small theater used for the exhibition of motion pictures. The results obtained in the experimental room were made the basis of the new calculations. The details were worked out to give very nearly the same amount of general illumination as the experimental room. In this case also, the results were found to be satisfactory and the general effect more pleasing with less strain on the eyes. The general conclusion which can be drawn from these experiments is that a relatively large amount of general illumination may exist in a motion picture theater without interfering with the projected picture provided the illumination is properly distributed.

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at the test plate and by changing the position of a small incandescent lamp in the instrument, a balance in intensity is secured between the light from the test plate and the light from the lamp. The illumination can then be read directly in foot-candles on the scale of the instrument.

Some observations were made during the course of the experiments which will probably upset some of the existing conventions and increase the comfort of the motion picture patrons. For instance, the black velvet frame which frequently surrounds the screen is found undesirable and a neutral gray is suggested in its place. The reason is simple. Suppose the illumination of the strongest highlight of the picture is 10 foot candles. Under these conditions the brightness of the black velvet frame would be found to be about 0.001 foot-candles. This makes the ratio of the two or the brightness contrast equal to 1 to 10,000. This contrast is beyond the power of the eye to record and results again in overtaxing the process of adaptation. By using a material with a higher reflecting power than black velvet, the contrast between the screen and the frame may be brought within the range of the eye. If the brightness of the frame is raised to 0.02 foot-candles, the contrast between the strongest highlight in the picture and the frame is 1 to 500. Scientists say that this is about the limit of contrast which the eye can endure with comfort. In general, therefore, the black velvet frame should not be used but, in its place, a material which has a reflecting power sufficient to raise the apparent brightness of the frame to something like 0.02 foot-candles.

The selection of the material will depend upon a number of factors: the illumination of the theater and the distance of the screen behind the front of the stage being the principal ones. For experimental purposes in the laboratory it was found that covering the black frame with white mill net was quite satisfactory. Such an expedient will not in general be found satisfactory in practice since this material will undoubtedly fail to harmonize with the elegance and richness of finish frequently found in the modern motion picture theater. In many cases the screen area is surrounded by drapings of silk, velvet, or other fabrics and in such cases it is suggested that a fabric harmonizing with the general decorative scheme be used as a draping immediately around the screen area, the color that will give a satisfactory result being such as in ordinary terminology is referred to as a rather dark gray. A very pleasing result was obtained in an experimental installation by the use of a screen frame covered with a warm-gray burlap such as is used for wall coverings. In case the decorative scheme is carried out not by the use of fabrics but by the use of painted surfaces, the frame should be made by use of a rather dark gray paint. Of course, it should be understood that in case a true gray does not harmonize well with the decorative scheme of the interior some rather dark color tone (including colors usually referred to as warm or cool grays) may be used with advantage. In any event, small samples of fabric or small panels painted with various colors should be tried by placing them temporarily in position near the screen and the final choice made when a material or paint is found having a reflecting power such as to make the frame appear of the correct brightness*.

For similar reasons, no area of the interior of the theater visible from any seat in the audience except the picture itself should have an apparent brightness of more than 2.5

*It should be pointed out that when a frame of relatively high reflecting power is used, the opening in the frame should coincide exactly in shape and size with the projected picture. In case the opening is slightly smaller than the projected picture, the overlapping at the edges will naturally be much more apparent and objectionable than when a black frame is used. In constructing the frame, therefore, care should be taken to prevent the occurrence of this undesirable feature. Since it may be somewhat difficult in some cases to establish and maintain exact register of picture with frame opening, it may be well to use a narrow border of very dark gray immediately around the picture. By using such a border, which need not exceed six inches in width and may be narrower if care is exercised, a picture slightly larger than the opening in the frame may be used. A stripe of such widths subtend such a small angle at the eye of the observer that its effect in producing disagreeably high contrast will be practically negligible.

to 3.0 foot-candles. This applies to the walls near a lamp, to the lamp itself if it is not concealed, to any diffusing globes or fixtures used, and in general to any part of the interior of the theater. For example, a sheet of white paper illuminated by a 25 watt lamp at a distance of one foot, has an apparent brightness of about 20 foot-candles. A sheet of music illuminated in this way, if visible from the audience, becomes a glare spot and may cause great discomfort. Arrangements should therefore be made which, while providing adequate illumination for the musicians, will prevent the illuminated sheets from being visible to the audience. Lights under a balcony are particularly bad and should be used only with a properly designed indirect lighting system. Considerable attention should be paid to the character and position of exit signs. While it is necessary to make such signs very conspicuous, this can be accomplished without making them so brilliant as to become disagreeable glare spots.

