B. E. STECHBART

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII JANUARY, 1932 Number 1

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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Published monthly at Easton, Pa., by the Society of Motion Picture Engineers

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

LIGHTING OF SOUND FILMS*

LOUIS DUNOYER

Summary.—*The author examines different types of illumination apparatus. He discusses their conditions of operation and describes the apparatus devised by himself in greater detail. This apparatus obtains an extremely fine exploring zone simply by projecting the image of a rectilinear incandescent filament on the film by means of a good objective. In order to correct the aberrations rigorously, the light coming from this filament goes through the walls of the lamp in a place where they form parallel faces worked optically.*

In conclusion, the author describes some comparative tests made on apparatus with a slit and on the rectilinear filament apparatus. The flux emitted by the latter is superior to the flux emitted by the apparatus with the slit, with a consumption approximately one-tenth as great. At the same time the disadvantages of the slits (dust, defective uniformity of illumination, delicacy of centering, etc.) are eliminated.

INTRODUCTION

1. Review of the Principle of Sound Films.—It is well known that on a sound film the section set aside for sound production is a small straight band only 3 millimeters wide, in general located between one of the series of perforations for moving the film and the edges of the picture images which are to be projected on the screen. On this small band the sounds first have been recorded by either of the two following processes which we shall review briefly to make them clearer.

In the constant density** process the sound band is divided in two regions, each of which has a uniform photographic density, one clear and the other dark, and whose common boundary is a line which is more or less indented or wavy. The bends of this line correspond to the recorded sound vibrations. In most cases this recording is performed by means of an oscillograph which receives the current from the receiving microphone after amplification by a triod. In vibrating, the spot of the oscillograph, which consists of a small luminous line perpendicular to the length of the band,

* Translated from *Revue d'Optique*, **10** (Jan.–Feb., 1931), Nos. 1–2, pp. 1–21, 57–68.

** *I.e.*, variable width.

produces an image on the film of a width which varies according to the amplitude and the frequency of the sound vibrations. Fig. 1 shows an example of constant density recording.

In the variable density process the photographic density of the sound band is the same at all points of its width but this density varies in the direction of the length of the band. The recording system which is used most at the moment consists in letting the film slide by a very fine slit illuminated by a flashing lamp. This lamp contains a gas under a low pressure illuminated by the discharge; the voltage at which this discharge is produced is modulated by the current from the recording microphone, conveniently amplified. The luminescence of the gas follows these modulations which are the more intense the higher the voltage. These modulations, therefore, are transferred to the sound band by corresponding modulations of the density in the direction of the length of the band. Figs. 2 and 3 show two examples of variable density recording. Fig. 2 refers to an invariable musical note (approximately 440 vibrations per second).

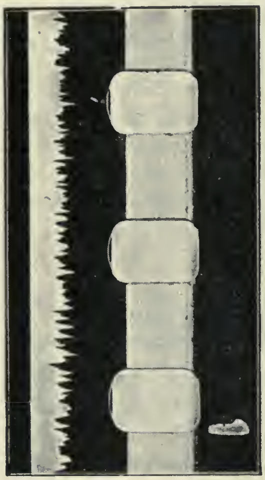

FIG. 1. An example of constant density recording.

In order to reproduce the sounds the entire width of the sound band must be illuminated, but only for a width equal to that of the spot or the slit which illuminated it during the recording; then having passed through the film the light is received by a photoelectric cell. If the photographic opacities are proportional to the luminous fluxes received during the recording, and if the photoelectric currents are proportional to the luminous fluxes received by the cell, these currents finally will be proportional to the currents of the recording oscillograph or to the brilliancy of the flashing lamp, according to the recording process employed. Then they are amplified and sent into a loud speaker. The distortion of the sound can be due only to the microphone circuit or the circuit of the loud speaker.

Since the light received by the cell should be only the light which has passed through the film in a rectangle 3 millimeters long and a few hundredths of a millimeter high (0.05 mm. at most) much light evidently must be concentrated in this rectangle, and naturally this entire flux must fall on the cell after having diverged on leaving the film. The latter condition is readily attained; the former constitutes the problem of illuminating devices for sound films.

We shall divide this paper in two parts. In Part I we shall first review briefly the various types of devices, and then examine the theoretical conditions which must be satisfied by the mode of illuminating the film in order to obtain a suitable sound performance.

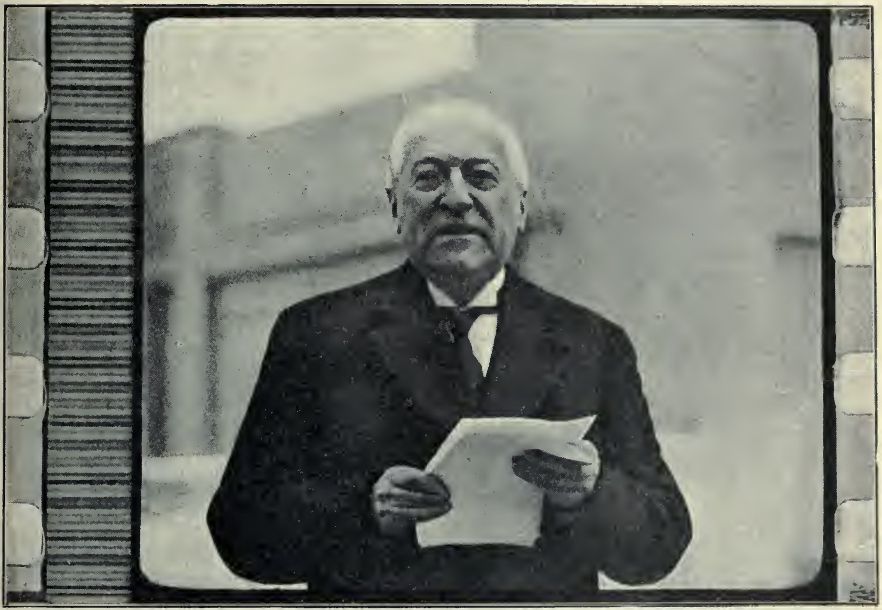

FIG. 2. Example of variable density recording.

In Part II we shall apply the results of this investigation; we shall discuss the properties of existing devices, and describe in detail the apparatus which we have devised and the results of a few tests.

PART I

THEORETICAL STUDY OF THE LIGHTING OF SOUND FILMS

2. *On the Width of the Illuminated Exploring Region.*—It is necessary in particular to know the length on the film occupied either by a period of the separating curve in the case of constant density recording, or by a period of the density in the case of variable density

recording, assuming, of course, that the recorded sound itself has a definite period. Let l be the length on the film occupied by one period and v the speed of unwinding the film. If the frequency of the sound vibration is N, we have:

$$l = \frac{v}{N} \tag{1}$$

since the film advances by l in $1/N$ second.

In general, the film speed is 45.5 centimeters per second. One

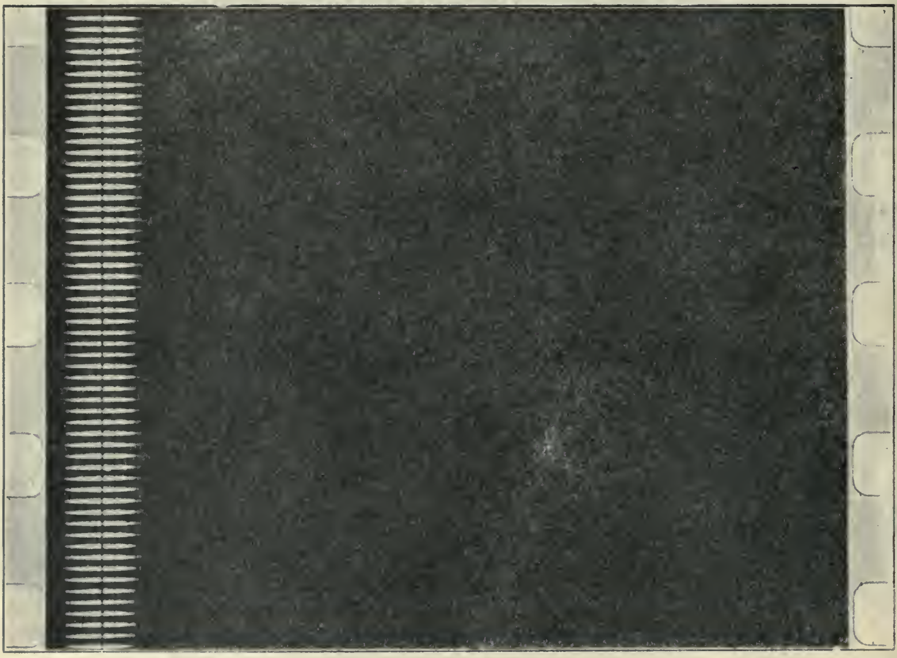

FIG. 3. Example of variable density recording; a constant frequency note.

period of la_3 or normal la, corresponding to 440 vibrations per second, thus would occupy a height of 1.03 millimeters on the film. It is necessary, however, to record much shriller sounds. First, the highest note used in music is re_7, corresponding to 4698 vibrations per second, which on the film gives a period of 0.097 millimeter. But this is far from sufficient for the correct recording of different timbres and for the timbre of the human voice. Much higher harmonics then must be attained and some hold that it will be necessary to record 20,000 vibrations per second, which on the film would correspond to a period of 0.02275 millimeter. We shall see the ratio which it is possible to allow between the period of the sound and the height of the illuminated region on the film. It is clear in any case that this height should be smaller than the period. It can be from 0.2 to 0.05 millimeter.

3. *Different Types of Lighting Apparatus.*—The majority of ap-

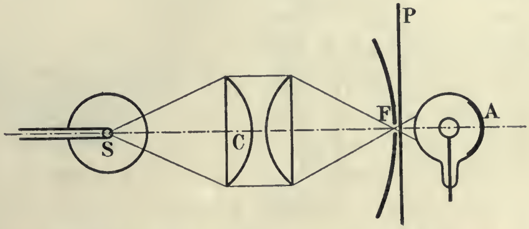

FIG. 4. One type of lighting apparatus in which the slit is placed as near as possible to the film.

paratus employed heretofore for illuminating the cell through the film involves the use of a fine slit which limits the height of the exploring zone. This slit can be used in two different ways.

In one group of devices (Fig. 4), the slit F is placed as near as possible to the film. The light supplied by an incandescent lamp, with the filament S as concentrated as possible, is projected on this slit by means of a condenser. The light which has passed

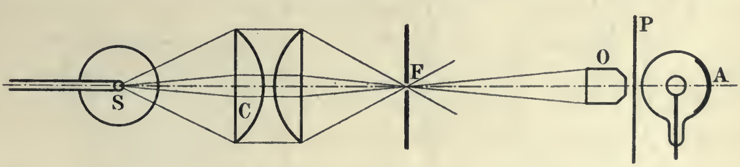

FIG. 5. Another type of lighting apparatus in which the image of the slit is projected on the film.

through the film then falls on the photoelectric cell C. Since the light rays diverge more from the window the wider the angular aperture of the beam from the condenser, thereby increasing the illumination of the slit, the illuminated region of the film will be sufficiently narrow only if the slit is very close.

In another group of devices (Fig. 5) the image of the slit is projected on the film by means of an objective O. This objective frequently is a microscope objective which produces a smaller picture on the film than the slit itself. The slit, therefore, can be comparatively wide but still all the light received by the condenser is

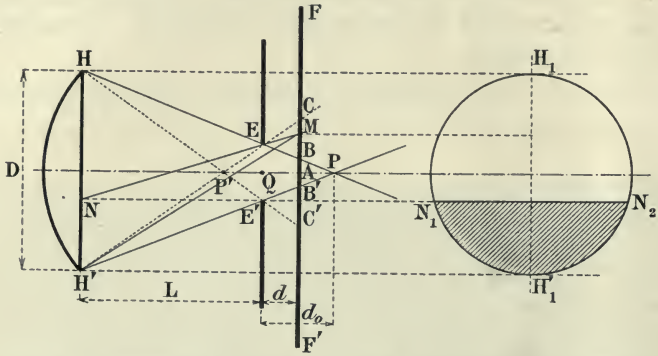

FIG. 6. Diagram for studying lighting effects on the film in the system illustrated by Fig. 4.

far from utilized. In this type of device the film is located at a distance from the back face of the microscope objective which is equal to its frontal distance, that is, a few millimeters.

In order to avoid the considerable losses of light which take place

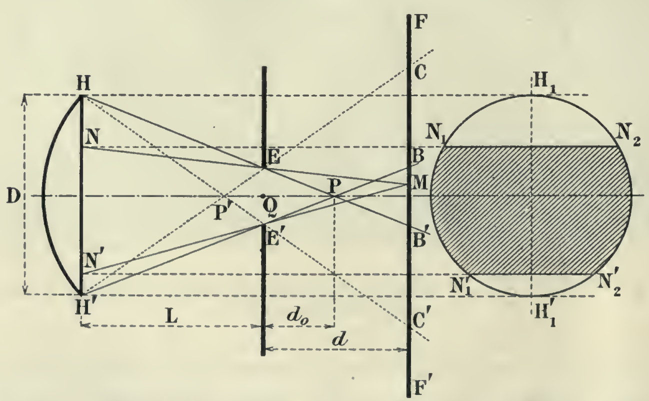

FIG. 7. Similar to Fig. 6, showing a different phase in the passage of the film past the aperture.

in these devices, the extreme nearness of the film and the slit in the former, and in a general manner the inconveniences outlined in Part II, which result from the use of a slit, devices without a slit can be used, and of these there also are two types. In one of these types a cylindrical or cylindrospherical lens is used. In the other type the reduced image of a rectilinear incandescent filament is produced on the film by means of a good objective. This solution, which is our own, then requires the construction of a special lamp.

4. Distribution of the Light on the Film.—Let EE' (Figs. 6 and 7) be the exploring zone, or more exactly, its projections on a plane through the axis of the sound band and perpendicular to the film, this plane being the plane of the figure. Whatever lighting apparatus is used, this plane also is a plane of symmetry of the illuminating beam, and the exploring zone receives light from a surface HH' which is the exit pupil of the illuminating apparatus; the luminous flux passing through a point of the exploring zone fills a cone whose peak is this point and the base this pupil. Let FF' be the film; for perfect illumination its plane should coincide with EE'. If the exploring zone consists of a slit (apparatus of the first type), the film should rub on the sides of this slit. Since this involves serious inconveniences, the film must be separated slightly from the slit as indicated in the figure. With the other illuminating apparatus the difference between the film and the exact position of the exploring zone may be due to an error in focusing.

Since this difference in a general manner is different from zero and equal to d, a point M of the film near the axis receives light from all points of HH' provided that it is inside the cone HPH' whose peak P is obtained by joining the edges of the pupil and of the exploring zone located on the same side of the axis. The fully illuminated field on the film, therefore, has the height BB'. But the film also receives a degraded illumination on the two bands, BC and $B'C'$, the points C and C' being those where the film is struck by the rays which join the edges of the pupil and those of the exploring zone located on both sides of the axis. The band CC' is the total field which we shall call the explored zone.

In order to calculate the luminous flux received by the point M of the explored zone (Fig. 6), the exploring zone is projected from point M on the plane of the pupil HH', and the common surface of the latter and the projection of the exploring zone is used. If the flux received by a point of the fully illuminated field is used as a unit, the flux received by the point M of the degraded field will be equal to the ratio between the area of the circular segment $N_1N_2H_1'$ and that of the circle H_1H_1'.

Let us assume that the film gradually is moved away from the exploring zone; the fully illuminated field BB' is reduced to zero when the film passes through point P. For this position the illumination decreases constantly from the center to the edge of the explored zone CC'. When the film is above point P (Fig. 7), the parts taken by HH' and EE' in limiting the rays are exchanged, the exploring zone now serving as outlet pupil and the surface HH' as a window. But the window surface employed decreases constantly when the point considered on the film moves away from the axis because, since the flux received by point P is used as a unit, the flux received by point M will be equal to the ratio of the circular segment $N_1N_2N_1'N_2'$ to that of the circle H_1H_1' and the area of this segment is maximum when N_1N_2 and $N_1'N_2'$ are symmetrical in regard to the center. The illumination of the explored zone decreases constantly from the center to the edge.

Let us calculate the heights h and h' of the field of uniform illumination and the explored zone. Let D be the height of the outlet pupil HH', L its distance to the exploring zone, ϵ the height of the latter, and d its distance to the film; finally d_0 is the distance QP which is important, as we shall see. Triangles which evidently are similar give (Fig. 6):

$$d_0 = \frac{L\epsilon}{D - \epsilon}$$

or since ϵ always is very small compared with D:

$$d_0 = \frac{L}{D}\epsilon \qquad (2)$$

Then

$$\frac{h}{\epsilon} = \frac{d - d_0}{d_0} \quad \text{or} \quad h = \epsilon - d\frac{D}{L}$$

or:

$$h = \epsilon\left(1 - \frac{d}{d_0}\right) \qquad (3)$$

and:

$$\frac{h'}{\epsilon} = \frac{d + QF}{QF} \qquad \frac{D}{\epsilon} = \frac{L - QF}{QF}$$

from which:

$$h' = \epsilon + d\,\frac{D}{L}$$

or:

$$h' = \epsilon\left(1 + \frac{d}{d_0}\right) \qquad (4)$$

If we should consider Fig. 7 instead of Fig. 6, we would find the same expressions for d_0 and for h'; since there is no field of uniform illumination, h cannot be considered.

It is useful to consider the values which the factor $\left(1 + \frac{d}{d_0}\right)$ may assume. We call attention to the fact that since the flux which flows through the exploring zone should be as intense as possible, the ratio $\frac{D}{L}$ should be large. If u is the opening half-angle of the beams which illuminate the exploring slit, we have:

$$\tan u = \frac{D}{2L}$$

The numerical aperture $\sin u$ of the illuminating apparatus in general should be at least 0.20 (u = 12 degrees) and with a microscope objective or a special photographic objective it may attain 0.4 (u = 24 degrees) which in the former case corresponds to $\frac{L}{D} = 2.5$ and in the latter case to $\frac{L}{D} = 1.12$; thus $\frac{L}{D}$ will be comprised approximately between 2 and 1. Consequently, according to formula (2) d_0 will be comprised between twice the height of the exploring zone and this height itself. Since this height may vary from 0.02 millimeter to 0.05 millimeter, it is clear that d_0 always will be very small, of the order of 0.02 to 0.1 millimeter. To assume that d may reach 10 times d_0, therefore, is not an inadmissible hypothesis. Moreover, we shall consider the maximum value. In any case an error in focusing which is entirely possible, amounting to 0.1 millimeter, for instance, may correspond to a value of $\frac{d}{d_0}$ of several units; and formula (4) shows that the explored zone can easily be several times greater than the exploring zone.

5. *Analysis of the Effects Produced by Enlarging the Explored Zone on the Film and by the Distribution of the Light in This Zone.*—We shall divide this analysis into two parts. We shall first examine the effect of enlarging the exploring zone, of uniform illumination, assuming that this zone is formed exactly on the film. We examine the influence of the width of the slit either when the film is in contact with the sides of it or when a perfectly focused image of a uniformly illuminated slit is formed on the film. This investi-

gation also applies to the case when apparatus without slit is used, provided that the illumination of the exploring zone is uniform. We also suppose that the exploring zone and the film do not coincide, and we shall examine the effect of the degraded illumination of the explored zone.

In both cases it is necessary to form a hypothesis of the manner in which the transparency of the film varies along its length or, which is the same, the manner in which the total luminous flux would vary, which would go through the film if it were explored by means of a zone infinitely narrow in regard to the length occupied by a period of the transparency. In the case of a variable density film this transparency is the same as that of the film. For a constant

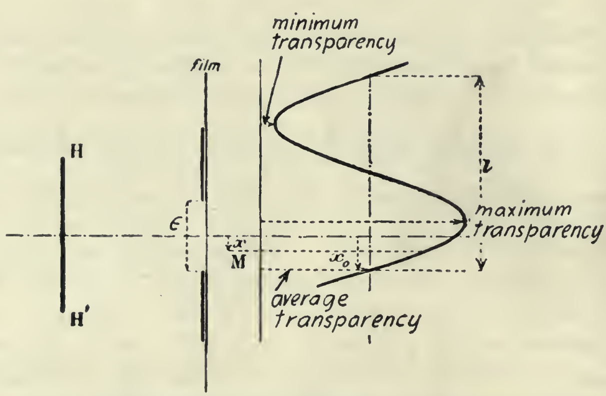

FIG. 8. Curve representing sinusoidal variation of the film transparency along its length.

density film it is defined by the ratio between the width of the part which is entirely clear and that of the opaque part. The most natural hypothesis which we can choose for the law of variation of the transparency of the film is that of a sinusoidal variation which would correspond to the perfect recording of a musical sound. In Fig. 8 the curve representing the variations of the transparency of the film along its length is plotted on the right. The abscissa x_0 of the beginning of a period in regard to the axis of the lighting apparatus defines a given position of the film. Its transparency y at a point M, with the abscissa x, of the explored zone then will be expressed by:

$$y = a + b \sin \frac{2\pi(x_0 - x)}{l} \tag{5}$$

where l as in formula (1) is the length of a period of the transparency on the film, that is, the length occupied by the recording of a complete sound vibration.

The constant b represents the half-amplitude of the variation of the opacity. It defines the amplitude or the intensity of the recorded sound. The constant a is equal to the mean value of the opacity when the film is unwound; in the photoelectric cell it corresponds to a constant current, hence is of no interest in regard to the sound.

6. *Effect of the Height of the Exploring Zone when Formed on the Film. Sound Efficiency.*—If the luminous flux which falls on the

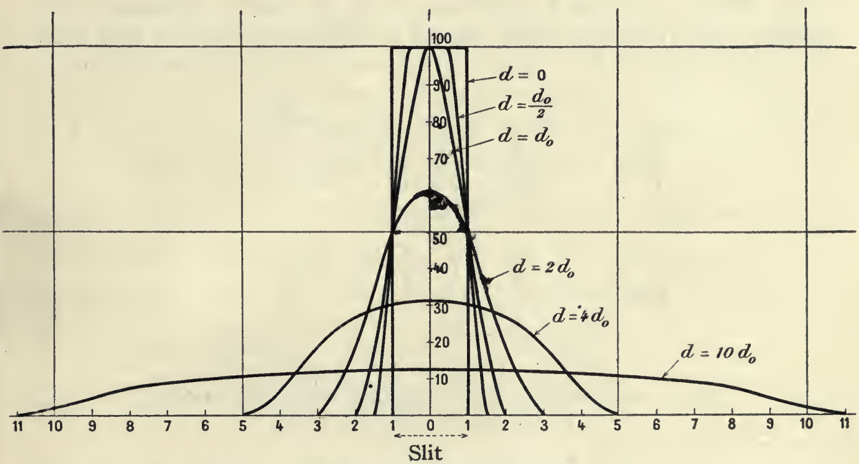

FIG. 9. Graphs of formulas (9), (10), and (11).

film is used as a unit, the flux which leaves the film through a band of the height dx centered in M in the exploring zone will be expressed by:

$$d\Phi = \left(a + b \sin \frac{2\pi (x_0 - x)}{l}\right) dx$$

The total flux which leaves the film thus will be expressed by:

$$\Phi(x_2) = \int_{-\frac{\epsilon}{2}}^{+\frac{\epsilon}{2}} \left(a + b \sin \frac{2\pi(x_0 - x)}{l}\right) dx$$

or:

$$\Phi(x_0) = a\epsilon + \frac{bl}{\pi} \sin \frac{\pi\epsilon}{l} \sin \frac{2\pi x_0}{l} \qquad (6)$$

Formula (6) shows that the leaving flux $\Phi(x_0)$ is a sinusoidal function of the abscissa x_0, of the same period l and the same phase as the transparency of the film. Whether the exploring zone is narrow or wide, the height of the sound is not changed and no harmonics will appear.

In principle, therefore, it is not absolutely necessary to employ an extremely fine exploring zone to plot a band on which musical sounds are recorded, even very shrill ones, provided that they are sinusoidal. But, as we shall see, the intensity of the sound produced decreases rapidly when the width of the exploring zone increases and approximates the period of the transparency on the film. In other words, the sound performance of the latter decreases very rapidly. If a non-sinusoidal sound is concerned, having high harmonics, the timbre will be deformed, the more so according as the width of the exploring zone increases, because the harmonics will be the more reduced the higher they are.

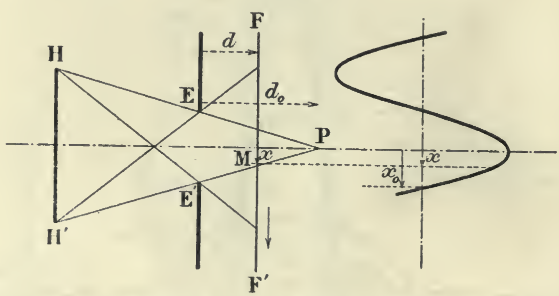

FIG. 10. Diagram for evaluating total flux passing through the film in a given position, x_0.

In reality, according to formula (6) the amplitude A of the variation of the emerging flux will be expressed by:

$$A = \frac{2 \cdot bl}{\pi} \sin \frac{\pi\epsilon}{l}$$

or

$$A = 2b\epsilon \frac{l}{\pi\epsilon} \sin \frac{\pi\epsilon}{l} \tag{7}$$

If we assume that the ratio, $\frac{\epsilon}{l}$, of the width of the exploring zone to the period of the transparency decreases toward zero, it is clear that the variations of the flux increase toward a maximum A_0 corresponding to an ideally fine exploration of the band; we have

$$A_2 = 2b\epsilon$$

The sound efficiency m of the exploring apparatus of the film can be defined by the expression:

$$m = \frac{A}{A_0} = \frac{l}{\pi\epsilon} \sin \frac{\pi\epsilon}{l} \tag{8}$$

The curve $\frac{d}{d_0} = 0$ of Fig. 11 represents the sound efficiency plotted as ordinates as a function of the ratio $\frac{\epsilon}{l}$ plotted as abscissae. It is clear that the efficiency still is 90 per cent when the width of the exploring zone is equal to one-quarter period. It is only 30 per cent when the width of the exploring zone is three-quarters of a period.

In order to calculate the frequency which is reproduced with a given efficiency, it is sufficient to eliminate N from formula (1) in which l is substituted by the value which gives to $\frac{\epsilon}{l}$ the value indicated for the efficiency by the curve in Fig. 11. Thus, with an exploring zone of 0.02 mm. the frequency obtained with an efficiency of 90 per cent will be $\left(\frac{\epsilon}{l} = \frac{1}{4}, \text{ hence } l = 4 \cdot 0.02\right)$:

$$N = \frac{455}{4 \cdot 0.02} = 5690$$

a frequency which is slightly higher than that of re_7 of a piccolo. The efficiency corresponding to this note will be exactly 94 per cent $\left(\frac{\epsilon}{l} = \frac{0.02}{0.097} = 0.206\right)$.

Another example: the frequency corresponding to an efficiency of 25 per cent will be:

$$N = \frac{455 \cdot 0.785}{0.02} = 17{,}880$$

$\left(\text{from which: } \frac{\epsilon}{l} = 0.785 \text{ and consequently } l = \frac{0.02}{0.785}\right)$.

The frequency 20,000 $\left(\frac{\epsilon}{l} = \frac{0.02}{0.02275} = 0.88\right)$ will be reproduced only with an efficiency of 13 per cent.

We note that probably a much higher sound quality could be obtained in regard to the reproduction of the voice and of timbres if the width of the exploring zone dropped to 0.01 millimeter. The frequency 20,000 then would be reproduced with an efficiency of 70 per cent. This is due to the very rapid decline of the efficiency

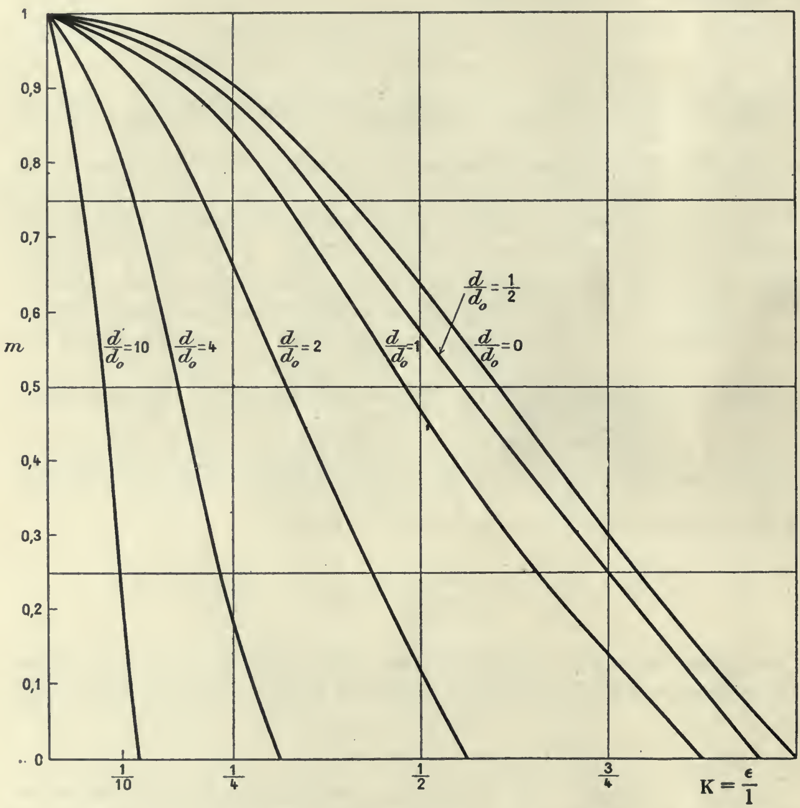

FIG. 11. Curves showing the sound efficiency m as a function of $K = \epsilon/l$ for various values of d/d_0.

indicated by the form of the curve when the width of the exploring zone exceeds one-quarter of the period of the transparency on the film.

7. *Effect of an Error in Focusing or of a Reduced Explored Zone.*—We refer to Figs. 6 and 7 for the investigation of this problem, The calculation of the luminous flux leaving the film, for a given posi-

tion of the latter, presupposes that the distribution of the incident flux is known. In order to calculate the flux which falls in a point M of the abscissa x in regard to the axis of the illuminating apparatus, we project, as mentioned above, the exploring zone on the plane of the outlet pupil HH' of the illuminating apparatus, and we consider the common surface of this projection and this pupil. Let S be this surface, which has been shaded in Figs. 6 and 7. Since the flux illuminating the fully illuminated zone is used as a unit, the flux illuminating the point M will be equal to the ratio between this common surface S and the surface πR^2 of the pupil:

$$\Phi_i(x) = \frac{S}{\pi R^2}$$

Calculation by integration of the surface S leads to the following results:

In the case of Fig. 6 ($d < d_0$) we have in the fully illuminated field:

$$\frac{S}{\pi R^2} = 1$$

and in the reduced part of the explored zone, that is, for:

$$1 - \frac{d}{d_0} < \frac{2x}{\epsilon} < 1 + \frac{d}{d_0}$$

$$\frac{S}{\pi R^2} = \frac{1}{2} + \text{arc sin}\,\frac{d_0}{d}\left(1 - \frac{2x}{\epsilon}\right) + \frac{d_0}{d}\left(1 - \frac{2x}{\epsilon}\right)\sqrt{1 - \frac{d_0^2}{d^2}\left(1 - \frac{2x}{\epsilon}\right)^2} \qquad (9)$$

In the case of Fig. 7 ($d > d_0$) we obtain two different expressions for S according as the projection of the exploring zone goes through only the outlet pupil or projects beyond it. In the former case we obtain:

$$\frac{S}{\pi R^2} = \frac{1}{\pi}\,\text{arc sin}\,\frac{d_0}{d}\left(1 - \frac{2x}{\epsilon}\right) + \frac{1}{\pi}\,\text{arc sin}\,\frac{d_0}{d}\left(1 + \frac{2x}{\epsilon} +\right) + \frac{1}{\pi}\frac{d_0}{d}\left(1 - \frac{2x}{\epsilon}\right)\sqrt{1 - \frac{d_0^2}{d^2}\left(1 - \frac{2x}{\epsilon}\right)^2} + \frac{1}{\pi}\frac{d_0}{d}\left(1 + \frac{2x}{\epsilon}\right)\sqrt{1 + \frac{d_0^2}{d^2}\left(1 + \frac{2x}{\epsilon}\right)^2} \qquad (10)$$

with:

$$\frac{2x}{\epsilon} < \frac{d}{d_0} - 1$$

and in the latter case:

$$\frac{S}{\pi R^2} = \frac{1}{\pi} \operatorname{arc\,cos} \frac{d_0}{d} \left(\frac{2x}{\epsilon} - 1\right)$$
$$- \frac{1}{\pi} \frac{d_0}{d} \left(\frac{2x}{\epsilon} - 1\right) \sqrt{1 - \frac{d_0^2}{d_0} \left(\frac{2x}{\epsilon} - 1\right)^2} \qquad (11)$$

with:

$$\frac{d_0}{d} - 1 < \frac{2x}{\epsilon} < \frac{d_0}{d} + 1$$

The formulas (9), (10), and (11) essentially assume that x is positive. It is clear that the incident flux $\Phi_i(x)$ is the same for two symmetrical points in regard to the axis. For negative x, therefore, x should be replaced by $-x$ in the second terms of the formulas (9), (10), and (11).

These formulas have been translated into curves (Fig. 9) for different values of $\frac{d}{d_0}$.

On the other hand, the transparency of the film as above is assumed to be expressed by the second term of formula (5) at point M of the film (Fig. 10). The luminous flux passing through the film in M through a band of the height dx is:

$$\Phi_i(x) \left(a + b \sin \frac{2\pi(x_0 - x)}{l}\right) dx$$

The total flux flowing through the film which is placed in a given position, that is, for a given value of x_0, will be obtained by integrating this expression from one limit to the other of the total field or explored zone which has the height h'. (See §4.) We have, therefore:

$$\Phi_e(x_0) = \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \Phi_i(x) \left(a + b \sin \frac{2\pi(x_0 - x)}{l}\right) dx \qquad (12)$$

Like the transparency of the film this function of x_0 has the period l. This is evident physically; this also is due to the fact that if x_0 increases from l, the function under the sign of integration does not change and that both limits of integration increase from l. The emerging flux $\Phi_e(x_0)$ also goes through a maximum for $x_0 = \frac{l}{4}$ and through a minimum for $x_0 = \frac{3l}{4}$; we have in reality:

$$\frac{d\Phi_e}{dx_0} = \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \frac{2\pi b}{l} \Phi_i(x) \cos \frac{2\pi(x_0 - x)}{l} \cdot dx$$

For $x_0 = \frac{l}{4}$ we have:

$$\frac{d\Phi_e}{dx_0} = \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \frac{2\pi b}{l} \Phi_i(x) \sin \frac{2\pi x}{l} dx$$

and since $\Phi_i(x)$ assumes equal values for equal values of x and opposite signs, it is clear that the preceding integral is zero. The same holds for $x_0 = \frac{3l}{4}$. The emerging flux $\Phi_e(x_0)$, therefore, has maxima and minima in the moments when the axis of the illuminating apparatus goes through the film in a region of maximum or minimum transparency. Finally, this flux oscillates around the same mean value no matter what the extent of the explored zone may be. If, therefore, we put $x_0 = 0$, we have:

$$\Phi_e(0) = \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \Phi_i(x) \left(a - b \sin \frac{2\pi x}{l}\right) dx = a \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \Phi_i(a)dx$$

The last integral represents the total flux illuminating the explored zone which is assumed to be constant and equal to 1 for any surface of this zone.

Since the curves represent the variations of the flux which has passed through the film, as a function of x_0, that is, of the position of the film and for every value of $\frac{d}{d_0}$, they are undulating curves of the same period and the same phase as the transparency of the film (with one exception which will be examined below), all having the same average ordinate. These curves naturally are a function of the coefficients a and b, but the value of the efficiency of the illuminating apparatus defined as above is not. In reality the amplitude A of the variations of the flux, according to what has been said, is equal to the difference between the values of $\Phi_e(x_0)$ for $x_0 = \frac{l}{4}$ and $x_0 = \frac{3l}{4}$. Hence:

$$A = 2b \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \Phi_i(x) \cos \frac{2\pi x}{l}\, dx \qquad (13)$$

If the explored zone having the height h' were infinitely narrow in regard to the period l (perfect exploration of the film), the amplitude of the variations of the flux would be as we have seen in the preceding paragraph:

$$A_0 = 2b\epsilon \qquad (14)$$

The efficiency m, therefore, will be expressed by:

$$m = \frac{1}{\epsilon} \int_{-\frac{h'}{2}}^{+\frac{h'}{2}} \Phi_i(x) \cos \frac{2\pi x}{l}\, dx \qquad (15)$$

with

$$h' = \epsilon\left(1 + \frac{d}{d_0}\right)$$

If we consider the formulas (9), (10), and (11), we find that $\Phi_i(x)$ really is a function of $\frac{2x}{\epsilon}$. If we write, therefore,

$$\frac{2x}{\epsilon} = X \quad K = \frac{\epsilon}{l} \qquad (16)$$

we get:

$$m = \int_0^{1 + \frac{d}{d_0}} \Phi_i(X) \cos K\pi X \cdot dX \qquad (17)$$

a formula which is independent of the coefficients a and b which enter into the law of variation of the transparency.

In order to calculate the efficiency according to formula (17), a value of K first must be chosen. Choosing a given value of $\frac{d}{d_0}$ we calculate for a sufficient number of values of X the ordinates of the curve $\Phi_i(X)$ corresponding to this value of $\frac{d}{d_0}$; we use the formulas (9), (10), and (11), bearing in mind that when there is a fully illuminated field $\Phi_i(X) = 1$ in this field. Thus the curves of Fig. 10 are plotted. The ordinates of these curves are multiplied by $\cos K\pi X$ and the curve $\Phi_i(X) \cos K\pi X$ is plotted. Then only the area which it defines above the axis of X remains to be measured.

The curves shown in Fig. 11 which represent the efficiency m as a function of K have been constructed in this way, each one being plotted for a given value of $\frac{d}{d_0}$. The uppermost curve corresponds to a perfect focusing ($d = 0$). We have already examined it in the preceding paragraph.

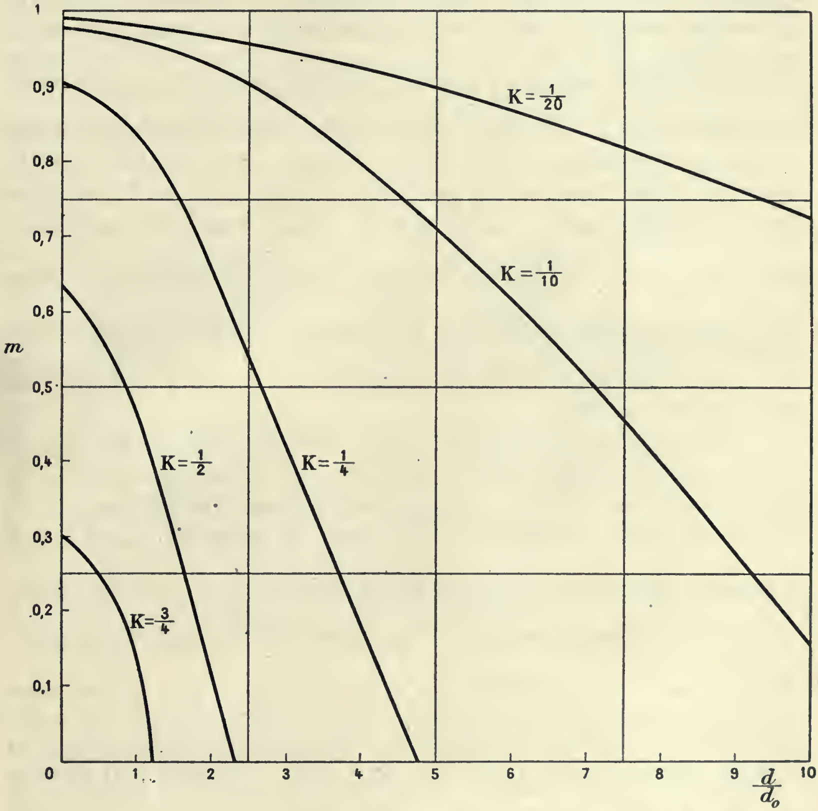

FIG. 12. Curves derived from those of Fig. 11, showing the variation of the efficiency with the focusing, *i. e.*, with d/d_0 the ratio K remaining constant.

The curves shown in Fig. 12, which are derived from those in Fig. 11, indicate how the efficiency varies when the focusing is varied, that is, $\frac{d_0}{d}$, the ratio K remaining constant as for a given illuminating apparatus and a given film.

It appears from the curves in Figs. 11 and 12 that the poorer the focusing is $\left(\text{large value of } \frac{d}{d_0}\right)$, the more rapidly the efficiency decreases when the ratio between the width of the exploring zone and the period of the transparency decreases.

The analysis of these curves clearly demonstrates the great importance of the focusing. Let us assume, for instance, that the note recorded on the film is *re*$_7$ (4698 vibrations) and that the width of the exploring zone is a quarter period, $K = \frac{1}{4}$ ($l = 0.097$ mm., $\epsilon = 0.024$ mm.). We have seen already that for perfect focusing the sound performance will be 90 per cent. If we assume that the aperture of the illuminating pencil is 60 degrees ($D = L$), we have $d_0 = \epsilon = 0.024$ mm. An error in focusing of only 0.1 millimeter will give $\frac{d}{d_0} = 4$. The curve in Fig. 11 corresponding to this value of $\frac{d}{d_0}$ shows for the abscissa $K = \frac{1}{4}$ that the sound efficiency drops to 17 per cent, that is, less than one-fifth of the value which it had with perfect focusing.

8. Remarks on the Case when the Explored Zone Covers Several Periods of the Transparency.—Each one of the curves in Figs. 11 and 12 is limited to an arc comprised between the efficiency limit 1 and the efficiency zero. They could be extended beyond this. According to formula (17) for a given value of $\frac{d}{d_0}$, m starting from 1 for $K = 0$ decreases when K increases and reaches the value 0. For $\frac{d}{d_0} = 4$, for instance, we have $m = 0$ for $\frac{\epsilon}{l} = 0.31$. If $\frac{\epsilon}{l}$ increases still more, m becomes negative. This is not surprising when we consider the formulas (13), (14), and (15). Formula (13) particularly shows that if $\frac{\epsilon}{l}$ or K exceeds the first value for which the amplitude A is zero, the sign of the latter changes, that is to say, the emerging luminous flux still has maxima and minima but in phase opposition with the transparency of the film at the point where it meets the optical axis. The efficiency then is equal to the absolute value of m. When $\frac{\epsilon}{l}$ continues to increase, this absolute value goes through a maximum, returns to zero, then again assumes positive values and so on.

It is clear that the successive maxima always are decreasing. Let us assume that $d = 0$ (exploring zone on the film), for example. The efficiency m decreases from 1 to zero when $\frac{\epsilon}{l}$ increases from 0 to 1. If the exploring zone is further enlarged, the emerging flux begins to fluctuate again; their amplitude will be maximum when the exploring zone covers $1^1/_2$ period on the film; the emerging flux will be maximum when the optical axis goes through the film in a minimum of transparency as shown in Fig. 13(a); it will be minimum

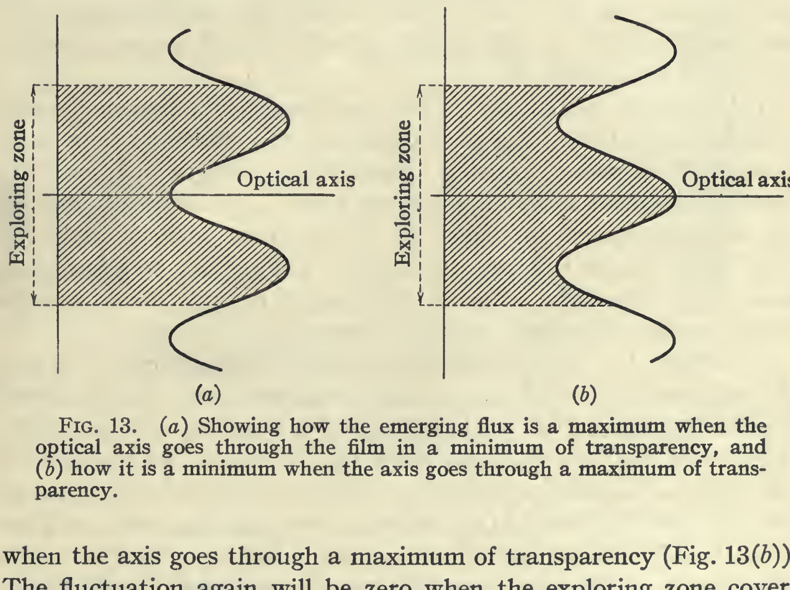

FIG. 13. (a) Showing how the emerging flux is a maximum when the optical axis goes through the film in a minimum of transparency, and (b) how it is a minimum when the axis goes through a maximum of transparency.

when the axis goes through a maximum of transparency (Fig. 13(b)). The fluctuation again will be zero when the exploring zone covers two periods of transparency; then if the exploring zone is further enlarged, other fluctuations will result with a maximum when it covers an odd number of half-periods and again become zero when it covers a whole number of periods. It is also clear that the difference between the maximum and the minimum of the flux, that is, the amplitude of the fluctuations, will decrease when the number of periods of the transparency simultaneously involved increases.

Consequently an adjustment of the focusing and the width of the exploring zone, which produces an efficiency equal to zero for a given frequency, will produce an efficiency which differs from zero for higher frequencies. In the case of perfect focusing, for instance, the efficiency according to formula (8) will have maxima for:

$$\frac{\epsilon}{l} = \frac{3}{2}, \frac{5}{2}, \frac{7}{2} \cdots \frac{2n+1}{2}, \cdots$$

and the values of the efficiency will be, respectively:

$$\frac{2}{3\pi} = 0.21, \frac{2}{5\pi} = 0.13, \frac{2}{7\pi} = 0.09, \frac{2}{9\pi} = 0.07, \ldots$$

The corresponding frequencies will be given by formula (1) when ϵ has been chosen. An exploring zone of 0.1 millimeter would give, for instance: for N = 4550, 9100, 13,650, *etc.*, an efficiency = 0; and for N = 6830, 11,390, 15,900, 20,450, *etc.*, efficiencies equal to 21, 13, 9, 7 per cent, *etc.*

This example clearly shows the disturbance or unbalance which a slightly wide exploring zone can produce in a symphonic reproduction even with perfect focusing. Such disturbances are inadmissible. For this reason we have in paragraphs 6 and 7 systematically limited the investigation of the efficiency to the range between its maximum limit and its first zero minimum. The remark, which we just have made, should be borne in mind and it no doubt could explain certain sound distortions actually observed.

9. *Effect of a Lack of Uniformity in the Illumination of the Exploring Zone.*—Heretofore we have assumed that the luminous flux flowing through the exploring zone was the same at every point. With some methods of illumination this is not so: for example, if the image of a spiral incandescent filament with the turns spaced too far apart is formed in the plane of the exploring zone, or if an error in centering the optical parts causes a lack of symmetry in the illumination of this zone, or if this zone is the image of a slit whose edges are not parallel or if this slit is partially closed.

This lack of uniformity presents the greatest inconveniencies for constant density films. If we assume, to consider the extreme case, that only a part of the width of the sound band (Fig. 14) is swept by the exploring zone, it is clear that only the peaks corresponding to the most intense vibrations produce fluctuations in the flux transmitted through the film and that the resulting sound will only be remotely related to the recorded sound. Without going to this extreme, it is clear that any lack of uniformity in the illumination of the exploring zone will favor certain parts of the recording curve and consequently certain sounds at the expense of others. A more or less strong sound distortion will take place.