The use of a projection screen set well back from the stage and shielded to a great extent from light reflected from the walls and ceiling would probably permit of even greater values of the general interior illumination than used in the tests performed by the laboratory. The results obtained in the tests indicate that the illumination should be about 0.1 foot-candles on the table plane* near the front of the theater and increase gradually to about 0.2 foot-candles near the back of the theater.

It is suggested that if the lighting of the vestibule, lobby and foyer be graded so that the transition from the sunlight to the interior of the theater is made gradual, the shock to the eyes on entering and leaving the theater will be diminished. If properly designed, it is possible that the time necessary for the adaptation of the eyes to the inter-

*The *table plane* is any horizontal surface 30 inches above the floor. The amount of illumination in a room is usually specified by measuring the illumination at the *table plane* for a number of different points in the room.

ior brightness when entering the theater will be consumed in passing into the theater so that ordinary print may be read at once. In any case, it would be unnecessary to equip the ushers with flashlights as is often done at present. A moving light of this sort is very annoying, especially to persons sitting close to the aisle.

The present high efficiency tungsten lamps which are almost universally employed for theater illumination give an effect which is rather harsh and excessively brilliant. This may be overcome by choosing a color scheme for the interior which uses warm tones. Another remedy is to dip the lamps in colored lacquer. The formula below gives a very pleasing amber color which is quite satisfactory. Other dye materials may be used when the amber color does not harmonize with the general color scheme of the interior of the theater.

Formula for Dipping Lamps

4½ ounces	Sandarac (Powdered)
½ ounces	Venice Turpentine
58 grains	Metanil Yellow No. 1955 (National Aniline Co., Buffalo, N. Y.)
½ fluid ounce	Lavender Oil (Garden)
26½ fluid ounces	Denatured Alcohol

In figure (I) is shown a possible arrangement of the lighting in a theater which, it is thought would be very satisfactory. This plan is presented as one way of handling the problem and many others may be worked out. The scheme is designed to duplicate as nearly as possible the results obtained in the laboratory and any scheme which will do this would work equally well. The ceiling, which consists of four arches, is illuminated by lamps concealed in the fixtures as indicated. The total candle power of the lamps in each fixture is indicated by such expressions as $i = 1x$, $i = 4x$, etc. Without knowing the size of the theater, it is quite impossible to specify the exact amount of light to be used. The symbols mean that four times as much candle-power should be used at the fixture marked $i = 4x$ as at the one marked $i = 1x$. Thus, if the size of the