On the other hand, this lack of uniformity has no importance for variable density films since the transparency of the film is the same on its entire width. Then only a difference in height between the ends of the exploring zone is detrimental (edges of slit not parallel), but less, of course, than if this zone had the height of the widest end on the entire width of the band.

For an equal height of the exploring zone the variable density films, therefore, are much less sensitive to the imperfections of the illuminating apparatus than the constant density films.

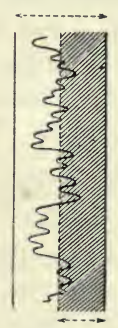

FIG. 14. Illustrating the case where only part of the sound band is swept by the exploring zone, due to ununiform illumination of the zone.

10. Résumé of Part I.—The essential points of the analysis which we have outlined above are summed up in the formulas (1), (2), (3), (4), (8), (9), (10), (11), (16), and (17). We have introduced the important idea of the sound efficiency of an illuminating device connected to a film which is supposed to be perfect, in the same way as all the devices which actually transform the fluctuations of the luminous flux passing through the film into sound vibrations are supposed to be perfect. The variations of the sound efficiency as a function of (1) the ratio between the width of the exploring luminous zone and the period of the transparency on the film and (2) the focusing, are represented by the curves in Figs. 11 and 12 which allow of determining primarily the efficiency under any given practical circumstance. Not only do they admit of calculating this efficiency for a pure sound (sinusoidal) of a given period but in the case of a fundamental sound accompanied by various harmonics they also admit of calculating the ratios in which these diverse composing vibrations will be reproduced. Thus they completely solve the problem of the sound distortion produced by a given illuminating apparatus.

These curves particularly demonstrate how rapidly the efficiency decreases as a result of an error in focusing or the widening of the exploring zone. We shall apply the results of Part I of our paper to the investigation of different types of lighting apparatus.

PART II

DIFFERENT LIGHTING APPARATUS

In section 3 of Part I we enumerated succinctly the different types of lighting apparatus in order to base the theoretical investigation of the lighting of sound films on sufficient concrete data. In Part II we shall not describe them in detail but study their operation.

11. Apparatus with Slit near the Film.—The simplest method of powerfully illuminating a very narrow zone of the sound band evidently is to place the film on the sides of a very fine slit and illuminate the latter strongly. To produce this illumination a source could be provided, so extensive, or placed so near the slit, that the angle under which the center of the latter is seen would be very great. If the source itself is very brilliant, it is clear that a more intense illumination is obtained in this manner than with any optical system. The apparatus at the same time would be extremely simple.

The available sources of great brilliancy, however, have a high temperature and cannot be placed sufficiently near the film. A condenser (Fig. 4) must be used which concentrates the light on the slit in forming a more or less good image of the source on the slit. If this image were perfect and the condenser did not absorb light, each of the surface elements of the image would have a brilliancy equal to that of the conjugate surface element of the source. In reality the reflection on the glasses of the condenser, the absorption of light by the latter, and the aberrations of this apparatus, which in general are considerable, materially reduce the effective brilliancy of the image formed on the slit. On the other hand, when the source is a spiral filament, as usually is the case, the aberrations have the effect of making the illumination of the slit uniform, a fact which is valuable for a constant density film. (See §9.)

The very serious disadvantage of these devices is that if the film rubs even very slightly on the edges of the slit, it is rapidly scratched and, besides, the slit soon is closed by dust. This dust cannot be avoided even if the sides of the slit are polished mirror-like and curved inward so as to touch the film only at points separated somewhat more than the width of the slit. Irregularly accumulated, it also can be carried along suddenly; thus it causes sudden variations of the luminous flux illuminating the film and hence inadmissible interfering noises.

In order to avoid them, a small space could be left between the slit and the film. A considerable decrease of the sound efficiency would result, however. In reality, we noted in §4 that the critical distance d_0 is the of same order as the width of the slit if the angular opening of the pencil which illuminates it is slightly large, as is necessary (24 degrees at least). If quite high frequencies are to be explored when the film is illuminated with sufficient intensity, d_0 never will be far from 0.02 to 0.05 millimeter. If the film does not touch the sides of the slit, the air current which it produces near its surface and its electrification carry along atmospheric dust particles which also adhere to the edges of the slit unless the space between the latter and the film is sufficiently large. We consider a space d of 0.1 millimeter as a minimum. The ratio $\frac{d}{d_0}$, therefore, will be comprised between 5 and 2. If $\frac{d}{d_0} = 4$, for instance, the efficiency, which is equal to 80 per cent when the height of the slit is 0.1 per cent of the period of the transparency of the film, drops to 17 per cent when the height of the slit reaches one-quarter of a period, and to 0 when $\frac{\epsilon}{l} = 0.32$. That is to say, with a slit of 0.025 millimeter, a space $d = 0.1$ millimeter, an angular opening of the illuminating pencil of 45 degrees ($d_0 = 0.025$ mm.), the efficiency is 80 per cent for a frequency of 1820 (approximately la_5 sharp), drops to 17 per cent for a frequency of 4550 (approximately sharp do_7) and to 0 for a frequency of 5820.

The dust could be avoided entirely by leaving only a space of less than 0.1 millimeter between the film and the slit but this makes the slit somewhat complicated. It could be covered with a film. In order that neither be scratched no other material than glass should be chosen. Thus a thin glass plate is attached to the sides of the slit by means of a suitable adhesive (Canada balsam, for instance); then the external face of this plate is ground by processes ordinarily used by opticians in order to reduce its thickness as much as possible. We do not know whether the system has been employed effectively for illuminating films during reproduction, but an entirely similar device is used particularly by the Fox Movietone for the sound recording of the film. The distance between the slit and the film thus can be reduced to a few microns.

12. Apparatus with Projected Slit.—In this type of apparatus an image of the slit is formed on the film by means of an objective (in general, a microscope objective). Since this image is smaller than the slit, the latter may be wider. Being separated from the film by the objective it can be placed in a closed space. For these two reasons dust is much less to be feared. The slit is illuminated by means of a lamp with a spiral filament, of the automobile head-

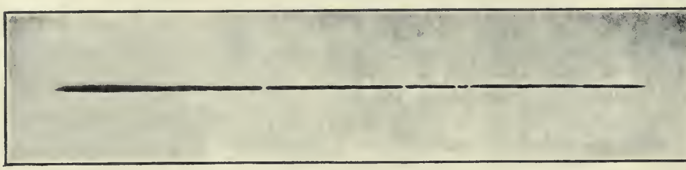

FIG. 15. A reproduction, enlarged approximately 14 times, of the image formed on the film in a high-grade apparatus with a slit which had been used only a short time. Note the breaks in the image caused by dust in the slit.

light type, with a condenser interposed. Let us analyze more closely the conditions of construction which obtain for this type of apparatus.

First, the necessary ratio between the length of the image (or exploring zone) and its width requires a very fine slit. It must not be forgotten that the width of the sound band is three millimeters and that the height (or width) of the exploring be approximately 0.02 to 0.05 millimeter, the latter dimension, moreover, being too large and acceptable only as a makeshift. Hence

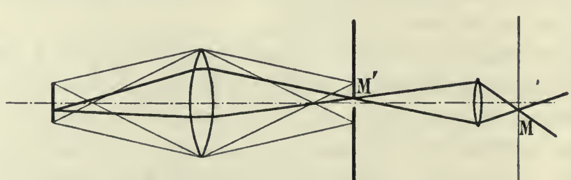

FIG. 16. One means of lighting the slit consists in forming an image of the filament on the slit by means of a condenser.

the slit itself should be from 100 to 150 times longer than it is wide. A slit of 0.5 millimeter should be from 50 to 75 millimeters long, which is difficult to employ owing to the space required and the difficulty of illuminating it sufficiently. In reality we have to use slits which are 0.1 millimeter wide and consequently 10 to 15 millimeters long.

Experiments show that dust from the air very easily clings to the edges of a slit 0.1 millimeter wide. Fig. 15 is the reproduction, enlarged approximately 14 times, of the image formed on the film in a high-grade apparatus with slit which has been in use only a little as yet. We note, however, that this image is cut six times by dust which has fallen on the slit. The latter was 12.5 millimeters long and 0.1 millimeter wide; a microscope objective formed an image of it 4.6 times smaller. The exploring zone thus was 0.022 millimeter wide. In order to obtain the photograph reproduced in Fig. 15 this image is retaken by means of a photographic objective.

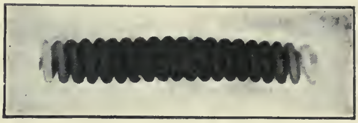

FIG. 17. Photograph of a coiled filament lamp, showing variations of brightness between turns.

In Fig. 15 we also find that the illumination of the image is little uniform from one end to the other. The centering had been particularly careful, however. The slightest lack of adjustment increases this lack of symmetry materially, which depends on the manner in which the slit is illuminated.

Among the methods of lighting the slit, two should be particularly considered. One consists in forming an image of the incandescent filament on the slit by means of the condenser (Fig. 16). The other (Fig. 18) consists in forming the image of the filament on the inlet pupil of the microscope objective; in the very same manner as when the image of a slide is to be projected on a screen, the image of the source of light is formed on the projection objective by placing the slide very close to the condenser.

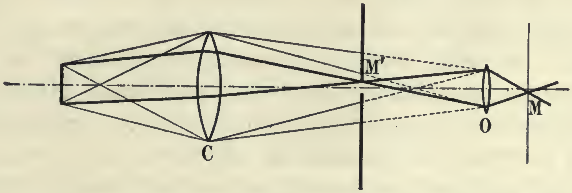

FIG. 18. Another method of illuminating the slit consists in forming the image of the filament on the inlet pupil of the microscope objective.

In the former case the illuminated part of the film is the image of the part of the conjugate source of light of the slit in regard to the condenser. The illumination of the exploring zone, therefore, is uniform only if the brilliancy of the source is uniform within this part of the source. This is not so when it consists of a helical filament even when the turns are so close that the images of the back half-turns are formed between those of the front half-turns because the temperature of the internal surfaces of the turns is higher than the temperature of their external surfaces. This is illustrated in Fig. 17 which reproduces the photograph of the filament of the lamp (automobile headlight type) used in the apparatus with slit to which Fig. 15 refers also.

On the other hand, in the case when the image of the source is formed through the slit on the microscope objective, the illumination of the exploring zone, image of the slit, is perfectly uniform. In reality, each point M of the exploring zone is illuminated by the continuous flux in a cone whose peak is the conjugate point M' of M on the slit and the base on the objective O is the part of the image of the filament limited by this objective (or more accurately, by its inlet pupil).

Evidently the former method of illumination is inadequate for illuminating a constant density film since for a film of this type the illumination of the exploring zone should be uniform (§9). This condition is not important for a variable density film. Nevertheless, the latter method of adjustment in general is used even for these films. In order that the total flux which falls on the film then can be as great as with the former method of adjustment, the microscope (or more generally projection) objective must be covered entirely by the image of the filament which the condenser produces.

In order to calculate it we shall neglect the losses of light due to absorption, reflection, and diffusion through the lenses and indicate the brilliancy of the source by B. In the first mode of adjustment (Fig. 16) the flux falling on the film is expressed by:

$$\Phi_1 = B \cdot k_1 S \cdot \frac{\Sigma}{q^2} \tag{18}$$

where k_1S is the surface of the part of the image of the source within the slit, with surface S, Σ the surface of the entrance pupil of the objective O, and q the distance from the slit to this objective. In the second mode of adjustment (Fig. 18) the expression of the flux falling on the film is:

$$\Phi_2 = \mathrm{B} \cdot \mathrm{S} \cdot \frac{k_2 \Sigma}{q^2} \tag{19}$$

when k_2S is the part of the surface of the objective covered by the image of the source which is formed on it by the condenser. The problem then is to know whether k_1 is larger or smaller than k_2. If the turns of the filament are sufficiently close so that the image of the back half-turns is projected between the images of the front half-turns, the slit is covered completely and we have $k_1 = 1$. The flux Φ_2, therefore, cannot be greater than the flux Φ_1 but it can be equal to it if $k_2 = 1$, that is to say, if the entrance pupil of the projection objective is completely covered by the image of the filament formed by the condenser.

Nevertheless, much light is lost with both methods. In the former method all the light is lost which forms the part of the image of the filament outside the slit and all the light which, after having passed through the slit, does not reach the objective O, the angular aperture of the condenser in general being larger than that of the projection objective. In the latter method of adjustment all the light is lost which does not go through the slit and, besides, all the light which, having passed through the slit, will pass through the points of the image of the filament located outside the entrance pupil of the projection objective.

From the above it results that the devices with projected slit always utilize only a small portion of the light projected by the source on the condenser and that their efficiency is low. Numerical data bearing on this subject will be given later on.

13. Apparatus without Slit, with Cylindrical or Cylindrospherical Lenses.—In order to avoid the disadvantage of dust on the slit, a disadvantage which the devices with projected slit do not avoid completely as we have just observed, and the losses of light involved in these devices, two solutions have been proposed. The first one is the solution which we have adopted and with which we shall conclude this article. But, first, we shall describe briefly the other solution which is based on the use of cylindrical or cylindrospherical lenses.

It is well known that the luminous rays sent from a point located on the axis of such a lens, after having passed through it, strike two perpendicular focal lines, one of which is parallel to the generators of the cylinder. A spiral filament whose axis is parallel to the generators also concentrates the light on two luminous bands, of which the one which is nearest the lens, and consequently is the narrowest, also is parallel to the generators. This small luminous band may replace the slit, and a projection objective (in general, a microscope objective) forms an image of it on the film.

Since the rays issued from every point of the source outside the plane of the principal section which is perpendicular to the generators and the plane of the principal section parallel to the latter pass through different points of the focal distance, the distribution of the flux in the small luminous band furnished by the cylindrospherical condenser is independent of the distribution of the intensity in the source and very uniform on the entire useful length of this band. This fact as well as the elimination of dust makes the device very attractive for constant density films.

Its disadvantage seems to be the difficulty of obtaining a sufficiently fine exploring zone for reproducing high frequencies with a sufficiently intense useful flux. If the small luminous band produced by the cylindrospherical condenser at the slit of the apparatus with the projected slit examined above is substituted, we note that this band should be 12.5 millimeters long and only 0.1 millimeter wide on the entire length. It seems difficult to obtain such an image with a spiral filament, which always would have a diameter of 2 to 3 millimeters at least, and with beams which should have a numerical aperture of at least 0.2. If it is possible to correct the aberrations in the plane of the principal section which is perpendicular to the generators in such a way that the image furnished by the rays comprised in this plane would be only 0.1 millimeter wide, it seems improbable that the rays which are not comprised in this plane and are oblique to the generators could be regulated with the same precision.

14. Apparatus without Slit, with Rectilinear Filament Lamp.—There is an extremely simple means of avoiding the dust, the losses of light on the sides of the slits, the aberrations of the cylindrical lenses, and the lack of uniformity of the brilliancy on the spiral filaments. It consists in constructing the lighting apparatus with a lamp which has only one filament set up rectilinearly and forming a reduced image of this filament on the film. If the filament is very fine and the aberrations of the optical system which forms its image are well corrected, it is clear that the exploring zone will be as fine as the separating power of the objective employed will permit. There is nothing to prevent it from being reduced to the width of the finest details which can be detected by a microscope, that is, less than 1 micron. According to §6 such a fine exploring zone

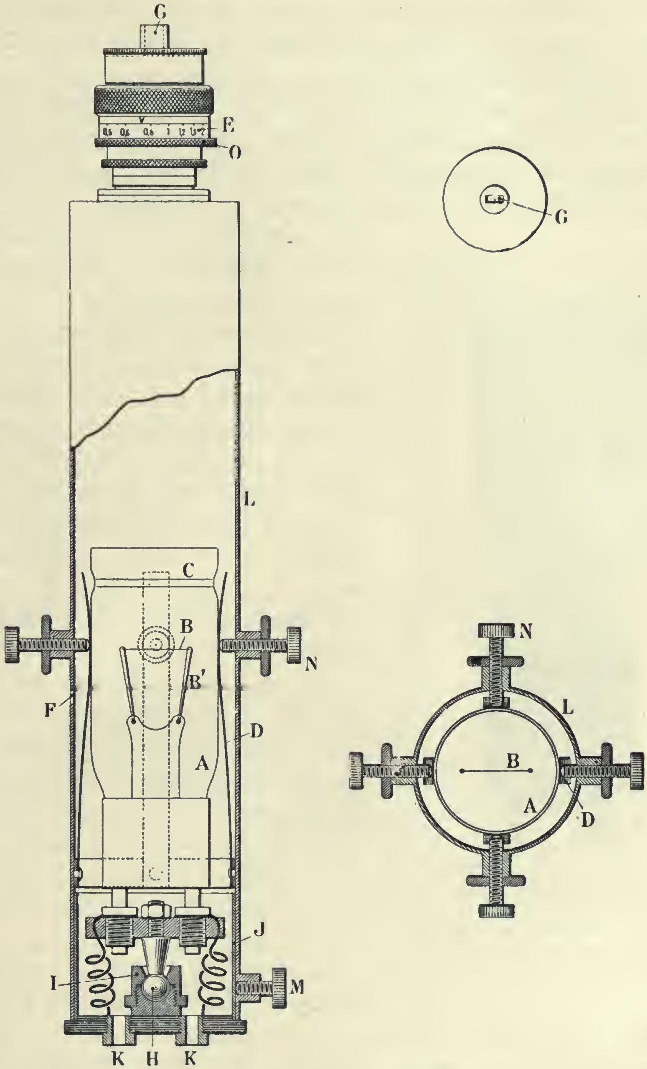

FIG. 19. Lighting apparatus with rectilinear filament for sound films. *A*, lamp; *B*, rectilinear filament; *C*, closing mirror soldered into the wall of the lamp; *D*, elastic plate used for guiding the lamp when introduced in the apparatus; *E*, objective; *F*, ventilation hole; *G*, window for letting out the luminous pencil, eliminating interfering reflections; *H*, swivel joint; *I*, socket of swivel joint; *J*, lamp holder tube for orientating the filament; *K*, covers of spikes of current supply; *L*, tube forming the body of the apparatus; *M*, tightening screw making the tube *J* immovable; *N*, screw for centering the filament; *O*, focusing ring.

makes it possible to reproduce vibrations of 120,000 cycles with an efficiency of 90 per cent, that is, well above the audible range. Moreover, since all the light falling on the entrance pupil of the projection objective is used to form the image, except for losses in this objective, the optical efficiency of the apparatus will be excellent. Eliminating the condenser will reduce the losses of light still more.

Figs. 19 and 20 show the first model of the apparatus which we had made according to this principle by the Société S. C. A. D. and the lamp which it contains.

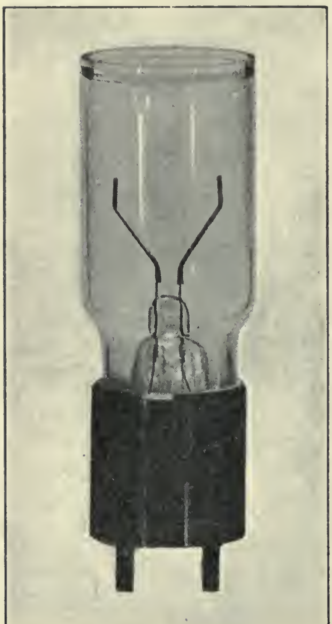

FIG. 20. Photograph of lamp used in apparatus shown in Fig. 19.

The filament of this lamp, which is of tungsten 25 mm. long with a diameter of 0.1 mm., is stretched between two metallic rods which conduct the current. The difficulty of constructing this lamp lies in the choice of the metal constituting these rods and in the tension which the filament should have. If it is stretched too much, it breaks at a high temperature; if it is not stretched enough, it does not stay rectilinear when it is brought to incandescence. Methods of construction have been perfected so that the filament remains perfectly rectilinear at its normal operating temperature (2290°K.) and at the same time its tension is low enough not to jeopardize its life, which is several hundred hours.

In order to obtain a rectilinear image of the filament and a careful correction of the aberrations, the rays employed must go through the walls of the bulb under conditions which are known perfectly. For this purpose the bulb of the lamp consists of a glass cylinder closed at the end opposite the base of the lamp by a lens with parallel faces ground optically and of a known thickness. By means of a special method this lens is fused into the walls of the cylinder, the deformations resulting from the junction not extending to the central part through which the useful rays are passing.

These rays fall upon a photographic objective of the anastigmatic triplet type. An objective of this type has been preferred to a microscope objective because the enlargement which is to be obtained is approximately $^1/_4$ in order that the exploring zone shall be 3 mm. long and 0.0125 mm. wide, which is considered sufficiently small at the moment. This width in reality is half as great as the width of most apparatus with a slit and still gives a sound efficiency of nearly 70 per cent (see §6) for the frequency 20,000, whereas twice the width gives an efficiency of only 13 per cent for the same frequency. The microscope objectives corrected for this magnification and an object field exceeding 3 mm. in general have a numerical aperture which is lower than 0.15, whereas anastigmatic triplet lenses are found to have an excellent definition in a field exceeding by far 3 mm. and having a numerical aperture of 0.25 at least. Moreover, with such objectives the distance separating the last lens from the film is greater than with ordinary microscope objectives, which also may be considered an advantage.

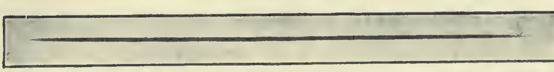

FIG. 21. The image of the filament.

Fig. 21 shows the image, on the same scale as the image of the slit in Fig. 15, of the image of the filament as received by the film. It can easily be proved that this image is perfectly rectilinear. The brilliancy of the exploring zone then will be perfectly uniform except in the immediate vicinity of the ends, whereas it is far from uniform with the apparatus with the slit, although adjusted with care, as shown in Fig. 15.

Naturally it would not be difficult to reduce the width of the exploring zone still more either by using a finer filament of the same length with the same objective and the same magnification or by reducing the magnification and increasing proportionally the length of the filament, which is assumed to have a constant diameter.

In the model shown in Fig. 20, the socket of the lamp is provided with spikes which sink into an insulating piece provided with a swivel joint H whose case is in one piece with the plug K fixed on the tube J which can rotate with slight friction against the external tube L. By turning the plug K the filament can be made horizontal (the film being unwound vertically). Four screws N whose points rest on the walls of the bulb through springs D make it possible to center the filament in such a manner that the exploring zone sweeps the sound band exactly. The blades of the spring also facilitate the introduction of the lamp mounted on the plug K in the tube L.

The pencil illuminating the exploring zone goes through the small window G without touching its edges, this window being used only to eliminate the interfering light reflected on the internal walls of the tube L.

Focusing on the film is performed by means of the ring O which displaced the objective or an element of the objective by small amounts.

15. Results of Experiments.—In addition to the satisfactory results obtained in operation with this apparatus we have tried to determine the total luminous flux which it sends through the exploring zone and its energy output, that is, the number of watts consumed to obtain this luminous flux. For comparison this investigation was conducted also with the apparatus with slit, already mentioned.

Either of these two lighting devices was fixed on a rotating support, the axis being vertical, so that the entire emerging flux was received by a photoelectric cell (hemipherical S. C. A. D. cell), and by one rotation of the support this flux could be substituted instantaneously by the flux from a standard lamp mounted on a rack support. The cell as usual was connected to a battery and a galvanometer. The lamps, that of the investigated lighting apparatus as well as the standard lamp, were supplied by a storage battery with potentiometers to regulate with precision the current in the lamps, standard ammeters to measure it and standard voltmeters to measure the voltages at the terminals of the latter. By experimenting, the distance of the standard lamp was regulated in such a manner that the deflection of the galvanometer was the same when the cell received the flux leaving the lighting apparatus or that from the standard lamp limited by a diaphragm of a known surface placed on the cell. The standard lamp was supplied in such a manner that its potential at the terminals was its standard potential, 102.9 volts; its luminous intensity then was 20.2 candles.

The results of a measurement made on our apparatus and on the apparatus with the slit are as follows:

	Apparatus L. D.	*Apparatus with Slit*
Current in the lamp, amperes	1.5	5.5
Voltage at the terminals, volts	3.44	7.69
Power consumed, watts	5.16	4.24
Diameter of the diaphragm placed on the cell illuminated by the standard lamp, centimeters	2.535	2.043
Distance of the standard lamp for the equilibration, centimeters	74.3	67.3
Flux leaving the lighting apparatus $\frac{20.2 \cdot \pi \cdot 2.535^2}{4 \cdot 74.3^2}$ (L.D.); $\frac{20.2 \cdot \pi \cdot 2.043^2}{4 \cdot 67.3^2}$ (with slit); lumen	0.0185	0.0146

Before we conclude this paper we wish to make the following remarks in regard to these results:

(1) Variations in the centering of the lamp of our apparatus produce no effect on the emerging flux, provided, of course, that the decentering is not so great that the pencil is partly hidden by the edges of the window *G*. On the other hand, very slight variations in the centering of the apparatus with the slit produce very great variations of the emerging flux. This is readily understood since the region of the spiral filament is varied, the image of which is formed by the condenser on the microscope objective. The flux obtained above is the maximum flux which we have been able to produce; a very slight irregularity which leaves an excellent centering upon examining the pencil makes the flux drop to 0.0122 lumen.

(2) If the energy output is expressed by the number of lumens emitted in the emerging pencil for 1 watt consumed, it is clear that the apparatus with rectilinear filament, which already is superior to the apparatus with slit in absolute value, is far superior in regard to efficiency. Its efficiency is 0.0036 lumen per watt, whereas the efficiency of the apparatus with slit is one-tenth as great, that is, 0.00034 lumen per watt. Such a result could be expected owing to the losses of light avoided in the apparatus with rectilinear filament. This advantage, which perhaps is little appreciated in the present talking picture installations, evidently may attain great importance.

(3) The efficiency of the apparatus with rectilinear filament would be increased still further in regard to that of the apparatus with slit if our lamp were as powerful as that of this apparatus. With 1.5 amperes the color temperature in the middle of the filament of our lamp is 2290°K., the output then being 7.75 lumens per watt

(at a reduced operation of 1.45 amperes, the color temperature drops to 2250°K. and the output to 6.70 lumens per watt). At an operating current of 5.5 amperes the color temperature of the spiral filament of the apparatus with slit is 2570°K. on the internal surfaces of the turns and 2400°K. on the external surfaces, the average output being 15.4 lumens per watt. The lamp of the apparatus with slit, therefore, is much more powerful than ours; its light is richer in blue rays to which the cell is more sensitive. If our filament were brought to the same temperature, although at the expense of its duration, the efficiency of the apparatus measured as above would be practically doubled since the output of the filament would be increased from 7.75 to 15.4 lumens per watt.

THE RAPID RECORD OSCILLOGRAPH IN SOUND PICTURE STUDIES*

A. M. CURTIS, T. E. SHEA, AND C. H. RUMPEL**

Summary.—*This paper describes a special oscillograph which was designed for making rapid records in sound picture studies. The oscillograph is briefly described, and illustrations are presented of records obtained in making the following studies: microphonic action of vacuum tubes; noise levels in amplifiers; investigations on rectifiers; studies on light valve clash; action of the biasing current of light valves as used in noiseless recording by the variable density method; acoustical studies showing the rise and decay of transients; loud speaker selection with regard to load carrying capacity and mechanical flutter investigations of reproducer sets.*

The recording oscillograph, although an extremely valuable instrument, is not in general very popular with engineers. This is especially true in sound picture work where time is often limited and the minutes and sometimes hours which must elapse after the oscillogram is taken and before it can be readily examined are a serious drawback. In addition, most types of recording oscillographs are found to be so insensitive over the frequency band used in sound pictures that the information which they give is frequently unreliable.

About two years ago the Bell Telephone Laboratories, realizing the limitations of the available oscillographs of the recording type, undertook to design an instrument which would as far as possible avoid these shortcomings. The instrument which was evolved is capable of recording frequencies accurately up to 6000 cycles per second, and can furnish a developed record almost immediately after the oscillogram has been taken. Usually, therefore, oscillograms may be taken as rapidly as the conditions under investigation can be changed, and the results of the changes may be known at once.

The oscillograph illustrated in Figs. 1 to 4 may be divided into two main parts, the galvanometer and the photographic mechanism. The galvanometer is of the string type, and is not unlike the light valve familiar to most sound picture engineers. There are, however,

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* Presented at the Spring, 1931, Meeting at Hollywood, Calif.

** Bell Telephone Laboratories, New York, N. Y.

three independent strings which permit the observation and recording of three simultaneous and separate phenomena with their phase relations.

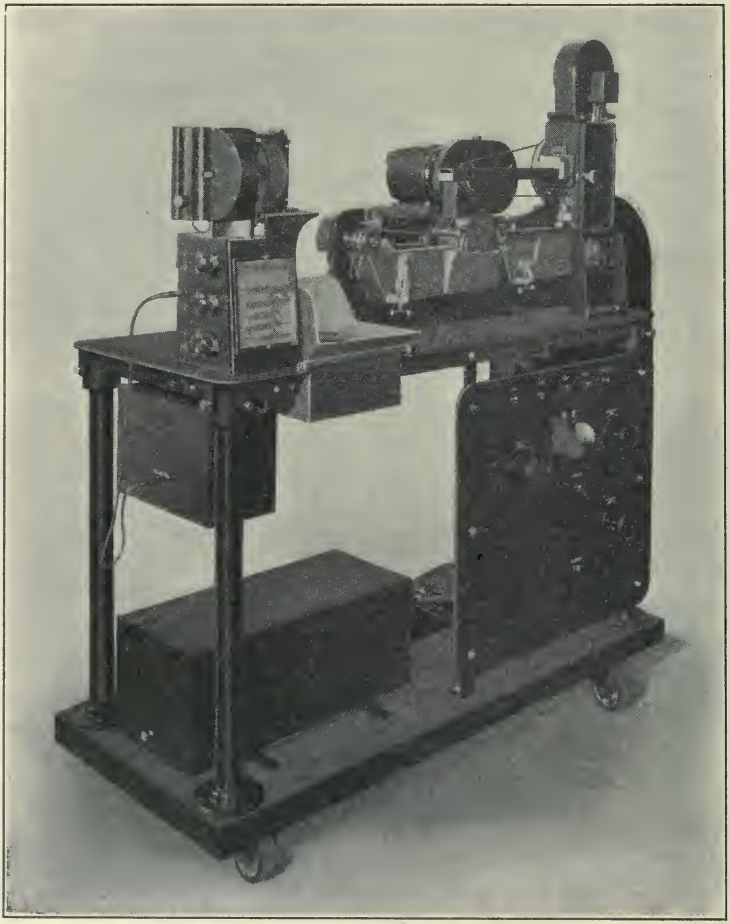

FIG. 1. Front view of the oscillograph.

A tungsten filament lamp and a simple lens arrangement magnifies the motions of the strings and compresses their shadows to black spots on a line of light which extends across the 35-mm. bromide recording paper. This provides an oscillogram with white lines on a dark gray background. Means are also provided to photograph amplitude and timing lines on the oscillogram if desired.

The photographic mechanism takes care of the exposing, developing, and fixing of the oscillogram. The exposing is done by passing the paper through the line of light at the desired speed, using a system of rollers rotated by the exposure motor. The paper, having been

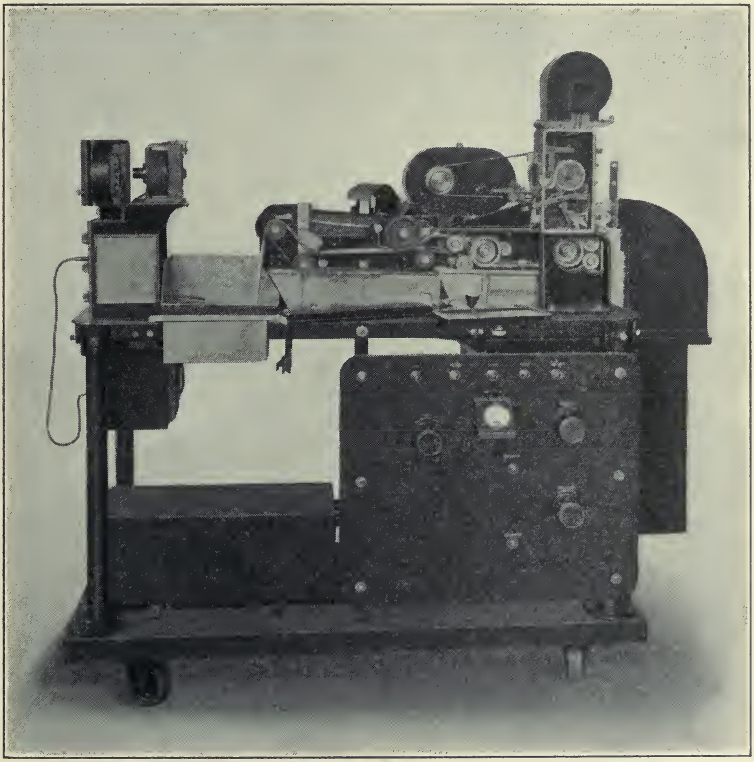

FIG. 2. Front view of the oscillograph with covers removed to show part of the exposing and developing mechanism.

exposed, is passed down a small chute into the developer tank through which it slowly travels by means of conveyor belts. From the developer the oscillogram is led into the fixing bath and is then passed out into a large fixing tank where it may be observed. Since oscillograms are generally taken much more rapidly than they are developed, a storage tank is provided into which the excess of exposed paper is passed, where it remains until led through the developer.

The process of taking an oscillogram is briefly as follows: the sources of current which it is desired to investigate are connected to

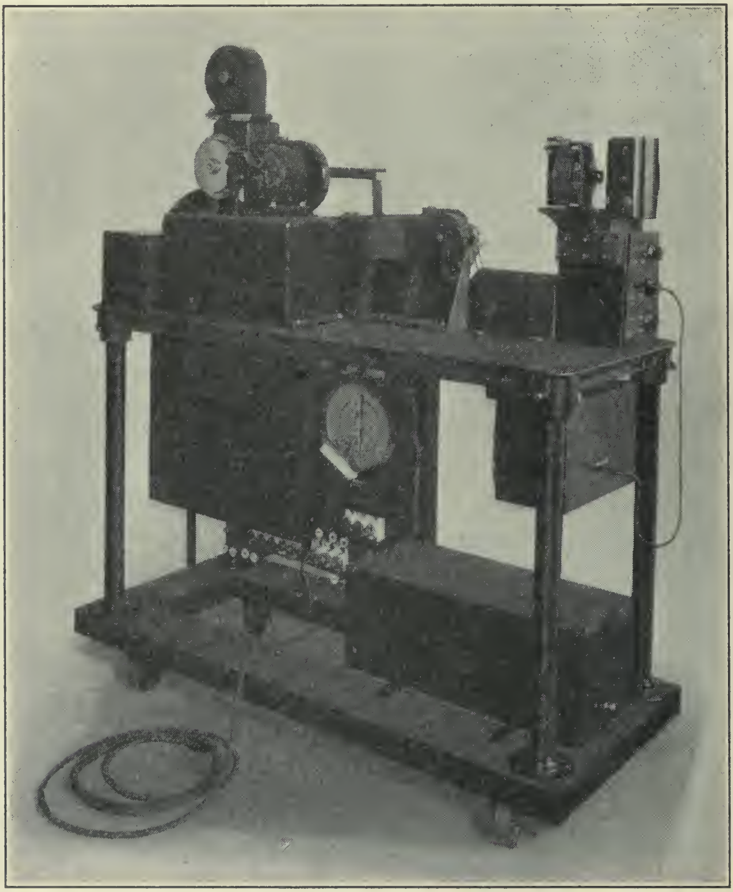

FIG. 3. Rear view of the oscillograph.

the galvanometer strings and the controls are adjusted until suitable deflections are observed on the viewing screen of the camera. The motors are then started and an operating lever is pulled out. After the deflection of the string images on the screen show that the expected phenomenon has occurred, the operating lever is returned to the normal position. The developed and fixed oscillogram begins to pass before the operator's view about ten seconds later. It may then be examined immediately, measured, and, if desired as a permanent

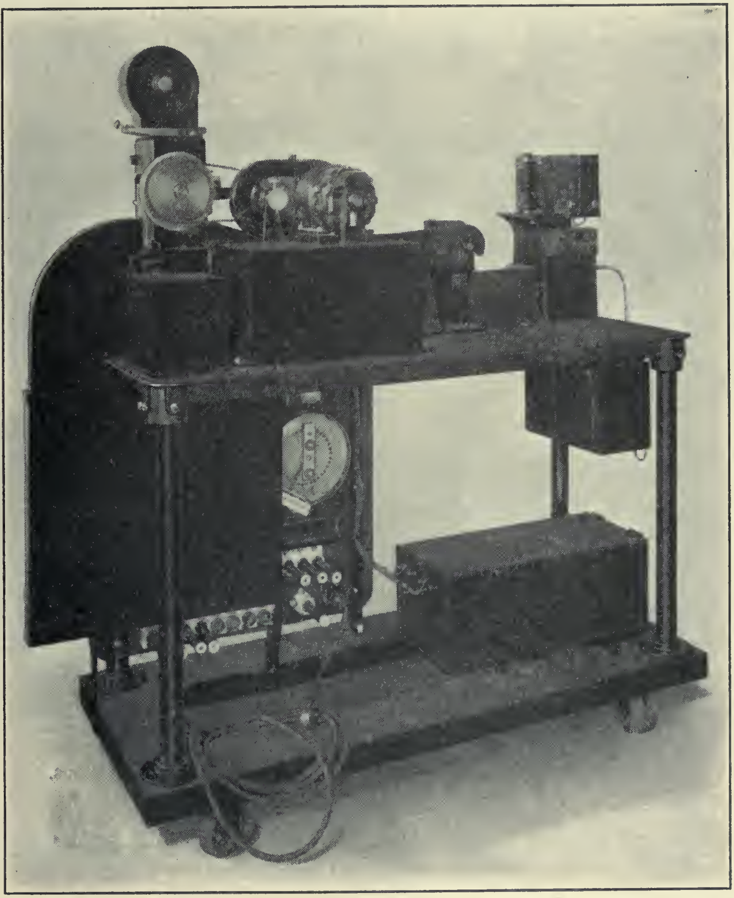

FIG. 4. Rear view of the oscillograph taken from another angle.

record, returned to the large hypo tank for a few minutes to complete the processing.

A particular feature of this instrument is the sharp definition of the string image, permitting accurate observations to be made with deflections much smaller than are common with other types of recording oscillographs. This allows the oscillograms to be enlarged for analysis, and tracks having a height as great as four inches still give sharply defined lines.

In order that the use of such an oscillograph in sound picture studies may be illustrated, a number of oscillograms have been prepared showing the application of this oscillograph to the solution of problems which are continually being investigated so that the sound picture may attain a greater degree of excellence. These

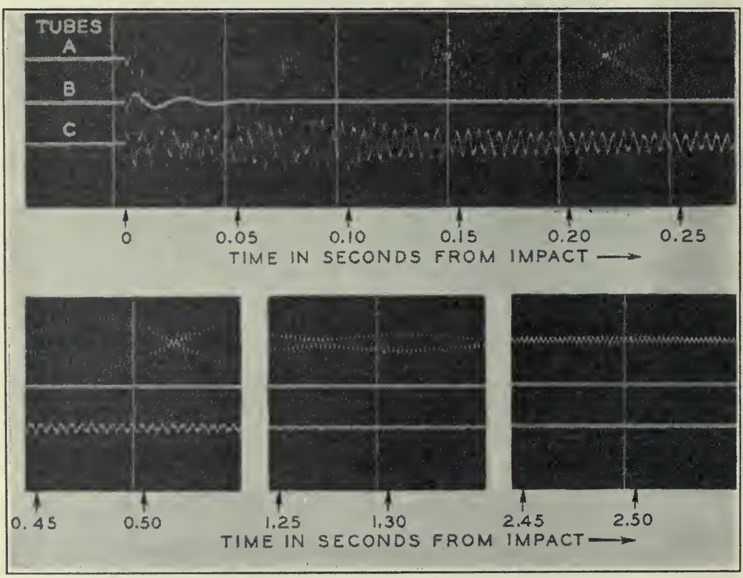

FIG. 5. Oscillogram of microphonic response of vacuum tubes.

oscillograms are not intended to show complete results of the various investigations but rather to point out how effectively this instrument may be used.

1. Microphonic Vacuum Tube Studies.—Microphonic vacuum tubes have imposed certain limitations both in recording and in reproducing systems. Those tubes, commonly used at low levels because of operating limitations, have been more microphonic than the higher powered tubes. Fig. 5 shows an oscillogram taken to illustrate the improvement which has been made in the microphonic response of a small vacuum tube as the result of studies which have been carried on during the past year. In this oscillogram three tubes were placed at the input to three amplifier channels having the same gain, each channel terminating at one of the oscillograph strings. The mounting upon which the three tubes were placed was given a single rap, causing the microphonic response of the tubes as shown. The relative freedom from microphonic effects of a recently produced vacuum tube (Tube *B*) is easily seen from a comparison with the

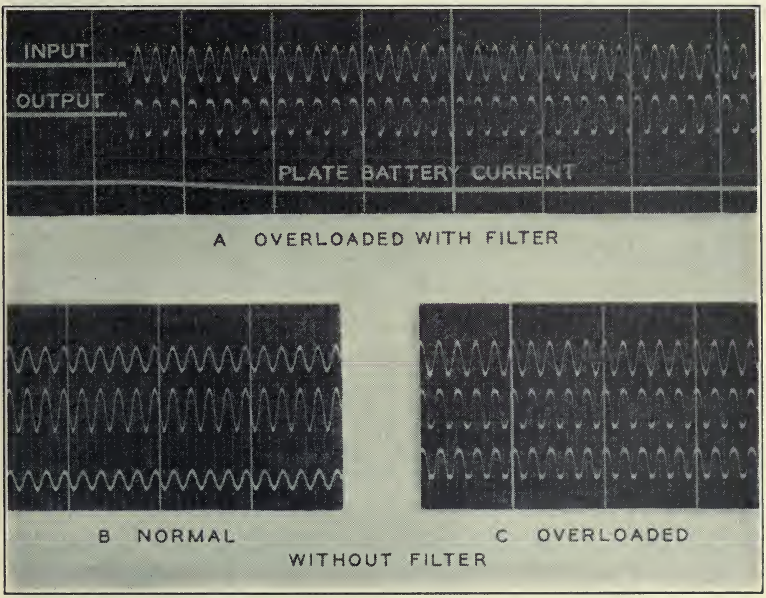

FIG. 6. Oscillograms of single tube amplifier.

response of the earlier type of tubes recorded on the two outer strings (Tubes *A* and *C*).

2. Amplifier Studies.—In recording, it is common practice to operate a large number of recording amplifiers from a common "B" battery. Figs. 6 and 7 show the noise level across this battery due to a single amplifier, which may cause objectionable cross-talk in the other amplifiers unless precautions are taken to reduce the effect. Fig. 6 illustrates the effect in a single tube amplifier operated both within its rating and overloaded; Fig. 7 shows the corresponding

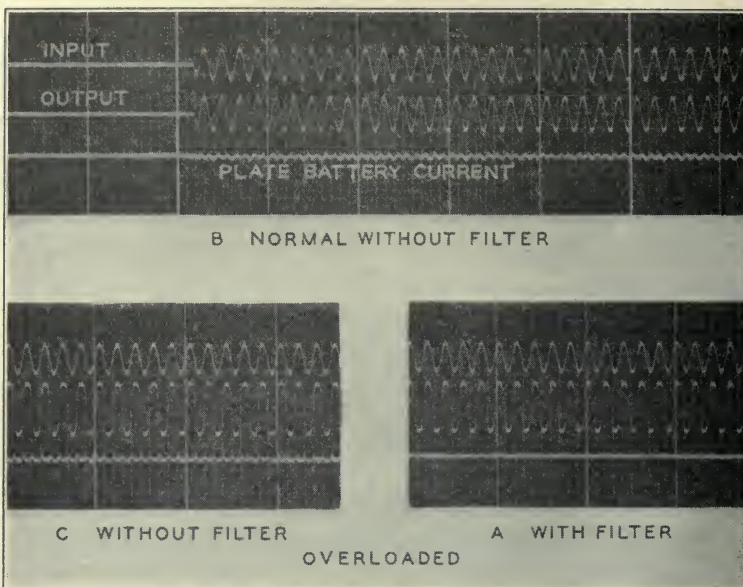

FIG. 7. Oscillograms of push-pull amplifier.

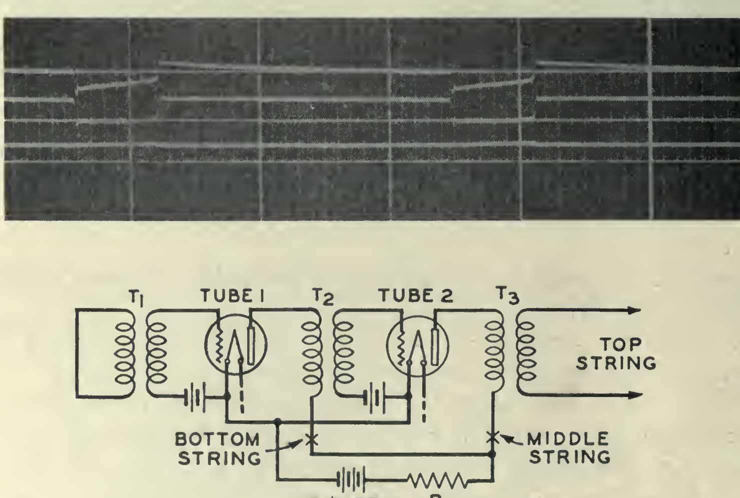

FIG. 8. Oscillogram of amplifier blocking.

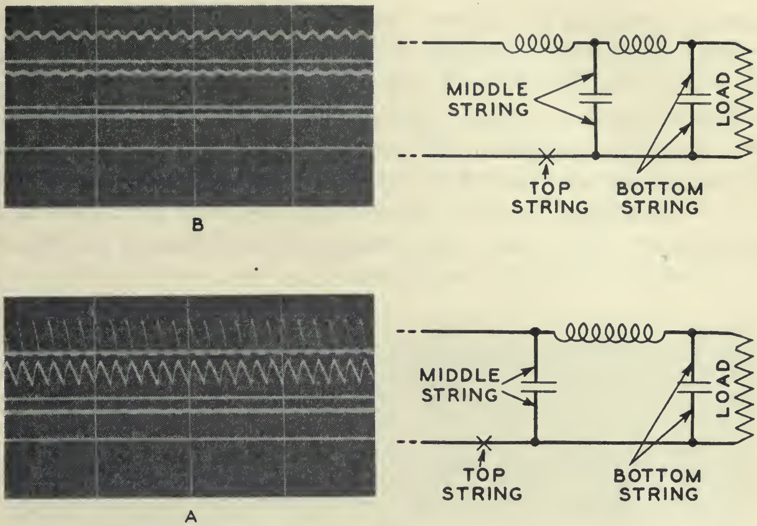

FIG. 9. Oscillograms of rectifier characteristics.