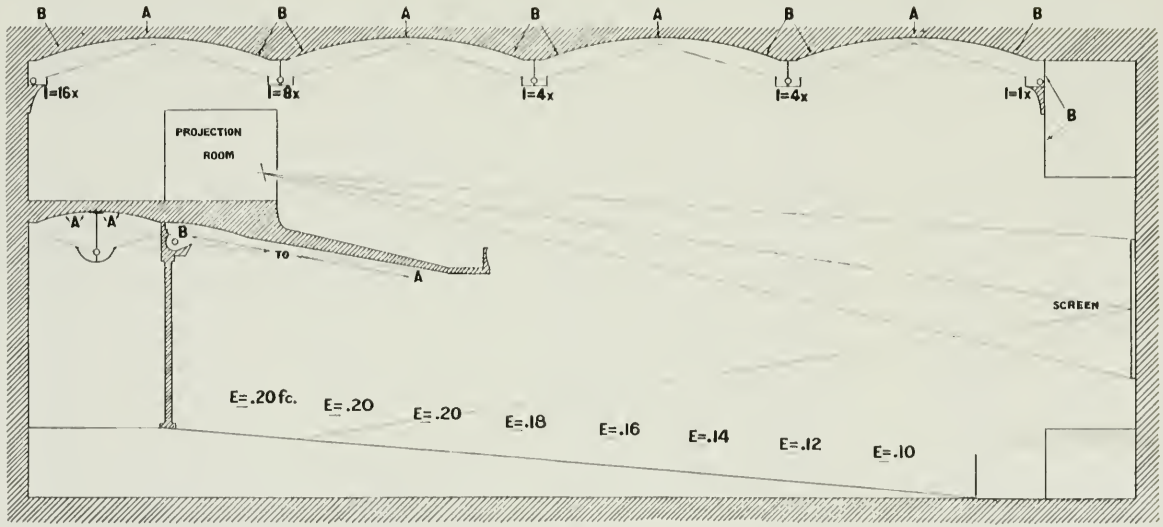

Fig. I
Theater illuminating plan showing one satisfactory method of scientific illumination

theater made it necessary to use 100 candle power at i = 1x, we should have to use 4 x 100 or 400 candle-power at i = 4x. This will give an illumination which is more intense at the back of the theater and which gradually becomes less toward the front.

Since the lamps must be placed comparatively close to the ceiling, it would be necessary in order to obtain a uniform ceiling brightness to arrange the decorative scheme so that the region marked B would have a relatively low reflecting power while that marked A should have a high reflecting power. In general, it is desirable to use a material of low reflecting power near the lighting fixtures in order to cut down the brightness to a point where it will not exceed 3.0 foot-candles.

Near the floor of the theater in the figure will be found numbers indicating approximately the values of the illumination at those points. The expression, $E = 0.10$ means that the illumination on the table plane at that point should be about 0.10 foot-candles. The arrangement of the fixtures is such that with the candle-power in each fixture indicated, the illumination at the table plane will be correct. No attempt is made here to work out the details of the interior illumination and decoration. They depend so much upon the size of the theater that each case must be considered separately. It is only desired to show the importance of proper interior illumination for motion picture theaters and to indicate the results that may be obtained by co-operation between the designer and the lighting engineer, making use of the results obtained in the research laboratory.

A complete and more technical account of the experiments carried out by the research laboratory can be found by consulting the list of articles given at the end of this pamphlet. The research laboratory is also ready to co-operate at any time in the solution of problems which may arise.

The Choice of a Suitable Projection Screen

DOES the motion picture screen appear equally bright from all angles of view? In other words, does the screen appear too bright for persons in the center of the theater and not bright enough for persons at the side. This was the second phase of the problem considered by the Kodak Research Laboratory. Nearly all the projection screens on the market were examined, and such wide differences between the many types were found that the results are being published to make it possible to choose the screen which will be suitable for the particular theater in which it is to be used. It is found that a screen which would be satisfactory in one theater might fail completely in another. The result of most interest to motion picture theater owners and managers is the fact that it is now possible to select the best screen for a given theater with scientific accuracy.

Every projection screen has its own reflection characterstics. Some reflect nearly all the light in a narrow beam giving plenty of light for persons sitting in the center of the theater and almost none for those at the sides. There are other screens which appear of nearly equal brightness from any seat in the theater. These represent extreme cases with the majority of screens occupying an intermediate position between the two. The choice of screen depends mainly upon the shape of the theater. However, in order to determine the best screen for a given theater, it is first necessary to determine accurately the reflecting power of the screens for all angles of view.

This the Research Laboratory has done for a number of commercial screens. Orders for samples of projection screens were placed with practically every maker whose advertisement could be located in the trade journals. A response was not obtained from all the makers but a fairly representative group of samples was received. A special apparatus, a gonio-photometer, was constructed for the purpose of measuring the reflecting power. A beam of light was thrown upon the sample of screen perpendicularly, thus illuminating it in very much the same manner as in the motion picture theater. A small instrument which could be set to view the screen from any angle was used to measure the reflecting power. (See Figure II.) In this way the

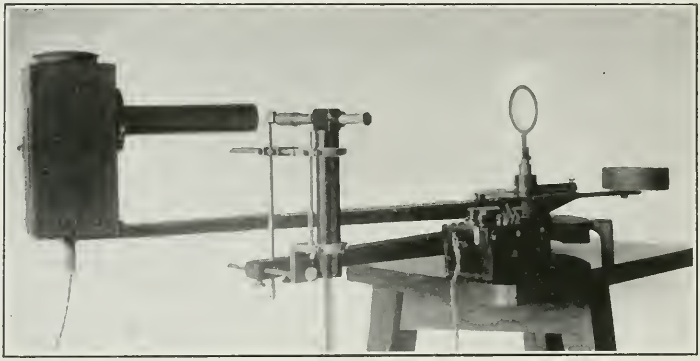

FIG. II

The Gonio-Photometer which was designed and built by the Kodak Research Laboratory for the purpose of measuring the reflection characteristics of motion picture screens.

reflecting power of a screen could be determined when viewed perpendicularly or at angles of 5 to 70 degrees from the perpendicular. These values are given for each screen in Table IV of the appendix. This table contains all the necessary data for the complete specification of the reflection characteristics of a projection screen.

Since we are interested in having the screen appear of satisfactory brightness to persons at the side of the theater as well as in the center, it is necessary to decide on the maximum amount that the reflecting power can fall off before the screen brightness becomes insufficient. Making use of all the existing data on the subject, the laboratory staff decided that the reflecting power for the persons sitting at the side of the theater should never be less than one-fourth of the reflecting power for persons in the center of the theater. That is, with the proper screen brightness for persons in the center of the theater, the brightness of the screen as seen by persons at the side should never be less than one-fourth of the proper amount. If the ratio of the reflecting powers is greater than four to one, it will result in diminishing the number of good seats in the theater. Obviously, a screen which would give excellent results in a long narrow theater might not be suitable in a very wide theater where the angle of view was greater.

The maximum angle of view can be determined from a floor plan of the theater. It may be found by drawing a line connecting the most extreme seat on the side with the center of the screen. The angle of view is then measured between this line and a line drawn through the center of the theater. It will sometimes be found that there are a few seats on the side which will add to the angle of the theater considerably. If these seats are usually vacant, it may be undesirable to increase the angle for the benefit of the few persons who might occupy them. The figure III will illustrate this. The required angle, counting all seats, is 40 degrees. However, 95 per cent of the seats are contained within an angle of 30 degrees. With the knowledge that these seats will not be as good, it is sometimes permissible to choose an angle which does not include them. The distortion, which no screen can correct, is often more annoying from the side of the theater than the falling off of the screen brightness.

In selecting a screen for a motion picture theater, the procedure should be somewhat as follows. First determine from the floor plan, the maximum angle of view. Let us suppose that this angle is found to be 30 degrees.

In table II will be found a list of commercial projection screens and in the second column the maximum angle for each screen is given. It would be undesirable to use a screen for which the maximum angle is 20 degrees in a 30 degree theater, so we may rule out the first few screens

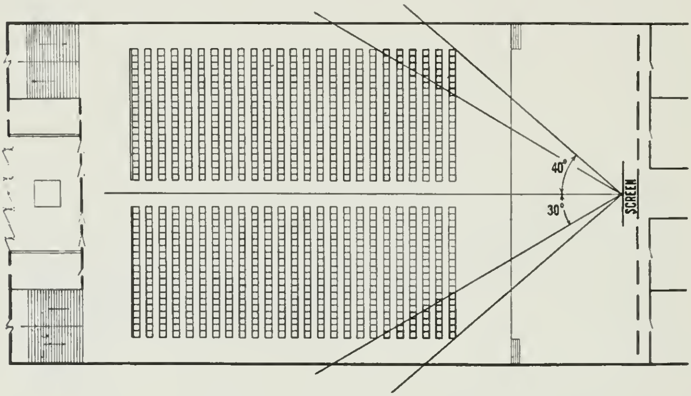

Fig. III
Floor plan of a typical theater with an extreme angle of 40 degrees. Ninety-five percent of the seats lie within an angle of 30 degrees.

which are listed as being suitable only to an angle of 20 degrees. It will then be noticed that any of the remaining screens may be used without exceeding the angle for which they become unsatisfactory. If there were no other factors to consider, the most efficient screen would be the one which had the highest average reflecting power. The values of the average reflecting power will be found in column 3. A low reflecting power is undesirable, since it necessitates a larger electric current through the arc of the projection machine and, therefore, increases the cost of operation.