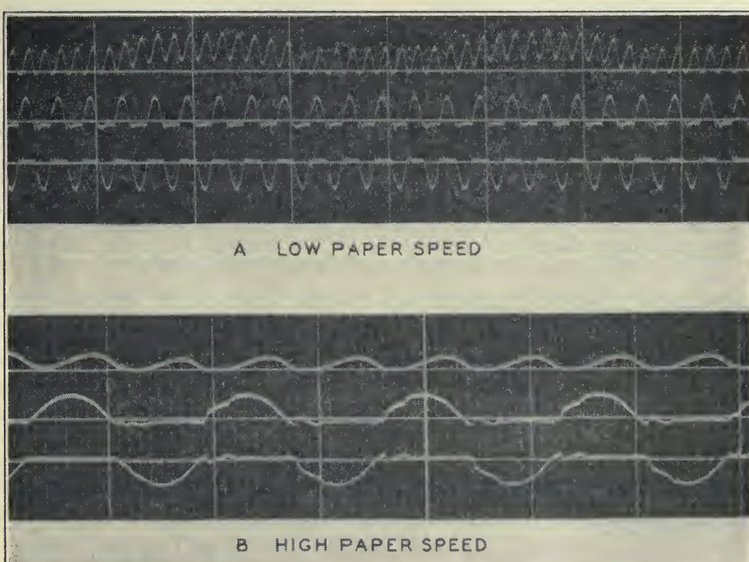

FIG. 10. Oscillograms of rectifier flickering.

effects in a push-pull amplifier. In each case record *A* illustrates the amplifier equipped with a simple filter composed of a single condenser and a small inductance, and indicates the absence of noise at the battery terminals. Records *B* and *C* show the presence of noise when the filter is removed. It is particularly interesting to note the presence of noise in the case of the push-pull amplifier as this is contrary to the fairly common supposition that such an amplifier is totally without this effect. The tubes used in obtaining this record were carefully selected for equivalence.

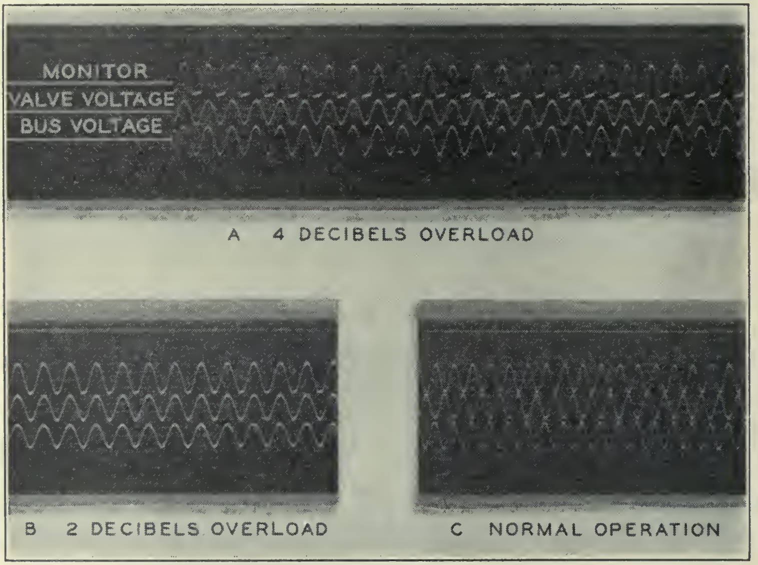

FIG. 11. Oscillograms showing light valve clash.

In a-c. operated amplifiers blocking is a familiar phenomenon due frequently to a common plate impedance between the various tubes. In certain cases, however, it is very difficult to determine what is taking place. Fig. 8 shows a simple form of blocking in a two-stage amplifier. A small change in the plate current in tube *2* causes a change in the plate current of tube *1* through the common plate impedance R_1. This resistance R_1 represents the impedance of the plate power supply which, in the case of an a-c. rectifier or a run-down "B" battery, might be quite high.

3. Rectifier Investigations.—Investigations of rectifier characteristics may be readily made with this oscillograph as is shown in Figs. 9 and 10. Record *A*, Fig. 9, shows the effect of working a gas rectifier tube directly into a capacity, as compared with working into an inductance (record *B*). This record was taken to determine the magnitude of the current peaks for the two types of filter, in order to determine the optimum condition for tube and condenser operation and thereby assure maximum service from the equipment.

Fig. 10 shows a peculiar phenomenon found in certain full-wave gas rectifier tubes when operating under light loads. The tubes may be seen to flicker at various frequencies, as shown in the oscillogram. In each case the upper trace is the input voltage of the filter, the middle and lower traces the voltage between each plate and the filament of the rectifier tube.

4. Light Valve Studies.—Figs. 11, 12, and 13 show how the oscillograph may be used in studying the light valve used in the variable density method of recording. In Fig. 11 light valve string clash is shown. It may be seen how, while the bus voltage (input to the power amplifier feeding the valve) and valve voltage are unaffected, the output, as picked up by a monitoring photoelectric cell placed back of the film, is considerably distorted, but on one side of the cycle only.

Figs. 12 and 13 illustrate the action of the biasing current of the light valve as used in noiseless recording by the variable density method. Fig. 12, record *A*, shows the action which takes place during attack or beginning of a sound wave. During this time the bias as shown by the center trace is being removed, allowing the light valve strings to resume their normal average spacing. This particular condition illustrates the effect of too slow a removal of the biasing current causing the valve ribbons to clash, as indicated by the irregularities in the wave shown on the bottom trace. Record *B* is the same as record *A* except that speech is used to modulate the valve instead of a single frequency. Fig. 13 shows the decay after the input to the valve has died down. It may be seen that the bias is placed upon the valve much more slowly than it is removed in order that the low level portions at the ends of the various sounds as they die down will not be cut off. The reason for this may be seen from Figs. 14 and 15.

5. Acoustical Studies.—Figs. 14 and 15 are records of sound build-up and decay, and were taken by placing the input to a loud speaker on the middle string or trace and picking up the sound by

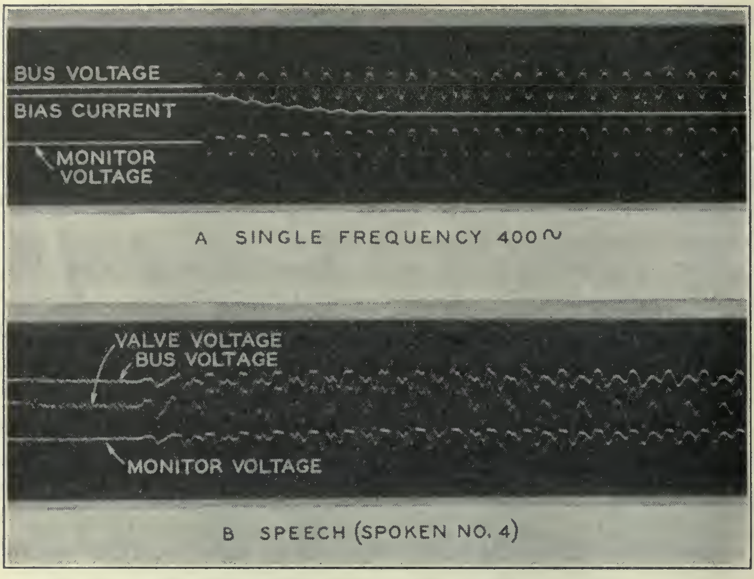

FIG. 12. Oscillograms of noiseless recording light valve bias (attack).

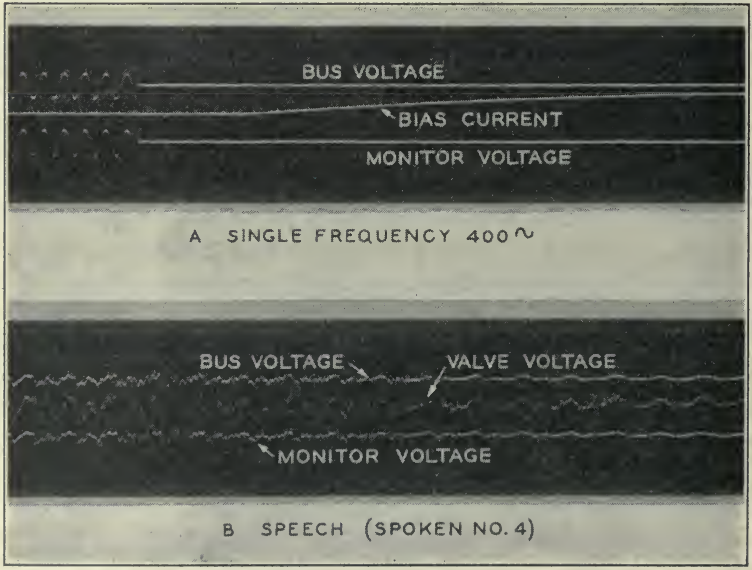

FIG. 13. Oscillograms of noiseless recording light valve bias (decay).

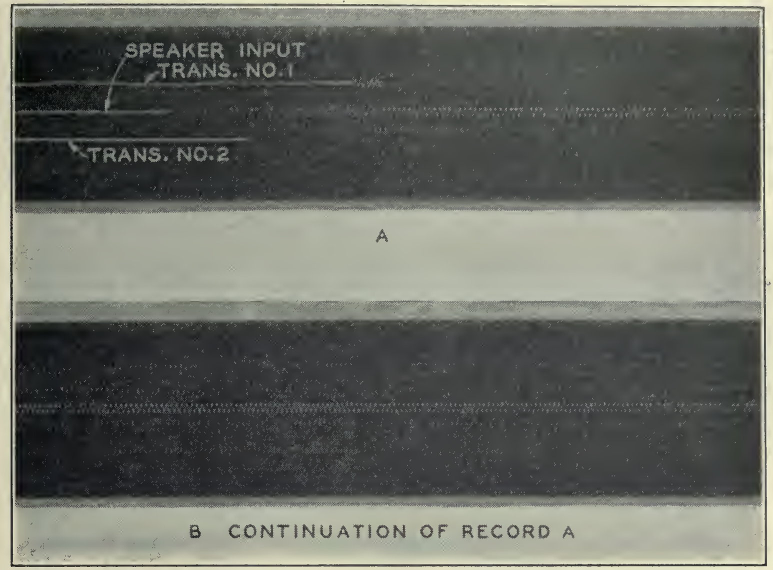

FIG. 14. Oscillogram of sound growth.

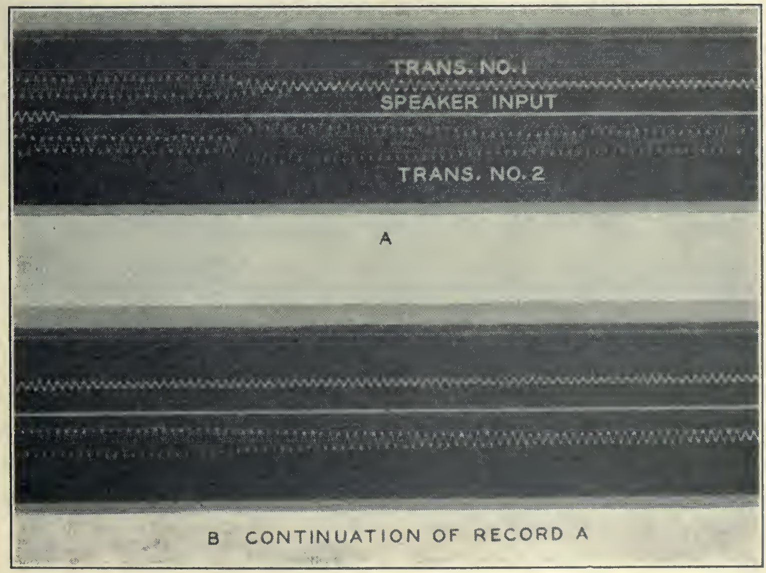

FIG. 15. Oscillogram of sound decay.

means of two differently placed microphones whose amplified outputs are shown on the outer two traces. The sound growth curve of Fig. 14 shows that in the case of a single frequency the sound builds up to its normal value very rapidly but may then drop or rise slightly depending upon the position of the microphone and the interference patterns set up. Fig. 15 illustrates different ways in which sound may

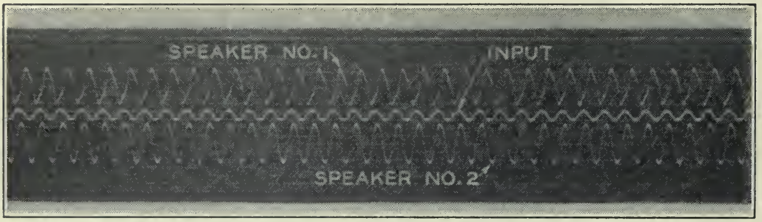

FIG. 16. Oscillogram of loud speaker overload.

decay when the input to the loud speaker is cut off. These differences are the results of interference, and it will be noted that they occur during the interval immediately following the cut-off of energy to the loud speaker. Being transient phenomena, the oscillograph is well suited to study them and is particularly valuable as an instrument supplemental to the reverberation meter, as by means of it

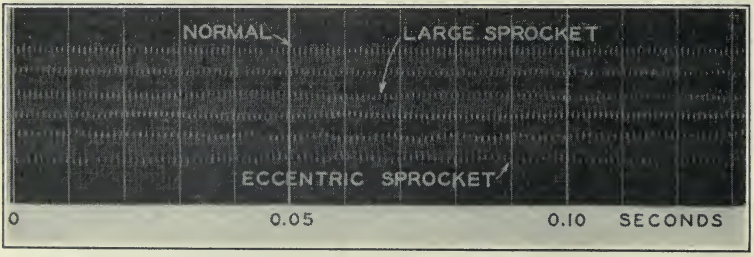

FIG. 17. Oscillogram of mechanical flutter.

particular portions of a decay curve may be studied in detail. However, because of the limited amplitude of the oscillograph record, over-all reverberation times are most accurately measured by means of a reverberation meter.

In selecting a loud speaker for a particular application it too frequently happens that this selection is made on the basis of frequency response characteristics; and that the load carrying capacity is entirely neglected. The record of Fig. 16 was taken to illustrate this point. The upper and lower traces of this record indicate the sound outputs, as picked up by two similarly located microphones, of two loud speakers each receiving the same input. Speaker *1* is obviously overloaded.

6. *Mechanical Flutter Investigations.*—Fig. 17 shows how the oscillograph may be used to assist in mechanical design. Three separate sound film reproducers were set up, and the output of each reproducer was put on one string of the oscillograph. The same sound print of a thousand cycle film record was used on each of the reproducers with the results as shown. The upper trace is the output of a normal reproducer. The middle trace shows a reproducer having too large a driving sprocket at the sound gate. The lower trace shows the effect of having the driving sprocket slightly eccentric producing ninety-six and six cycle flutter.

PHOTOGRAPHIC SENSITOMETRY, PART III*

LOYD A. JONES**

Due to its length, Mr. Jones' paper on sensitometry which was presented in part on three consecutive days at the Spring, 1931, Meeting of the Society at Hollywood, Calif., will be published in the JOURNAL *in four issues. The following is the third of the four installments. The paper deals in a tutorial manner with the general subject of sensitometry, its theory and practice. The fourth installment will be published in the March, 1932, issue of the* JOURNAL.

OUTLINE

I. Introduction.
- (*A*) Definition.
- (*B*) Scope of field.
- (*C*) Applications.
- (*D*) The characteristic *D*-log *E* curve.

II. Sensitometers.
- (*A*) Light sources.
  - (1) *Historical résumé.*
    - (*a*) Natural light (sunlight, skylight, *etc.*).
    - (*b*) Activated phosphorescent plate.
    - (*c*) British standard candle.
    - (*d*) The Hefner lamp.
    - (*e*) The Harcourt pentane standard.
    - (*f*) The acetylene flame.
    - (*g*) Electric incandescent lamps.
  - (2) *Spectral composition of radiation.*
    - (*a*) The spectral emission curve.
    - (*b*) The complete radiator.
    - (*c*) Color temperature of sources.
    - (*d*) Effect of color temperature on sensitivity values.
  - (3) *Modern standards of intensity and quality.*
    - (*a*) Acetylene flame plus dyed gelatin filter.
    - (*b*) Acetylene flame plus colored glass filter.
    - (*c*) Acetylene flame plus colored liquid filter.
    - (*d*) Electric incandescent, plus colored filters
  - (4) *The international unit of photographic intensity.*
- (*B*) Exposure modulators.
  - (1) *Intensity scale instruments.*

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* Presented at the Spring, 1931, Meeting at Hollywood, Calif.

** Kodak Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

(a) Step tablets (*I* variable by finite increments).
(b) Wedge tablets (*I* variable by infinitesimal increments).
(c) Luther's crossed wedge tablet.
(d) Tube sensitometer.
(e) Optical systems with step diaphragms.
(f) Optical systems with continuously variable diaphragms.

(2) *Time scale instruments.*
(a) Exposure intermittent.
Finite exposure steps (discontinuous gradations).
Infinitesimal exposure steps (continuous gradations).
(b) Exposure non-intermittent.
Finite exposure steps (discontinuous gradations).
Infinitesimal exposure steps (continuous gradations).

III. Development.

(A) Developers.
(1) *Standards for sensitometry.*
(a) Ferrous oxalate.
(b) Pyro-soda.
(c) *p*-Aminophenol.
(2) *Standards for control of processing operations.*
(B) Temperature control.
(C) Development technic.
(1) *For standardized sensitometry.*
(2) *For control of processing operations.*

IV. The measurement of density.

(A) Optical characteristics of the image.
(1) *Partial scattering of transmitted light.*
(2) *Diffuse density.*
(3) *Specular density.*
(4) *Intermediate density.*
(5) *Relation between diffuse and specular values.*
(6) *Effective density for contact printing.*
(7) *Effective density for projection.*
(8) *Color index.*
(B) Fog and fog correction.
(1) *Source of fog.*
(a) Inherent fog.
(b) Processing fog.
(2) *Fog correction formulas.*
(C) Densitometers.
(1) *Bench photometer.*
(a) Rumford.
(b) Bunsen.

(*c*) Lumer Brodhun.

(2) *Martens polarization photometer.*

(*a*) Simple illuminator.

(*b*) Split beam illuminator.

(3) *Integrating sphere.*

(*a*) For diffuse density.

(*b*) For diffuse and specular density.

(4) *Completely diffused illumination.*

(*a*) For diffuse density.

(5) *Specialized forms.*

(*a*) Furgeson, Renwick, and Benson.

(*b*) Capstaff-Green.

(*c*) High-intensity (Jones).

(*d*) Density comparators.

(6) *Physical densitometers.*

(*a*) Thermoelectric.

(*b*) Photoelectric.

(*c*) Photovoltaic.

V. Interpretation of Results.

(*A*) Speed or sensitivity.

(1) *Threshold speed.*

(*a*) Scheiner speed numbers.

(*b*) Eder-Hecht.

(2) *Inertia speeds.*

(*a*) H & D scale.

(*b*) Watkins scale.

(*c*) Wynne scale.

(3) *Luther's crossed wedge method.*

(4) *Minimum useful gradient.*

(*B*) Gamma infinity, γ_∞.

(*C*) Velocity constant of development, K.

(*D*) Time of development for specified gamma.

(1) $T_d\ (\gamma = 1.0)$.

(*E*) Latitude, L.

(*F*) Fog, F.

VI. Spectral Sensitivity.

(*A*) Dispersed radiation methods.

(1) *Monochromatic sensitometers.*

(2) *Spectrographs.*

(*a*) Ordinary.

(*b*) Glass wedge.

(*c*) Optical wedge.

(*B*) Selective absorption methods.

(1) *Tricolor.*

(2) *Monochromatic filters.*

(3) *Progressive cut filters.*

V. INTERPRETATION OF RESULTS

Having now exposed the photographic material to a definitely known quantity and quality of radiation, developed the exposed material under standardized conditions, and measured the densities resulting from the various exposures, it remains to interpret the results thus obtained. As previously stated, some sensitometric testing methods, such, for instance, as the Scheiner, Eder-Hecht, *etc.*, do not require the measurement of density, the result being judged directly by inspection of the developed material. Much

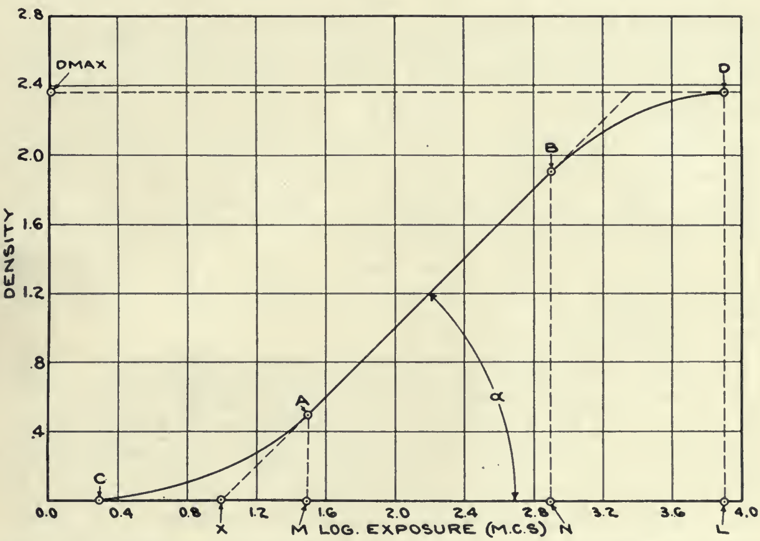

FIG. 38. Typical curve showing the relation between density and log exposure.

more complete information may be obtained by methods involving the measurement of density and subsequent analysis of the results. For this purpose it is customary first to express the results in graphic form, and then to read off directly or to compute, by means of previously established analytical relationships, the values of certain numerical constants useful in specifying the characteristics of a photographic material. The various graphic forms in which the sensitometric data may be shown will now be considered, after which numerical values derived therefrom and their significance for various theoretical and practical purposes will be considered.

By plotting density, D, as a function of the logarithm (to the base 10) of the exposure, $\log_{10} E$, a curve as shown in Fig. 38 is obtained. This is the graphic form proposed first by Hurter and Driffield (*loc. cit.*) for the presentation of sensitometric data and is therefore quite commonly referred to as the *H & D curve* although the terms *D-log E curve* and *characteristic curve* are frequently used in reference thereto. It has been found experimentally that in the case of many photographic materials a considerable portion of the D-log E curve is represented satisfactorily, within the limits of experimental errors, by a straight line. The limits of the straight line region are designated by the points, A and B. The exposure region covered by the straight line portion of the characteristic curve is the *region of correct exposure* since throughout this exposure range density is directly proportional to log E. Therefore, for the correct proportional rendering of the negative of the various object brightnesses, the camera exposure must be adjusted so that only the straight line region is used. For the fulfillment of this condition the minimum density in the negative (corresponding to the deepest shadow in the object) must not be less than that of point A and the maximum negative density (corresponding to the highest light in the object) must not exceed that of point B.

The relation between a given log E interval or increment, $\Delta \log E$, and the corresponding density interval or increment, ΔD, is given by the ratio $\Delta D/\Delta \log E$ which is an expression of the average slope or gradient, G, for the interval $\Delta \log E$. Since the gradient is not in general constant, but changes continuously from point to point (for instance, in the region between C and A), it is necessary in order to express the gradient of the curve at any point to reduce the finite increments $\Delta \log E$ and ΔD to the corresponding infinitesimal increments $d \log E$ and dD. The gradient, G, at any point reduces therefore to the differential form

$$G = dD/d \log E$$

For the straight line portion, however, G is constant and may be conveniently expressed in terms of the angle α subtended by the line AB and the log E axis. The tangent of this angle is called gamma, γ. For the straight line portion, therefore,

$$G = dD/d \log E = \text{constant} = \tan \alpha = \gamma$$

Thus, gamma is the proportionality factor giving the relation between a given log E difference, Δ log E, and the corresponding density difference, ΔD.

$$\Delta D / \Delta \log E = \gamma$$

Thus, if, in an object being photographed, two areas have brightnesses of 10 and 80 units, the $\Delta \log E$ value becomes $\log 80 - \log 10 = 0.90$. Now, if both are rendered on the straight line portion of the D-log E curve and if $\gamma = 0.8$, then

$$\Delta D / 0.90 = 0.8$$

and

$$\Delta D = 0.72$$

If $\alpha = 45$ degrees, tan α or γ becomes unity and any log E increment is rendered in the negative by an identical density difference. This is the condition which must be fulfilled if it is desired to reproduce exactly in the negative the brightness contrast in the object. If gamma is less than unity, correct *proportional* reproduction will be obtained but with compression of the brightness scale, while, if gamma is greater than unity, correct proportional reproduction will also be obtained but with expansion of the object brightness scale.