There are several other factors, however, of as much importance as a high reflecting power. The texture and color must also be considered in choosing a projection screen. These factors are listed in columns four and five of Table II. It is, of course, difficult to describe the color or texture in exact terms. Samples, which could be described by the same terms, may appear very different when placed by side by side. Columns four and five must be considered, therefore, as giving only a general idea of the character of the surface of the screen.

The laboratory is not in a position to advise on two other factors which will influence the choice of a screen; namely, the durability and the cost. The problem, which was undertaken by the laboratory, was to determine the most satisfactory conditions of projection, regardless of their cost. It is believed, however, that improvements as suggested by this booklet will be soon paid for at the box office.

The Kodak Company is prepared to measure the reflection characteristics of samples of motion picture screens, and a testing department is maintained at the research laboratory for this purpose. A sample screen eight inches square is required. The Company is also ready at any time to co-operate in the choice of a suitable screen to fit a given theater. A nominal charge only is made for such services. All correspondence or samples of screens should be addressed to the Motion Picture Film Department.

TABLE I

No.	Name of Screen	Manufacturer
1	Superlite	C. S. Wertsner & Son, 211-221 N. 13th St., Philadelphia, Pa.
2	Special	"
3	Green Back	"
4	White Back	"
5	Plain White Coated	"
6	Imsco Silver No. 1	Independent Movie Supply Co., 729 7th Ave., New York City
7	Imsco Gold No. 1	"
8	Imsco No. 2	"
9	Imsco No. 3	"
10	Imsco No. 4	"
11	Imsco White Muslin	"
12	Idealite—Grade 1A	Ludcke Picture Screen Co., St. Peter, Minn.
13	Idealite—Grade 1B	"
14	Idealite—Grade 2	"
15	Dalite Crystal White	Da-Lite Screen & Scenic Co., 922 W. Monroe St., Chicago, Ill.
16	Dalite Gold Fiber	"
17	Dalite Silver	"
18	Gold King	Gold King Moving Picture Screen Company, 327 East California St., Oklahoma City, Okla.
19	Half-tone	Raven Screen Company, 257 So. 2nd Ave., Mt. Vernon, N. Y.
20	Aluminum Paper	W. G. Preddy, 187 Golden Gate Ave., San Francisco, Calif.

TABLE II

No. See Table I	Maximum Angle	Average Reflecting Power	Color	Texture
6	20°	218	Metallic White	Coarse Grain
18	20°	209	Metallic Yellow	Smooth
1	20°	205	Metallic White	Coarse Grain
2	30°	204	Metallic White	Coarse Grain
7	30°	184	Metallic Yellow	Coarse Grain
8	30°	165	Metallic White	Coarse Grain
9	30°	150	Metallic White	Medium Grain
17	30°	128	Metallic White	Fine Grain
20	30°	96	Metallic White	Smooth
3	40°	136	Metallic White	Fine Grain
10	40°	129	Metallic White	Fine Grain
4	40°	121	Metallic White	Fine Grain
13	50°	104	Metallic White	Medium Grain
16	50°	79	Metallic Yellow	Fine Grain
12	70°	92	Metallic White	Fine Grain
14	70°	89	Metallic White	Fine Grain
19	70°	70	White	Smooth
5	70°	69	Yellow	Smooth
15	70°	68	Blue Green	Smooth
11	70°	62	White	Smooth

Appendix

After measuring the reflection characteristics of various motion picture projection screens, it was decided to examine a number of miscellaneous surfaces. It was thought that an examination of their characteristics might point the way to the manufacture of even better and more efficient screens than at present.

The results of this examination are given in Table III which is similar to Table II for the commercial projection screens. It will be noted that only two of the miscellaneous surfaces fall in the 20 degree class and the rest in the 70 degree class. The surfaces numbered 28 and 29 are quite similar and are not suited for use beyond 20 degrees. Number 28 is prepared by placing a mirror directly behind a ground glass focusing screen; while number 29 is a mirror, the first surface of which has been sand blasted.

In the 70 degree class, the surface of chalk (Magnesium Carbonate) is the most interesting. The reflecting power is high and very nearly constant out to 70 degrees. It has a pure white color and a surface which appears perfectly smooth to the eye. For this reason scientists have adopted this surface as the standard of a diffusely reflecting substance, although it would naturally be unsuited as a projection screen.