Since gamma is equal to the ratio of the negative density difference to the corresponding log exposure difference, it is frequently used as a means of expressing the contrast of the negative or of the photographic material. It should be borne in mind constantly that gamma gives information pertaining only to the straight line portion of the curve and tells nothing of the contrast characteristics of other portions of the D-log E curve. This sensitometric constant is of great value and importance in both the theory and practice of photographic sensitometry.

Projection of the straight line portion of the D-log E curve on the log E axis determines the log exposure range over which direct proportionality between D and log E exists. By dropping perpendiculars from A and B to the log E axis the points M and N are established. These fix the limits of this exposure range. The distance between M and N is called *latitude*, L, and may be expressed either in log E units or in exposure units. Thus,

$$\text{Latitude, } L = \log E_n - \log E_m \text{ (Log } E \text{ units)}$$

or

$$\text{Latitude, } L = E_n / E_m \text{ (Exposure units)}$$

The value of latitude for any given D-log E curve determines the maximum object contrast (ratio of maximum to minimum object brightness) which may be rendered with strict proportionality between density and log exposure on that photographic material processed under the specified conditions used in obtaining the characteristic curve. Latitude is not a constant for a given photographic material, since its value depends profoundly upon the extent to which development is carried and, to a lesser extent, on other processing factors. It depends also upon certain exposure conditions, such as the quality (spectral composition) of the exposing radiation.

The straight line, AB, extended cuts the log E axis at the point x and the value of E at this point is called the *inertia*, i. Since a material of low sensitivity has a high inertia value, and *vice versa*, it is necessary to take the reciprocal of the inertia in order to obtain a value which is directly proportional to sensitivity, hence

$$\text{Sensitivity} \propto 1/i$$

The absolute values obtained by taking the reciprocal of the inertia may be inconvenient for practical purposes since they may be less than unity, and hence expressible only as decimals or fractions. It is customary, therefore, in setting up practical sensitivity or *speed* scales to multiply this reciprocal by a constant, k, chosen more or less arbitrarily so as to give a series of convenient numbers. In general, therefore, speed is defined by the equation

$$\text{Speed, } S = \frac{1}{i} . k$$

The values of k commonly used will be discussed later.

Now, from point A (Fig. 38) the D-log E curve continues to the left into the region of decreasing exposure with constantly decreasing gradient, G, until at the point C this gradient becomes zero ($G = 0$), that is, the curve becomes parallel to or, if proper correction for fog has been made, coincident with the log E axis. This region, C to A, is called the *region of underexposure* or sometimes the *toe* of the characteristic curve. Since the gradient, dD/d log E, decreases progressively from A to C, it follows that the density difference, ΔD, corresponding to a given small Δ log E, decreases continuously as the exposure is decreased, becoming zero at the exposure value corresponding to the point C. Thus, the power of the photographic material to show detail due to brightness differences in the object becomes less and less throughout the underexposure region vanishing entirely at an exposure value corresponding to the point C.

From the point B, the upper limit of the straight line, the curve continues to the right into the region of increasing exposure with a constantly decreasing gradient until at the point D the gradient becomes zero, that is, the curve becomes parallel to the log E axis. The value of density corresponding to the point D is the *maximum density*, D_{max}, obtainable with the specified processing conditions, development time, developer constitution, temperature, *etc.* Its value is not fixed entirely by these processing factors, but depends to some extent upon the quality of the exposing radiation. This region, B to D, is called the *region of overexposure*, or sometimes the *shoulder* of the characteristic curve. Here, as in the underexposure region, the

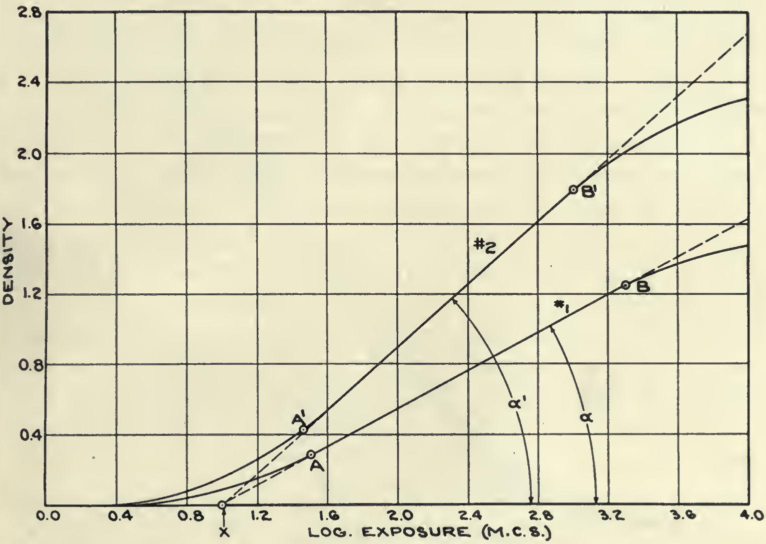

FIG. 39. D-log E curves obtained with development times of T and $2T$.

density difference, ΔD, corresponding to a small log E difference Δ log E, decreases progressively with increasing exposure and becomes zero at point D. Thus, the detail rendering power decreases progressively with increasing exposure and vanishes completely at the exposure value corresponding to point D.

Points C and D, therefore, represent the limits of the exposure range within which the material is capable of rendering an object brightness difference by some density difference although near the limits (points C and D) this may be negligibly small, even for very great object brightness differences. This exposure range is termed the *total scale* of the material and may be expressed either in log E units or as the ratio of the limiting exposures. Thus,

$$\text{Total scale} = \log E_L - \log E_C \text{ (Log } E \text{ units)}$$

or

$$\text{Total scale} = E_L/E_C \text{ (Exposure units)}$$

The latter form is more commonly used and is perhaps better for most purposes, since it is more directly interpretable in terms of the ratio of maximum object brightness to minimum object brightness, which is the form in which data relative to the brightness of the object are usually available.

The shape, and frequently the position of the characteristic curve,

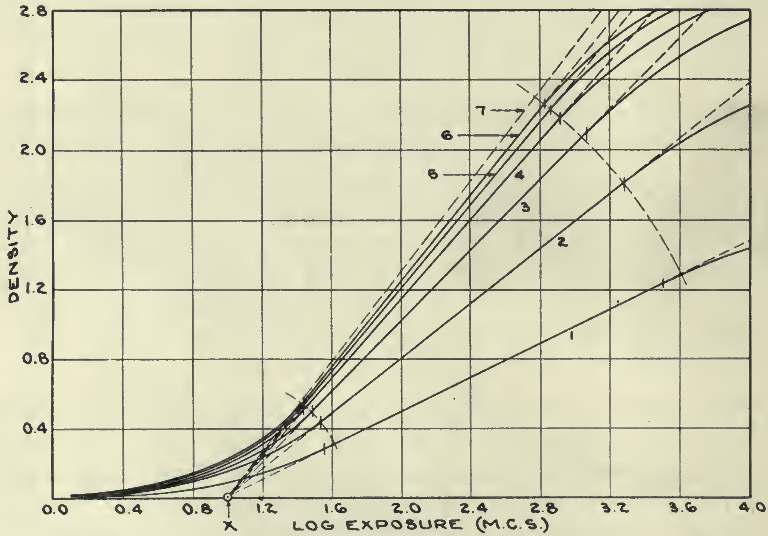

FIG. 40. Family of D-log E curves illustrating the approach to γ_∞ for increasing development time.

depends upon the development conditions. A simple case is illustrated in Fig. 39 in which curve No. 1 represents the D-log E characteristic obtained for a development time of T, while curve No. 2 is that obtained for a development time of $2T$. In this particular case the straight lines intersect at a point x lying on the log E axis. Therefore, the inertia value is the same for both times of development, and speed expressed in terms of inertia is the same for both curves. This is by no means true for all materials and all processing conditions, since in many cases the intersection point of the straight line portions is found to lie either above or more frequently below the log E axis. Since inertia is defined as the value of exposure where the straight line extended cuts the log E axis, it follows that the value of the speed, based upon inertia, is not the same when determined from curves representing different developing times unless their intersection point lies on the log E axis. Angle α' is appreciably greater than α, hence gamma increases as development time is lengthened. This is true in practically all cases except when development is forced to such an extent that excessive fog is produced which may cause a decrease of gamma with development time. Such conditions are rarely met in practice and hence the statement that α increases with time of development is for all practical purposes a correct generalization. Projection of the straight line portion, A' to B', of curve No. 2 on the log E axis is appreciably shorter than that of the similar region, A to B, of curve No. 1, hence in this case latitude has decreased with the increasing time of development. The curves in Fig. 39 do not extend sufficiently far into the region of increasing exposure to show the final values of D_{max}, but it is quite evident that the value of D_{max} increases with development time.

A somewhat more complete picture of the change in the shape of the D-log E curve is shown in Fig. 40 in which the curves numbered from *1* to *6*, inclusive, represent the data obtained from sensitometric strips developed for 2, 4, 6, 8, 10, and 12 minutes, respectively. Values of γ, $\Delta\gamma$, L, and i for these various times of development are

TABLE XI

Data Derived from Fig. 40

T_d	γ	$\Delta\gamma$	L	i
2	0.50	...	1.94	0.10
4	0.80	0.30	1.74	0.10
6	1.02	0.22	1.56	0.10
8	1.14	0.12	1.40	0.10
10	1.20	0.06	1.34	0.10
12	1.24	0.04	1.30	0.10
α	1.30	...	...	0.10

shown in Table XI. For the two-minute development time a gamma of 0.50 is obtained. At 4 minutes gamma is equal to 0.8, an increase of 0.30. Increasing the time of development by another 2 minutes gives a gamma of 1.02, an increase of 0.22. For each successive two-minute addition to the development time the increase in gamma becomes less and less. This change in the rate of growth in gamma is more clearly shown in Fig. 41 (curve *A*) which is plotted from the data in Table XI. This curve is practically parallel to the T_d axis at 16 minutes and by extrapolation it is ascertained that it will not exceed, for any kind of development, a value of 1.30. It is evident that as T_d is prolonged, gamma approaches a limiting value, and this is called *gamma infinity* (γ_∞). This limiting gradient is illustrated in Fig. 40 by the dotted line designaed at 7. The value of gamma infinity is of great significance in both theoretical and practical sensitometry and will be discussed more fully a little later.

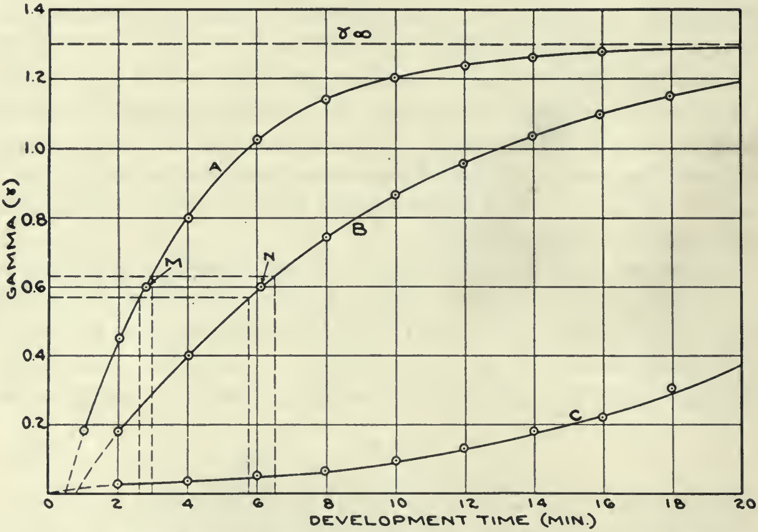

FIG. 41. Time of development-gamma curves, *A* for high rate of development, *B* for low rate of development. Curve *C* is the corresponding time of development-fog curve.

It will be noted by reference to Table XI and Fig. 40 that the value of latitude, *L*, tends to decrease as the time of development increases. Small vertical lines drawn through the various curves mark the limit of the straight line portions. In many cases when all of the straight lines (extended) intersect at a point lying on the log *E* axis, the points marking the limits of the straight line portions lie approximately on the circumference of circles drawn with the intersection point as a center. Under such conditions the actual length of the straight line is approximately constant, and hence is related in a definite manner to gamma. The frequency of occurrence of this state of affairs is relatively low, and hence it is unsafe to attempt to make any generalization as to the relation between latitude and gamma except to say that latitude usually decreases as gamma increases, and, therefore, as the time of development increases.

Curves of the type shown in Fig. 41 are frequently of great value in analyzing the characteristics of a photographic material, particularly from the standpoint of its behavior during processing. These are known as *time-gamma curves* and are obtained by plotting gamma as a function of development time. As has been mentioned, curve A is obtained by plotting the data shown in Table XI which were derived from the family of characteristic curves shown in Fig. 40. Curve B illustrates the results obtained by processing the same material in a different developing solution. It is evident from a comparison of the two curves that gamma increases at a much lower rate in the case of curve B, although if the development time is sufficiently lengthened gamma appears to be approaching the same limiting value.

The time-gamma curve is of use where it is desired to determine the development time which will yield some specified value of gamma. If such a curve is available for the material and the processing conditions being used, it is only necessary to read from the curve for any gamma value the corresponding development time. Such curves are also very useful in obtaining some idea as to the permissible variation in development time when it is desired to control processing so as to obtain gamma values lying within certain prescribed limits. For instance, let it be assumed that it is desirable to obtain a gamma of 0.6 and that the permissible variations from the value are set at ± 0.03. The corresponding permissible variation in development time can be readily determined for the two conditions represented by curves A and B. The horizontal dotted lines are drawn through gamma values of $0.60 + 0.03$ and $0.60 - 0.03$. Where these horizontal lines intersect with curves A and B, perpendiculars are dropped onto the development time, T_d, axis. In the case of curve A it is found that the development time must be held between 2.6 and 3.0 minutes, thus permitting a total allowable variation of 0.4 minutes which may be expressed as 2.8 ± 0.2 minutes. In case of the curve B it is found for the same tolerance in gamma, minimum time is 5.7 and the maximum 6.5, which may be expressed as 6.1 ± 0.4 minutes. It is evident, therefore, that the allowable error in development time for the required precision in control of gamma is twice as great in the case of curve B as for curve A. The relation between a given gamma increment and the corresponding development-time increment is, of course, given directly by the gradient of the $\gamma - T$ curve at any particular point. If it is desired, therefore, to express numerically this relationship, it is only necessary to evaluate the differential $d\gamma/dt$ at any given point. The value of the differential at any point is inversely proportional to what may be termed *processing latitude.* In other words, the greater the gradient of the time-gamma curve at any point, the more precise must be the control of processing conditions in order to maintain a given tolerance in gamma.

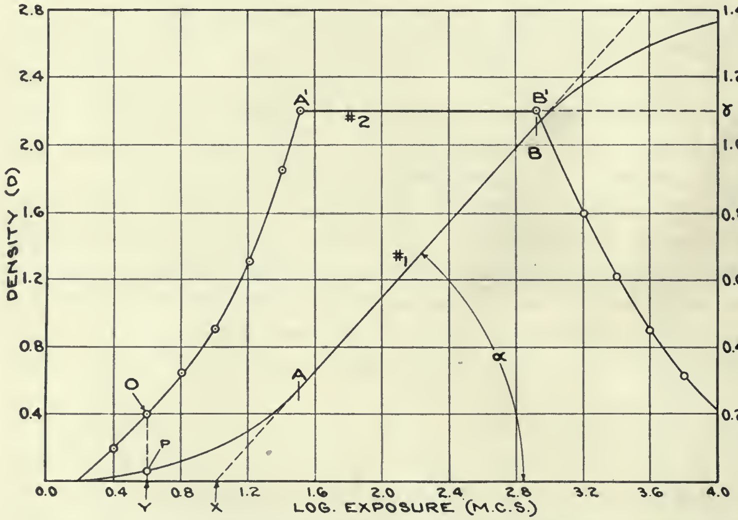

FIG. 42. Illustrating the general form of the first derivative, curve $OA'B'$, of the D-log E curve, AB.

Curve C in Fig. 41 shows the relation between fog and development time. Fog is determined by measuring the density of an area on the photographic material which has received no exposure but which has been developed. In general, for most photographic materials the value of fog is relatively low for the shorter times of development, but usually grows at an increasing rate as the development time is extended. Any value of fog which is given for a photographic material obviously must be accompanied by some specification of the development time or the extent of development (in terms of gamma) in order to have any definite significance. The complete T_d-fog curve is, of course, a complete representation of the relation between fog and the extent of development and in graphic methods of showing sensitometric results should be used rather than attempting to express this factor by a single numerical value.

In Fig. 42 another useful graphic form is shown. Curve No. 1 is the usual D-log E characteristic curve. Curve No. 2 is the first derivative of the characteristic curve. It is obtained by plotting values of gradient, dD/d log E, as a function of log E. This curve

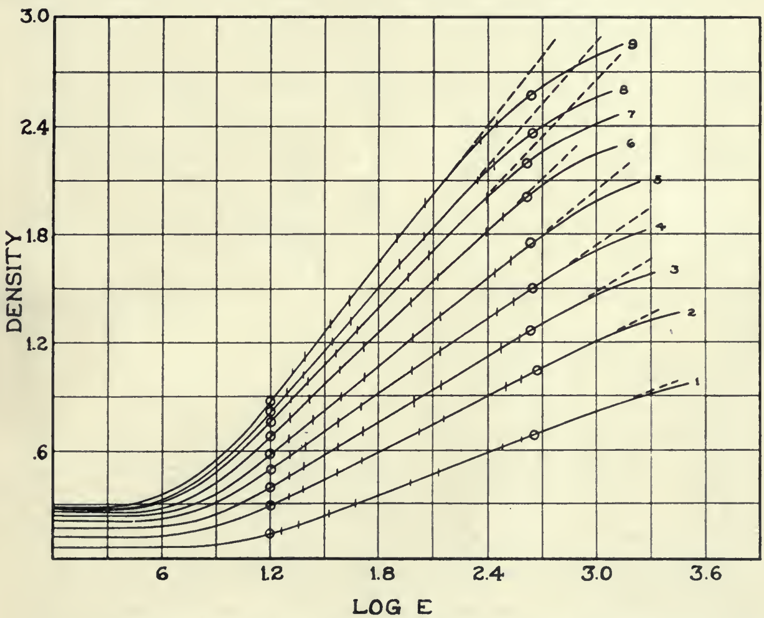

FIG. 43. Family of D-log E curves obtained by plotting densities as read, without fog correction.

shows somewhat more clearly the way in which gradient changes with log exposure. For the straight line portion of the curve lying between points A and B gradient is constant and equal to gamma. The first derivative curve throughout this region is a straight line parallel to the log E axis and having an ordinate value equivalent to gamma as shown on the gradient scale at the right of the figure. For values of exposure less than A and greater than B the first derivative curve takes the form as shown. This graphic form is useful where it is desired to determine precisely the exposure value corresponding to some particular slope of the D-log E curve. This form of presenting the data contains no more information nor can it be drawn with any greater precision than the D-log E curve itself, but for many purposes it presents the data in more convenient form and gives a more vivid mental picture of the relation between gradient and exposure.

All the characteristic curves thus far shown have been plotted from data which have been corrected for fog. For many purposes for which sensitometric work is done this procedure is to be preferred, but

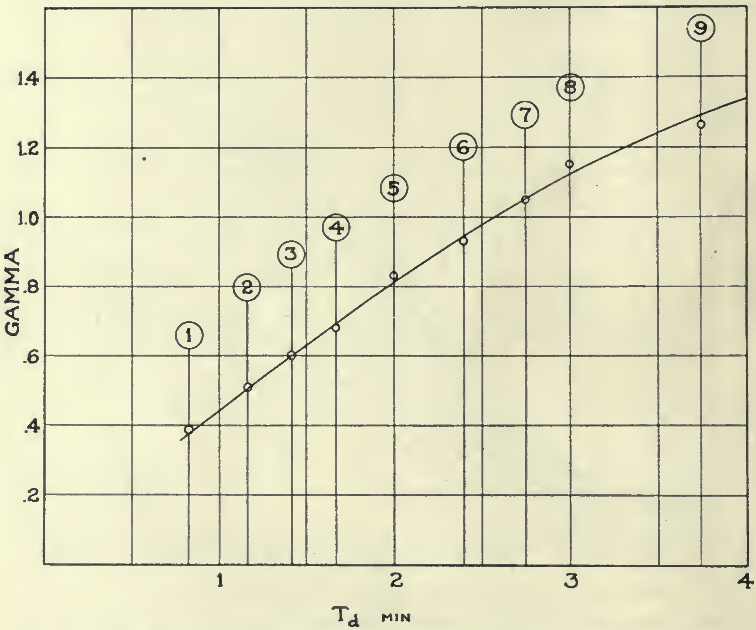

FIG. 44. The time of development-gamma curve derived from Fig. 43.

for certain practical purposes it may be preferable to deal with the sensitometric data without making the correction for fog. This is true, for instance, in certain problems relating to tone reproduction where it is desired to obtain information as to actual density differences in the negative corresponding to known brightness differences in the object, and also to compute the time of exposure required for the making of a positive from the negative. In such problems it is essential to deal with the actual density values on the negative rather than with the corresponding values which have been corrected for fog.

In Fig. 43 is shown a family of D-log E curves drawn from the measurements as read directly from the sensitometric strips without fog correction. It will be noted here that in the underexposure region the curves do not come down to the log E axis but become parallel to it at density values which are equivalent to the fog for the development times in question. In this group of curves it will also be noted that latitude decreases very markedly as the contrast or gamma of the characteristic curve increases. In Fig. 44 is shown the time-gamma curve plotted from values read from the curves in Fig. 43. This

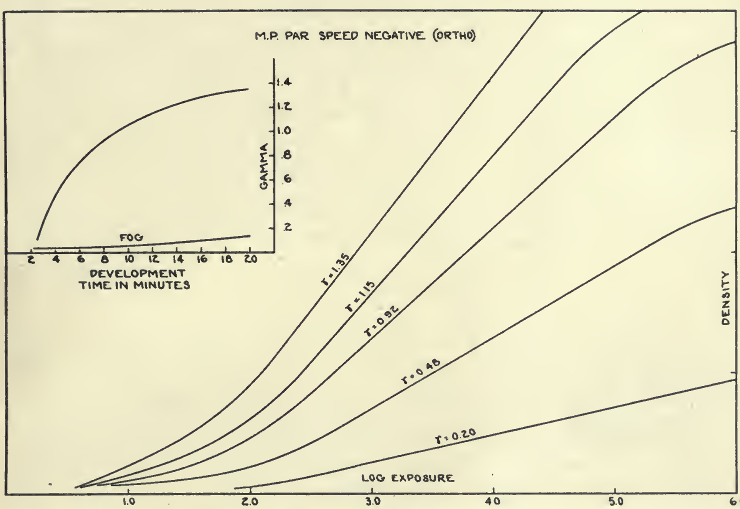

FIG. 45. The graphic representation of sensitometric characteristics of a high-speed negative material, including D-log E curves for various times of development, time of development-gamma curve, and time of development-fog curve.

curve, of course, represents the effective contrast as a function of development time. It should be remembered that the correction for fog changes the values of the measured densities by different amounts, this change being proportionately greater for the lower densities, thus modifying the magnitude of gamma. When the data are to be used in tone reproduction problems, careful attention should be given to this point.