The actual values of the reflecting powers of all substances are given in Table IV for all angles of observation at which measurements were made. The reflecting power was measured by comparing the brightness of the surface being examined to that of a surface of magnesium carbonate viewed perpendicularly under the same conditions of illumination. The reflecting power of the magnesium carbonate was assumed to be 100 and the reflecting powers of the other substances referred to it.

TABLE III

No.	Maximum Angle	Average Reflecting Power	Surface
21	20°	339	Focusing Screen and Mirror
22	20°	305	Sand blasted Mirror
23	70°	94	Magnesium Carbonate (Chalk)
24	70°	82	Photo-Stock Coated
25	70°	75	Opal Glass
26	70°	74	White Drawing Paper
27	70°	67	Photo-Stock Uncoated
28	70°	62	White Blotting Paper
29	70°	49	Sand blasted Aluminum

TABLE IV.

Angle

No.	0°	5°	10°	15°	20°	30°	40°	50°	60°	70°
1	268	256	215	168	120	64.8	34.3	21.8	16.8	14.2
2	300	284	255	206	167	93.9	52.2	26.5	17.0	13.3
3	208	203	188	161	134	85.0	53.3	33.0	22.4	18.3
4	177	174	165	143	122	85.9	53.0	33.0	23.8	17.7
5	72.9	72.2	70.8	70.5	69.4	68.9	68.1	68.8	67.0	64.0
6	286	273	229	173	129	66.0	33.0	21.4	15.2	13.7
7	311	288	234	180	125	66.0	35.0	21.7	15.6	14.0
8	230	200	200	171	141	83.1	47.4	29.6	20.3	16.0
9	208	197	177	152	127	80.6	47.9	34.3	24.3	19.9
10	186	183	169	146	120	79.8	47.9	31.3	22.2	17.6
11	66.4	66.3	65.2	63.6	62.4	61.0	60.4	60.0	59.3	58.9
12	154	151	136	112	97.0	75.1	56.0	52.9	47.0	43.0
13	193	187	154	124	98.5	72.2	58.4	50.2	45.2	40.9
14	142	137	122	103	93.6	76.4	63.7	55.6	50.8	46.8
15	71.7	71.7	70.8	69.9	69.2	63.6	67.1	66.0	65.3	64.8
16	126	120	116	104	90.7	68.8	47.1	34.3	26.5	21.9
17	183	172	157	134	107	65.0	42.1	28.8	20.9	16.8
18	292	271	216	160	108	49.2	28.4	17.4	13.1	9.7
19	78.6	78.6	74.9	73.3	71.1	68.6	65.3	63.9	62.3	59.5
20	148	136	111	93.6	74.1	50.2	34.1	26.5	22.6	19.5
21	460	430	373	257	176	73.3	31.9	20.5	19.0	19.4
22	473	399	297	224	121	62.0	40.2	34.2	32.0	31.1
23	100	100	99.9	98.0	96.9	94.9	92.4	89.5	84.8	78.8
24	91.1	88.0	84.9	82.5	80.5	79.3	78.7	78.7	76.9	74.3
25	77.1	77.1	76.0	76.0	74.8	73.7	73.7	72.6	70.5	68.2
26	82.7	82.7	81.5	77.8	74.4	72.0	69.5	63.3	67.6	65.4
27	73.9	73.9	71.2	70.0	67.0	65.0	63.5	62.2	61.1	58.4
28	68.9	67.9	65.9	64.0	63.0	60.8	59.7	57.2	54.8	54.2
29	66.3	64.1	61.4	57.6	52.4	46.5	40.1	36.0	35.3	32.6

Bibliography

For a more technical account of the subject matter of this booklet, the reader is referred to the following articles published by members of the staff of the Kodak research laboratory. The Company has available a limited number of copies of these articles and they will be sent upon request to interested persons. Please address the request to the Motion Picture Film Department.

On the Interior Illumination of Motion Picture Theaters

Electrical Review,
Vol. 77, Page 757, Nov. 13, 1920.

Transactions Society Motion Picture Engineers,
No. 10, Page 83, 1920.

Transactions Illuminating Engineering Society,
Vol. 15, Page 645, Dec. 30, 1920.

On the Reflection Characteristics of Motion Picture Screens

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No. 11, Page 59, 1920.

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