Various ways of presenting sensitometric data in graphic form have now been considered and it is evident that in order to convey a maximum of information more than one graphic form is necessary. It has been found in practice that a complete family of D-log E curves obtained with various development times together with a time-gamma curve and a time-fog curve serves as a fairly satisfactory graphic

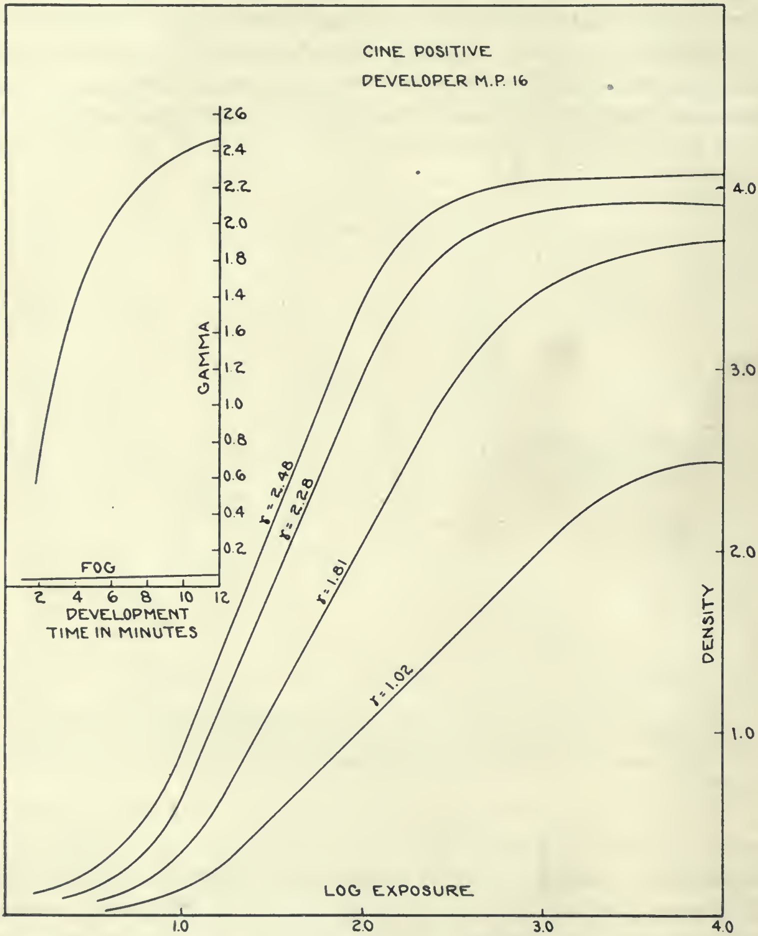

FIG. 46. The graphic representation of sensitometric characteristics of motion picture positive film, including D-log E curves for various times of development, time of development-gamma curve, and time of development-fog curve.

representation of the sensitometric characteristics. In Fig. 45 is illustrated one way in which these various functions may be conveniently shown together. The characteristic curves themselves are drawn in and the value of gamma for each is indicated. In the upper left-hand portion of the rectangle are shown the time-gamma and time-fog curves derived from the D-log E curves. The curves shown in Fig. 45 apply to a high-speed negative material for which gamma infinity is relatively low, being of the order of 1.4 to 1.5 as indicated by extrapolation of the time-gamma curve. In Fig. 46 is shown a similar group of curves for motion picture positive film which of course is a relatively slow, high contrast material. Having now dealt in some detail with the various graphic methods of presenting sensitometric data, the problem of deriving from these graphic forms certain significant numerical values, which may be used as convenient specifications of these sensitometric characteristics, will be considered. It is quite impossible to express completely by means of a relatively few numerical values all of the information contained in the various possible graphic forms which may be used in presenting these data. Such numerical values, however, are convenient when it is desired to summarize in tabular form the sensitometric characteristics of various materials for purposes of record and intercomparison.

SPEED OR SENSITIVITY

In the case of negative materials one of the most important characteristics about which information is desired is that of sensitivity or speed, and in the earlier stages of the evolution of photographic sensitometry great emphasis was placed on the determination of this characteristic. Several different methods of expressing speed have been evolved and have been used rather widely in this country and abroad. It may be of interest to consider the significance of these various methods of speed specification and the inter-relation between the resultant numerical values.

Threshold Speed.—One of the earliest methods used for the expressing of sensitivity was to specify the exposure required to produce a just perceptible density. In methods of sensitometry not involving the measurement of the developed densities this is the only feasible method of speed expression which can be used. This was adopted by Scheiner who devised a sensitometer which has already been described in an earlier section of this paper. The sector wheel in the Scheiner sensitometer was so cut that exposure increased logarithmically from 1 to 100 units. The distance between the points on the photographic material corresponding to these exposure limits was divided into twenty equal steps, numbered consecutively from 1 to 20. The

Scheiner speed scale, therefore, consists of numbers in arithmetic progression, 1, 2, 3, 4, *etc.*, from 1 to 20, covering the sensitivity range of from 1 to 100. Relative sensitivity represented by any given number in the scale is 1.27 times as great as the relative sensitivity corresponding to the next lower number in the scale. This relation is shown in Table XII, in the first column of which the Scheiner numbers are given, and in the last column will be found the corresponding relative sensitivity values. The consecutive numbers of the

TABLE XII

F/209 Intercomparison of Speed Values as Expressed by Various Well-Known Methods

Scheiner	Eder-Hecht	H & D	Watkins	Wynne	Relative
1	42	7	11	*F*/21	1.0
2	46	9	13	*F*/24	1.27
3	48	12	17	*F*/21	1.62
4	50	15	22	*F*/30	2.07
5	53	19	28	*F*/34	2.64
6	56	24	36	*F*/38	3.36
7	58	31	45	*F*/43	4.28
8	61	40	58	*F*/49	5.45
9	64	50	74	*F*/55	6.95
10	66	64	94	*F*/63	8.86
11	68	82	122	*F*/71	11.3
12	71	104	153	*F*/79	14.4
13	74	133	196	*F*/90	18.3
14	77	170	250	*F*/101	23.4
15	80	216	317	*F*/114	29.8
16	82	276	405	*F*/129	37.9
17	84	351	515	*F*/145	48.3
18	86	448	660	*F*/165	61.6
19	88	570	840	*F*/196	78.5
20	90	727	1065	*F*/209	100.0

Scheiner scale which increase in arithmetical progression correspond to a geometrical progression in relative sensitivity. The scale interval, therefore, is slightly greater than that given by using consecutive powers of the cube root of 2 in which the multiplying factor from step to step is the cube root of 2 or 1.26.

The Eder-Hecht sensitometer, as has already been mentioned, is of the tablet type consisting of a neutral gray wedge with a continuous gradient. On this are printed a series of numbers in arithmetical progression and equally spaced. This speed scale is, therefore, also of the logarithmic form, assuming that the neutral gray wedge has a constant gradient. The numbers actually used on the Eder-Hecht sensitometer tablet as compared with the Scheiner scale are as shown in the second column of Table XII.

While the threshold method of expressing sensitivity has certain features to recommend it, it leaves much to be desired from the standpoint of precision and significance. The magnitude of the least perceptible density depends profoundly upon the conditions under which the inspection is made. In fact, the judgment which is actually made is not that of least perceptible density, but least perceptible density difference. Under the most favorable conditions of observation, the human eye can detect a brightness difference of 1.7 per cent. This corresponds to a density difference of 0.008. Under other conditions of inspection, however, such as relatively low illumination and uncomfortable visual conditions, this just perceptible density difference may be easily as great at 0.04. It is evident, therefore, that, unless great care is taken to standardize and maintain the visual conditions under which judgment of the just perceptible density is made, values of threshold speed read from the same actual test strip may fluctuate over a considerable range. Furthermore, if conditions are adjusted to give maximum visual sensitivities so that a very slight density difference may be detected, such, for instance, as the value mentioned above, namely, 0.008, the absolute value of speed is rather high, regarded from the practical standpoint. For instance, the point on the toe or underexposure region of the characteristic curve where a density of 0.007 is obtained, is in almost all cases at a point of extremely low gradient. It is questionable whether the underexposure region at or near the point where D is equal to 0.008 is of any practical value. While it may be argued that the effective speed should be considered to go down into the region of low exposures to the point where a just perceptible density is produced, this seems somewhat fallacious, when it is considered that the real function of a photographic material is to reproduce, as perceptible density differences, the brightness differences which exist in the object. It seems, therefore, that we should be more concerned with the definition of speed in terms of the power of the material to reproduce satisfactorily some minimal contrast.

Inertia Speeds.—Hurter and Driffield in their work on photographic sensitometry suggested that the speed of a material could be specified satisfactorily in terms of the inertia. They proposed, therefore, the expression of speed as the reciprocal of the inertia multiplied by a constant for which they chose a value of 34. The use of this number gave a series of speed values of convenient magnitude for practical use. In the third column of Table XII are shown the H & D speed numbers in direct comparison with relative values as shown in the last column.

The Watkins speed scale is also based upon inertia, but instead of using 34 as suggested by Hurter and Driffield, Watkins adopted 68 as the value of constant k. The actual relation between the Watkins and H & D numbers, however, indicates that the Watkins constant is more nearly 50 than 68. In the fourth column of Table XII are shown the values of the Watkins speed scale in comparison with the other well-known systems.

The Wynne system of expressing speed is not used to any great extent but is of some interest. This is also based fundamentally upon inertia values but uses numbers which are expressed in terms of lens aperture as indicated by the symbol F which precedes the number. These numbers are proportional to the product of 6.4 by the square root of the Watkins number. A Watkins speed of 100 (equivalent to H & D speed of 68) gives a Wynne number $F/64$. This scale is shown in the fifth column of Table XII.

For many purposes and under many conditions, the expression of speed in terms of inertia is of great value. As long as all of the straight line portions of a family of D-log E curves pass through a common intersection point and this point lies on the log E axis, *inertia* and hence *speed* are independent of development time. Under such conditions the speed becomes a very significant constant for the photographic material. Unfortunately the existence of a common intersection point lying upon the log E axis is frequently not found in practice. In most cases of normal development a common intersection point is found, provided that proper corrections have been made for fog. This intersection point, however, very frequently lies below the log E axis and in relatively rare cases is located above that axis. This subject has been dealt with at great length by Nietz.[100] It has been found that in the presence of free bromide, whether it be in the developing solution or present in the photographic material itself, the intersection point is, in general, depressed to a position below the log E axis. Such a condition is shown in Fig. 47 which represents the straight line portions of a family of D-log E curves. Assuming for the moment that a common intersection point does exist, its coördinates may be represented by a and b as shown in Fig. 47, and it has been proposed to define the speed of the material in terms of the coördinates of this point. Under such conditions it is evident that the *inertia* is a function of gamma, and hence speed based upon inertia value will become a function of gamma, and a speed value of this nature can only be significant provided the corresponding gamma value is specified. For the purpose of certain theoretical investigations into the nature of exposure and development, a knowledge of the coördinates of the

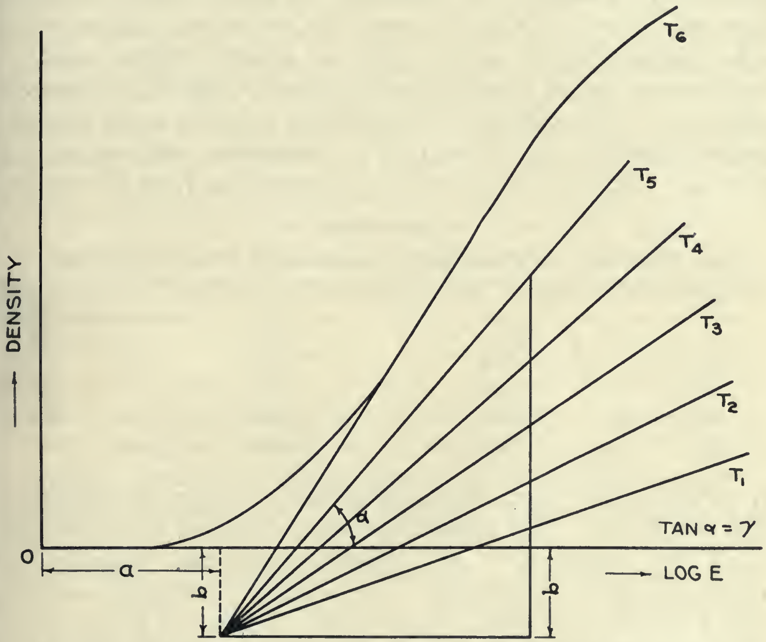

FIG. 47. The straight line portions of a family of D-log E curves illustrating the existence of a common intersection point below the log exposure axis, thus causing inertia to depend upon time of development.

intersection point, as shown in Fig. 47, may be of great value, but it does not appear to be very significant for the purposes of determining the practical speeds.

The extent of the dependence of the inertia speed upon gamma is illustrated in Table XIII. These data are derived from measurements made on a high-speed negative material processed in a developing solution containing some bromide. The straight line portions of the D-log E curves intersect at a point well below the log E axis. The development times, T_d, extend from 3 to 20 minutes, the corresponding gamma range being from 0.27 to 1.12. For this range in development, the reciprocal inertia changes from 22 to 140, a six-fold increase in speed as derived from inertia values.

The complication involved in expressing speed by means of the inertia does not end here. Many materials are found for which there is no single point of intersection for the straight line portions of the D-log E characteristics. In fact, some materials do not give very satisfactory straight line relations between density and log exposure. There is wide divergence in the relative shape of the underexposure regions and, in fact, an almost endless variety of conditions are found which makes it extremely difficult to generalize satisfactorily the expression of practical or effective speed of photographic materials for all purposes. Anomalous behavior in both shape and position of the D-log E curves resulting from development for different times seems to be particularly common in materials of high sensitivity. This subject has been discussed at considerable length by Sheppard.[101] He classifies emulsions generally into *orthophotic* and *anorthophotic* categories. Orthophotic materials show a definite convergence point of the straight line portion of the characteristic curves, while anorthophotic materials depart widely from this condition showing no tendency to give a common point of convergence. Sheppard concludes from his study of the subject that emulsions of the anorthophotic type have characteristics which are much less reproducible from batch to batch than those of the orthophotic class. In many fields of work reproducibility is highly important; for instance, when these materials are used as a means of making quantitative measurements in science and technology, when it is desired to employ automatic processing methods, and in those cases where it is desirable to make application of the laws of tone reproduction. It would appear that this demand on the part of the

TABLE XIII

Data Illustrating the Dependence of Inertia upon Time of Development

T_d	γ	i	$1/i$
3	0.27	0.045	22
5	0.43	0.020	50
8	0.68	0.012	82
12	0.83	0.010	100
20	1.12	0.007	140

users of photographic material for reproducibility may tend automatically toward the rejection of materials of the anorthophotic type. Hence photographic materials may respond to evolutionary laws, their characteristics tending to become predominantly orthophotic as a result of the survival of the fittest. While it is impossible to ignore the existence of certain materials which, during the course of development, do not even approach to the classical behavior required by H & D theory, it would seem that in the development of sensitometry greatest attention should be paid to the evolution of sensitometric systems applicable particularly to the materials which do approach to *normal* types. The case, therefore, is not quite as hopeless as it may appear and it does not seem unreasonable to assume the existence of a *normal* type behavior from which the great majority of materials used in large volume depart but little and in a known and specifiable manner. In any case it seems more profitable to take the position that normality and orderliness are the rule rather than to assume the attitude of destructive criticism and maintain that "all photographic materials are exceptions," thus abandoning the entire field of systematic sensitometry to chaos.

Luther's Crossed Wedge Method.—In the section dealing with sensitometers the crossed wedge method proposed by Luther[20] for obtaining directly the D-log E curve is mentioned. A few words relative to the interpretation of the results obtained in this manner seem to be in order. The envelope of the darkened area gives directly the D-log E characteristic. If the density and density gradient of each wedge are known, it is possible to establish the correct density and log exposure scales. The linearity of these scales, that is, the representation of a specified density or log E difference by a constant linear interval throughout the respective scales, requires that the density gradient of the wedges be constant, and also that the wedge density be uniform along any line perpendicular to the gradient direction. Considering the difficulties involved in the manufacture of wedges of satisfactory uniformity, both of density and density gradient, having sufficient freedom from selective absorption, and in the exact calibration of these wedges, it does not seem likely that the precision obtainable in the final result can be as great as that resulting from the exposure of the photographic material in a well-designed and carefully operated sensitometer of the time-scale type followed by the measurement of density with suitable densitometers. However, as a rapid and convenient means of testing, the method has much to commend it. Yielding as it does the typical D-log E curve, the interpretative methods are identical to those applicable to similar curves obtained by other methods, and values of the usual factors, such as gamma, inertia, fog, *etc.*, may be derived.

Minimum Useful Gradient.—Thus far two methods for the expression of sensitivity or speed have been discussed, one based upon exposure corresponding to a just perceptible density (Schwellenwert), and the other based upon the value of inertia read at the point where the straight line portion of the D-log E curve cuts the log E axis. While both of these methods have certain points to commend them, both also have very serious deficiencies. Threshold speeds are not independent of the time of development and therefore cannot be said to be strictly a constant of the photographic material. Moreover, the absolute value obtained under inspection conditions yielding maximum visual sensitivity gives a speed which is too high, when it is desired to compute the exposure required for the satisfactory rendering of detail in the shadow regions of the object. It has been seen, further, that speed values based upon inertia are dependent in many cases upon time of development and hence require an accompanying expression of gamma in order to be significant. Even under these conditions, the absolute value of speed is not very useful in computing the exposure time required in order to give satisfactory rendering of shadow detail. A study of a large number of characteristic curves shows that the gradient corresponding to the inertia value varies between wide limits. When it is considered that the chief function of a photographic negative material as used in practice is to reproduce as density differences the brightness differences existing in the object photographed, it seems logical to demand that the minimum useful exposure be determined by some specified gradient of the D-log E characteristic. This idea has been discussed by Luther[102] and its use advocated by him, especially in cases where the fog of the emulsion is relatively high. The subject has also been discussed at some length by Jones and Russell.[103]

There seems to be little doubt that this idea is based on a sound theoretical foundation. The difficulty met, however, is that of deciding upon the value which is to be taken as representing the minimum useful gradient. Luther suggested that this value should be 0.5. Judging from data available in publications by Goldberg and found in a paper by Jones[104] dealing with the contrast of photographic printing papers, it appears that this value is too high and that satisfactory reproduction of object detail can be obtained by utilizing portions of the characteristic curve of lower gradient. The subject has also been discussed by Sheppard[101] who states that the minimum useful gradient "will in general depend not only upon the negative but also upon the positive aspect of tone reproduction so that its fixation is not expressible by a unique function of the negative material itself." This conclusion is undoubtedly correct and its validity is supported by the data and the discussion given by Jones (*loc. cit.*).

It seems quite possible, however, for certain definite classes of work

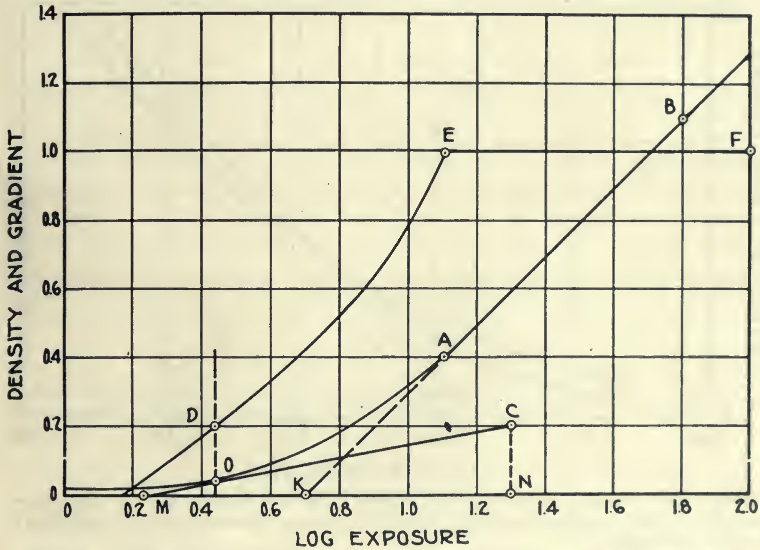

FIG. 48. *D*-log *E* curve, *OAB*, and its first derivative, *FED*. The construction illustrates the method of finding the relation between gradient and log exposure.

to establish a value of minimum negative gradient in terms of which sensitivity or speed may be expressed in a manner of considerable practical utility. For instance, from a knowledge of common practice which results in acceptable tone reproduction in the field of motion picture photography, it is possible to draw fairly definite conclusions as to the minimum useful gradient of negative materials used in this work. This knowledge is based upon careful densitometric analyses of a large number of motion picture negatives and positives. The value indicated by the available information lies between 0.2 and 0.3. A similar value is known to represent fairly well the conditions existing in the field of amateur photography. It is not possible with the information available at the present time to say definitely whether or not a fixed value of minimum limiting gradient can be chosen which would be satisfactory in all fields and, if so, just what the absolute value of this quantity should be. It is definitely known, however, that in the motion picture field and in the amateur field practically all negatives utilize the greater portion of the underexposure region of the D-log E characteristic. Furthermore, it is logical to conclude that the toe of the characteristic curve below

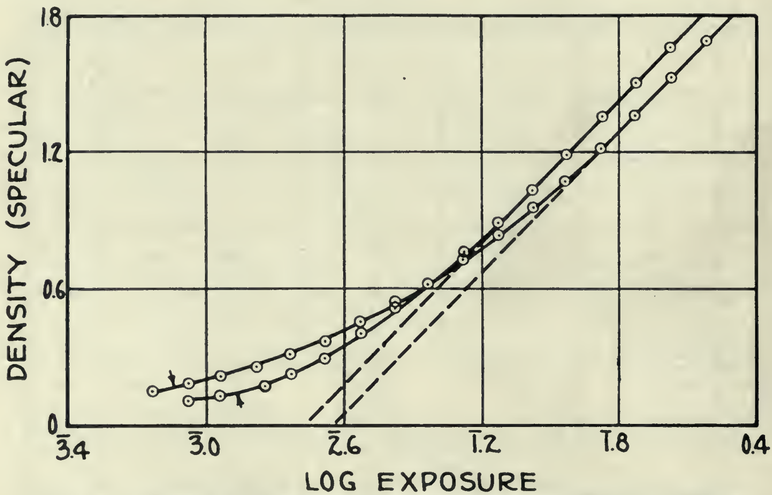

FIG. 49. Typical D-log E characteristic curves illustrating the disagreement between speed values based upon inertia and those based upon minimal useful gradient.

some definite value of gradient is too flat for satisfactory reproduction of object brightness differences. It seems desirable, therefore, to give this suggested method for the specification of speed very careful consideration and some data based upon an arbitrary assumption of the value of minimum limiting gradient may be of interest. For this purpose a value of G equal to 0.2 will be assumed.

In Fig. 48 the most precise method of determining the exposure value corresponding to this specified gradient is illustrated. Curve OAB represents the underexposure and part of the correct exposure region of the D-log E characteristic, curve FED being its first derivative. Through the gradient value of 0.2 a horizontal line is drawn which establishes point D. A perpendicular dropped from this point cuts the characteristic curve at point O, which is the point having the gradient of 0.2. The exposure value, E_m, corresponding to the point O, is that desired in order to express speed in terms of a minimum useful gradient equal to 0.2. Speed and sensitivity are of course inversely proportional to E_m.

A typical case which illustrates the merits of this method of expressing speed is shown in Fig. 49. The two materials illustrated have been developed to the same gamma, and on the basis of the inertia method of expressing speed; the material of which the straight line

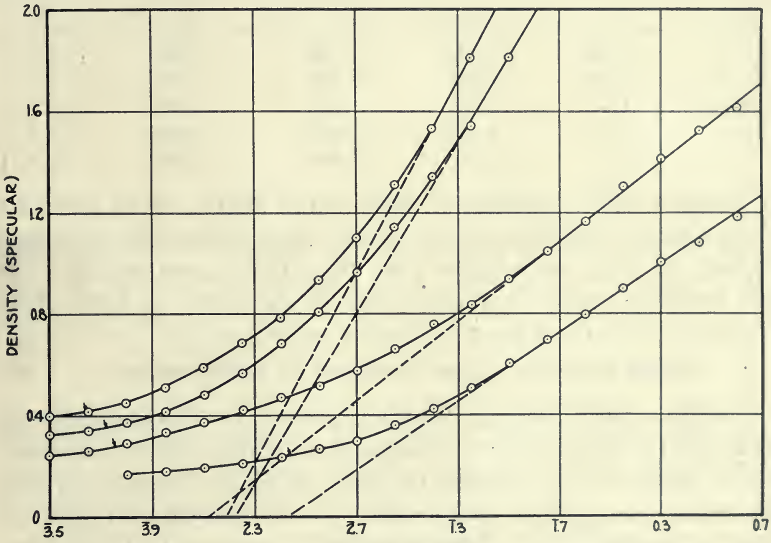

FIG. 50. Family of D-log E curves illustrating the dependence of minimum useful gradient speed upon time of development.

portion cuts the log E axis farthest to the left has the higher speed of the two. The small arrows indicate the points on the underexposure region where G is equal to 0.2. It will be seen that the minimum limiting gradient method reverses the speeds of the two materials. If we express inertia speed as 10 times the reciprocal of the inertia and the gradient speed as 10 times the reciprocal of E_m, the numerical results derived from Fig. 49 are as follows:

	$10/i$	$10/E_m$
A	220	1360
B	269	720

Further illustration of this suggested method is given in Fig. 50 in which are shown the underexposure regions of four D-log E characteristic curves obtained by using different times of development. Again, the points of gradient equal to 0.2 are indicated by the small arrows attached to each curve. In the case of the shortest time of development it will be noted that the gradient for 0.2 is obtained for

TABLE XIV

Data Illustrating the Relation between the Values of Speed Based upon Inertia, i, and Those Based upon the Exposure, E_m, Corresponding to the Minimum Useful Gradient

T_d	γ	Fog	i	E_m	R
1.5	0.68	0.15	0.045	0.0280	1.6
2.0	0.80	0.22	0.025	0.0058	4.3
4.5	1.7	0.32	0.026	0.0053	4.9
6.0	2.0	0.47	0.024	0.0044	5.5
9.0	2.6	0.51	0.033	0.0050	6.6

an exposure value practically equal to the inertia value, while for longer times of development the speed values based upon minimum gradient are very much higher than those based upon inertia. The data derived from the curves in Fig. 50 are shown in Table XIV. The ratio of i to E_m is given in the last column.

GAMMA INFINITY, γ_∞, AND CONSTANT OF DEVELOPMENT, K

The importance of gamma infinity, both for theoretical and practical sensitometry, already has been emphasized and in Fig. 41 an experimental method of determining the value of gamma infinity has been illustrated. In certain cases, similar to that illustrated in Fig. 40 where development takes place in the manner assumed by the classical H & D theory, it is quite possible to compute from the data contained in two or more D-log E curves a theoretical value for *gamma infinity*. Along with this may be derived the value of K, the *velocity constant of development*. According to the method introduced by Sheppard and Mees,[105] this computation is based upon the gamma values obtained from two D-log E curves, for one of which the development time is twice that of the other. The necessary data are therefore derived from a pair of curves such as those shown in Fig. 39 where this ratio of development times was used. From theoretical considerations it can be shown that the relation between development time and growth of gamma can be expressed by the equation

$$\gamma = \gamma_\infty(1 - e^{-Kt}) \qquad (1)$$

By substituting in this equation values of gamma and time of development obtained from curve No. 1, equation (2) is obtained, and similarly by using values of gamma and the time of development read from curve No. 2, equation (3) is obtained.

$$\gamma_1 = \gamma_\infty(1 - e^{-Kt_1}) \tag{2}$$

$$\gamma_2 = \gamma_\infty(1 - e^{-Kt_2}) \tag{3}$$

Combining (2) and (3) we obtain

$$\gamma_1(1 - e^{-Kt_1}) = \gamma_2(1 - e^{-Kt_2}) \tag{4}$$

Since

$$t_2 = 2t_1$$

$$\frac{\gamma_2}{\gamma_1} = 1 + e^{-Kt_1} \tag{5}$$

$$\frac{\gamma_2 - \gamma_1}{\gamma_1} = e^{-Kt_1} \tag{6}$$

$$K = \frac{1}{t_1}\log_e \frac{\gamma_1}{\gamma_2 - \gamma_1} \tag{7}$$

$$\gamma_\infty = \frac{\gamma_1}{1 - e^{-Kt_1}} = \frac{\gamma_2}{1 - e^{-Kt_2}} \tag{8}$$

From the known values of γ_1, γ_2, t_1, and t_2 it is therefore possible to compute values of γ_∞ and K. From any other pair of characteristic curves for which the times of development are related by the expression $t_2 = 2t_1$, additional values of these constants may be computed which should, of course, check those based on any other similar pair of sensitometric curves. It should be emphasized that these theoretical relationships do not hold in all cases, their validity depending upon the *normality* of the family of D-log E characteristics as judged by the requirements of the H & D theory.

By differentiation of equation (1) the relationship

$$d\gamma/dt = K(\gamma_\infty - \gamma)$$

is obtained. Now $d\gamma/dt$ is the slope of a time-gamma curve such as that shown in Fig. 41. The values of this gradient can be determined graphically from an experimental time-gamma curve for any value of gamma, and if gamma infinity is known, having been determined, let us say, experimentally as illustrated in Fig. 41, it is possible to compute the corresponding value of K. All values of K computed in this way for various values of gamma should, of course, be the same provided the curve is of the exponential form. It is found in practice that when such a time-gamma curve is derived from a *normal* family of characteristic curves, and when the experimental determination of γ_∞ is valid, this condition, K equal to a constant, is fulfilled. In many cases, however, the value of K, computed from different assumed values of gamma and corresponding graphically determined values of $d\gamma/dt$, is not constant. This is evidence of *abnormality* in the time of development-gamma relation and can usually be traced back and found to be due to improper correction for fog, lack of a common convergence point, or other departures from what may be termed the *normal* behavior.

Certain development characteristics of any particular photographic material may be deduced from the values of γ and K.

For instance, if K is high and γ_∞ is high:

Development will start quickly, proceed at a high rate, and gamma will continue to build up to a high value. Process plates and motion picture positive film are typical examples of the materials having these characteristics.

If K is high and γ_∞ is low:

The image will flash up quickly and γ will build up rapidly at first but soon cease to increase, reaching a limit at a relatively low value. In the case of these materials the image appears very quickly but fails to carry through and build up high densities.

If K is low and γ_∞ is high:

Development starts slowly and γ increases at a relatively low rate, but by extending the time of development the value of γ may be built up to a high value.

If K is low and γ_∞ is low:

Development starts slowly, γ increasing at a relatively low rate which very soon decreases and flattens out at a final low value. Further development will not serve to increase contrast.

TIME OF DEVELOPMENT FOR A SPECIFIED GAMMA, $T_{\gamma=x}$

In practical specification of sensitometric characteristics it is sometimes desirable to measure directly, in terms of a single constant, the dependence of gamma or contrast on time of development. Such a figure combines to a certain extent the information contained in the values of γ_∞ and K and usually is more easily obtained. This is accomplished by stating the time of development required to give a specified gamma. In choosing the gamma value for which this time of development is stated, it is, of course, desirable to use the contrast to which the material is in practice usually developed. It is, of course, impossible to find any single value of gamma which fits the requirements of all possible classes of photographic work. In some cases as, for instance, motion picture photography, the negative is usually developed to a relatively low gamma such as 0.5 or 0.6. In the amateur field somewhat higher gammas are usual. In portrait work it seems probable that a gamma of 0.8 represents a fair practice. In commercial work this value is unity or even somewhat above, while in process work gamma is pushed as near as possible to γ_∞, practical values lying between 1.8 and 3.0. In the case of motion picture positive film it is probable that a gamma of 1.8 represents a fair average. For the purposes of preparing tables showing relative sensitometric characteristics, a gamma value of unity is usually chosen, the time of development required by various materials to obtain this value under standardized processing conditions being determined. This factor is usually expressed symbolically as $T_{\gamma = 1.0}$.

LATITUDE, *L*

Latitude has already been defined in the earlier discussion and the method of determination explained. As stated previously, latitude varies with gamma and therefore only has significance when accompanied by a statement in terms of gamma of the extent to which development has been carried. Various attempts have been made to find a theoretical or analytical expression relating latitude and gamma. While some equations have been proposed, none of these seem to be of sufficient general validity to warrant consideration. It is customary, therefore, to determine latitude graphically directly from the plotted characteristic curves. It is usual to express latitude in the form of the ratio of the maximum to the minimum exposure lying on the straight line portion of the curve. A knowledge of latitude is in certain classes of work of considerable importance. It defines the ratio of object brightnesses which may be rendered by the material, when developed to the gamma specified, without non-linear distortion of the object contrasts. For most high-speed negative materials, the magnitude of gamma is considerably greater than the ratio of maximum to minimum brightness in average photographic subjects under normal illuminations. It is extremely unusual in out-of-door work to encounter subjects in which the contrasts, that is, ratio of maximum to minimum brightness, is greater than 100. Extreme cases show values as high as 250, but these are rare. In studio work it is, of course, possible to obtain artificial lighting in which the contrast is greater than that mentioned above. However, the measurement in a great many portrait and motion picture studios indicates that in this class of work contrast seldom exceeds 100 or at the most 200. For the low values of gamma usually used in motion picture studio and portrait work, it is not infrequent to find that the photographic materials have latitudes well above 500 and in some cases greater than 1000. For the low-speed, high-contrast materials, *latitude ~~gamma~~ of course is much lower. Here again the value will depend upon the extent to which the material is developed. For the high contrast to which motion picture positive film is usually developed, a latitude of 32 to 64 is usual.

FOG, *F*

The definition of fog and the method of measurement has already been defined in the previous discussion. Its value is dependent upon the extent to which development has been carried and of course is profoundly influenced by the composition of the developing solution. In giving fog as a sensitometric value it is necesaary, therefore, to specify both the composition of the developer used and the extent to which development has been carried usually in terms of gamma. As stated previously complete information as to fog giving propensities of photographic material is shown best in graphic form by the time of development-fog curve as illustrated in Fig. 41. In cases where the time of development required to give gamma of unity and inertia for gamma of unity are given, it is customary to express fog also for gamma of unity.

TABLE XV

Sensitometric Constants of Typical Photographic Materials

Material	F	K	γ_∞	T_d-($\gamma = 1.0$)	L	i	$10/i$
Motion picture film super-speed	0.15	0.24	1.6	4.0	400	0.010	1000
Motion picture film normal	0.10	0.20	1.8	4.0	300	0.017	600
Motion picture film positive	0.03	0.30	2.8	1.5	50	0.330	30
Portrait film normal	0.08	0.20	1.6	5.0	200	0.020	500
Portrait pan film super-speed	0.15	0.24	1.6	4.0	300	0.010	1000
Amateur film, fast	0.10	0.16	1.8	5.0	150	0.017	600
Amateur film, normal	0.07	0.18	1.6	5.5	80	0.025	400
"Press" plate	0.15	0.16	1.8	5.0	100	0.010	1000
Commercial ordinary	0.05	0.18	2.5	3.0	75	0.040	250
Commercial ortho	0.08	0.19	2.2	3.2	75	0.028	350
Commercial pan	0.10	0.20	2.0	3.5	100	0.020	500
Process plate ordinary	0.04	0.28	3.0	1.5	25	0.250	40
Process plate pan	0.08	0.28	3.0	1.5	25	0.067	150
Lantern plate	0.03	0.32	3.2	1.2	25	0.650	15

* as per letter from Editor of SMPE Jr. 12-24-32

In Table XV are shown some typical numerical sensitometric values for a variety of photographic materials. The values given do not refer to any particular material but represent a fair average of materials which fall within the classifications as indicated in the first column. They neither represent the best now available nor the "ideal" material in each class, but specify the characteristics that may reasonably be expected of these materials. The various sensitometric constants tabulated and the specification of conditions under which the determinations were made are as follows:

All of the sensitometric strips were developed in a solution made up according to the two-solution pyro formula given in the section on development* used at a temperature of 20°C.

F. The particular value of fog given is that obtained for the development time giving $\gamma = 1.0$

$T_d(\gamma = 1.0)$. This is the development time in minutes required to give a $\gamma = 1.0$.

γ_∞. The value of gamma infinity shown in the table is that determined experimentally by extrapolation of the time-gamma curve. In the construction of this curve, development time was sufficiently prolonged so that the curve showed a definite tendency to become parallel to the D-log E axis, thus decreasing the amount of extrapolation required to obtain a fair estimate of the value of γ_∞.

K. The values for this term as shown in the table were computed from the equation $d\gamma/dt = K(\gamma_\infty - \gamma)$. By determining graphically the slope of the time-gamma curve at the point where $\gamma = 1.0$, the value of $d\gamma/dt$ at that point was obtained and when substituted in the equation above, together with the already experimentally determined value of γ_∞, permits the computation of K. The values shown in the table, therefore, may be termed the instantaneous value of K for the condition $\gamma = 1.0$, and consequently for the time of development as shown in the fourth column. Since many photographic materials do not conform to the classical H & D theory with respect to growth of gamma with increasing development times, it follows that K cannot be regarded strictly as an invariant constant for all materials. It seems, therefore, that from the practical standpoint a value of K, as determined above, may be of somewhat greater value than one computed as previously described by using two D-log E curves obtained for development times of T and $2T$, respectively.

* *J. Soc. Mot. Pict. Eng.*, **XVII** (November, 1931), No. 5, p. 700.

Obviously it is, of course, possible to put the value of K and γ_∞ shown in the table back into the above equation and compute $d\gamma/dt$. The value of this term, as has already been pointed out, is useful in obtaining some idea as to the *processing latitude* of the material, that is, the variation in the time of development which is permissible for a specified gamma tolerance.

L. The values of latitude shown are those given by the material when developed to a contrast at which the material in question is customarily used. This conveys definite information as to the log exposure scale which can be rendered with non-linear distortion.

i. Values of inertia are those of exposure at the point where the straight portion of the characteristic curve having a gamma value of 1.0 cuts the log E axis. They are expressed, of course, in terms of visual candle meter seconds, *m.c.s.*, of radiation of daylight quality.

10/i. Sensitivity values given in the last column of the table are obtained by using 10 as a constant in the expression for speed

$$S = \frac{1}{i} \cdot k$$

The constants as shown in Table XV are probably as useful as any for the purpose of specifying numerically the characteristics of a photographic material. Emphasis should again be given to the statement already made to the effect that it is hopeless to attempt to convey in any set of numerical values as much information as can be deduced from a complete set of graphical representations of the sensitometric data. While numerical constants are very convenient and useful for many purposes, they should not be expected to serve as a substitute for the more comprehensive graphic representation.

From a consideration of what has already been said relative to the interpretation of sensitometric data, it should be evident that it is quite impossible to formulate any single interpretative method which will meet the requirements of all of the purposes for which sensitometric data may be required. Interpretation must depend to a great extent upon the use for which the information is intended. For purposes of standardization sensitometry, it may be desirable to adopt a single developer in which all materials to be compared are developed, and to express a group of numerical constants derived in such a manner as to facilitate intercomparison between the various materials. For the control of uniformity of product an entirely different procedure may be necessary. For instance, it may be necessary to adopt a particular developing solution and technic for each different material, and to maintain this with high precision over long periods of time. Emphasis may be laid upon the determination with utmost precision of some particular characteristic, such as speed or contrast for fixed time of development. From the standpoint of the user of a photographic material it may be necessary to establish a sensitometric procedure which duplicates precisely the processing conditions which exist in practice, and lay particular stress on the maintenance of this equality at the expense of other factors. If, for instance, sensitometric data are to be used for the control of the uniformity of the product turned out by continuous developing machines in the motion picture laboratory, great care must be taken to insure that the sensitometric strips are developed under conditions identical to those occurring in the developing machine. If such is not feasible, it is necessary to establish, by an extended series of experiments, a correlatoin between the results obtained by some adopted sensitometric conditions and those existing in practice. It is quite possible that it may be necessary to develop particular methods for analyzing the data. For instance, in the sensitometric work done in connection with the photographic reproduction of sound it is frequently more convenient to plot transmission of the silver deposit as a function of log exposure. In such cases, of course, it is only necessary to transform density to transmission and plot this as a function of log exposure. The analyses of these curves require special treatment. It may be useful for some purposes to express transmission as a function of exposure rather than of log exposure. There are almost numberless variations in interpretative methods. It is quite impossible to treat all of these completely at this time, but it is hoped that the subject matter which has been presented may form a foundation upon which further elaboration of analysis and interpretation may be built.

(*Concluded in the March issue of the* JOURNAL)

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THERMIONIC TUBE CONTROL OF THEATER LIGHTING*

BURT S. BURKE**

Summary.—*The development of thermionic tubes has opened an entirely new field in control of theater lighting. This development has made possible the obtaining of preset dimming proportional dimming, and a small compact switchboard such as has been heretofore impossible.*

The preset dimming feature allows an operation whereby a board may be set up for any desired number of effects in advance, so that these effects may be called for at the will of the operator by operating a single control. This feature might be termed an ability of the switchboard to learn effects and bring them out when called upon by its master, the operator.

Proportional dimming, a new feature, allows the lights to be controlled in such a manner that they may be dimmed out in combinations while retaining the same color tone throughout the dimming process.

The third desirable feature is that a small compact control board may be so arranged that it can be placed as desired in the orchestra pit, or some similar location so that the operator becomes a light artist, taking his place in the performance along with the organist or other artists.

In the past 15 years the equipment for controlling illumination in theaters has developed from the simple knife-switch type of switchboards to the complex arrangement of circuits and dimmers which are required by the elaborate stage productions of the present day. Two general qualities are essential in a modern theater switchboard: flexibility in the selection of circuits, and flexibility in controlling the light intensity of these circuits. The first has been well provided for in the various types of multi-preset switchboards which have been built for the past several years. The second requirement, as provided for in the dimmer systems which are built into the usual multi-preset switchboard, leaves much to be desired.

In the past three years a new means for controlling the intensity of the light circuit has become available. The development of thermionic devices for industrial uses has made possible new systems for accomplishing the complex lighting effects required in modern

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

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theaters. Architects, illuminating engineers, and theatrical producers are now able to use lighting in ways that have never before been possible.

The thermionic tubes used in theater lighting equipment have been of the hot cathode grid-glow type, whose output may be regulated by properly controlling the grid circuit of the tube. The whole control system consists briefly of a reactance type dimmer, similar to the reactance dimmers which have commonly been in use for many years, a thermionic tube unit for supplying direct current to saturate the reactance dimmer and a control means consisting of a network of potentiometers for properly controlling the output of the tube unit.

A system of this type was used for the control of the stage and auditorium lighting of the new Los Angeles theater which was opened January 30, 1931. This paper will describe this equipment, which is typical of the thermoionic tube type of control for theater lighting.

The Los Angeles theater, similar to many theaters of its size, is equipped for both motion pictures and stage presentations. On this basis, the control switchboard was split into two parts, one of which was located in the projection room for controlling the auditorium lights, and the second of which was located at the stage floor for controlling the stage lights. On the stage floor is also located a remote panel which allows the operator to obtain color master control of the auditorium circuits as well as control of the five-scene preset arrangement which will be desired later. Dual control for the footlights, the first border, the orchestra floods, and the stage floods is provided so that these circuits may be controlled either from the stage floor or from the projection room. A transfer scheme is used to transfer these controls from one place to the other so that no interference of control is possible.

Each of these two switchboards consists essentially of a reactance dimmer bank, a set of tube units for use in connection with the d-c. coils of these reactors, and a control board used to control the output of the tube unit, thus indirectly controlling the intensity of the lighting circuit.

The reactance dimmers are similar to the standard theater duty reactance dimmer in that they consist of a-c. coils and a d-c. coil mounted on an iron core. The reactance of the dimmer is varied by changing the amount of direct current in the d-c. leg of the reactor, thus varying the saturation of the iron. With no direct current in this coil, the iron is unsaturated and of very high reactance, thus dimming out the light circuit with which it is associated. By increasing the direct current the iron becomes saturated, so that the reactance of the dimmer becomes lower, thus increasing the voltage across the lamps and bringing them up to full brilliancy.

The direct current supplied to the coil of the reactance dimmer comes from the thermionic tube unit which consists of two grid-glow tubes, a control tube, and the requisite transformers for supplying the proper filament and plate voltages for these tubes. The tube unit receives its power from the 115-volt, 60-cycle, single phase mains, which is applied to the two grid-glow tubes through a suitable transformer in order to obtain the proper voltage on the plates of the tubes. The a-c. voltage is rectified by these tubes and the resulting rectified alternating current is impressed on the coil of the reactor. The magnitude of the d-c. output of the tube unit is varied by changing the relation of the grid voltage to the plate voltage of the grid-glow tubes. This is done by means of the control tube, which is a vacuum tube similar to the standard *UX-226* tube used in radio circuits. The output of this control tube is varied by a system of potentiometers located on the control board which will be described in the following paragraphs. One set of these tube units was mounted on the reactor bank located in the projection room for the auditorium lights, and a second set of the tube units was mounted on the reactor rack located in the basement which was for the stage lights.

The two control switchboards, one located in the projection room for the auditorium circuits, and the second located on the stage floor for the stage circuit, are similar except for the circuits controlled, and may be briefly described as follows:

For the control of each individual circuit there is provided a pilot switch, a selector switch, an indicating lamp, 5 preset potentiometers, and an individual control potentiometer. In addition to this there is provided for each circuit a scene-fader by means of which it is possible to fade from one effect into the next effect giving a gradual transition from one to the other. These faders are ganged together and have a common drive, operated either by a handwheel or a motor.

The pilot switch serves a purpose similar to that of the pilot switch on the standard switchboard. That is, one throw of the pilot switch connects the circuit directly to a hot-bus connection so that the circuit may be controlled independently of any of the master set-ups. A second position of this switch connects the circuit through a color master control so that it is possible to control an entire color by means of a single color master. The middle position of the switch is the *off* position. The pilot lamp is wired in connection with the pilot switch so as to indicate when the circuit is hot; that is, when the switch is thrown directly to the hot bus position or when the pilot switch is thrown to the color master position and the color master is energized.

The selector switch is used for transferring the control from the individual control potentiometer to the preset potentiometer. In one position of this switch the grid lead from the tube circuit is connected to the moving arm of the individual potentiometer. In this position, the output of the tube circuit may be controlled by manipulating the individual potentiometer, and it is not affected by any changes made in the preset potentiometer. In the second position of the selector switch the grid lead is connected through the fader to the preset potentiometer. In this position the circuit is controlled through the preset control by means of which the intensities of the circuit may be set for five scenes in advance.

Regarding the operation of the preset potentiometer, let us first go back to the operation of the tube unit. As has been previously stated, the output of the tube unit, and consequently the intensity of the lighting circuit, is changed by altering the grid potential on the control tube. The grid potential is obtained through a system of potentiometers from the d-c. control source as indicated on the attached diagram. (Fig. 1.)

This preset operation is accomplished by two methods, one of which allows a gradual fading from one effect to the next and a second of which permits the operator to flash immediately from the effect in progress to any other effect that has been previously set up. These two operations are accomplished by means of the dimming fader and the multi-contact flashing relays as described in the following paragraphs.

One dimming fader is provided for each circuit. In addition to this there are five multi-contact flashing relays, *1* to *5*, and a fader disconnecting relay (*I*). (Fig. 1.) One contact of each relay is connected in each control circuit as shown on the diagram. The normal position of the relays for operating through the dimming fader is to have relays *1* to *5* open and relay (*I*) closed. Now to set up circuit No. 1 for full intensity the slider of preset potentiometer No. 1 is moved to the positive end of the potentiometer. To set up circuit

No. 2 for black-out the slider is moved to the negative end. In order to obtain intermediate intensities on the other scenes, the sliders are moved to intermediate positions corresponding to the intensities desired.

Now assuming that the switchboard is operating on scene No. 1, the pointer of the dimming fader will be connected to point 1 on this piece of apparatus. In order to transfer to scene No. 2, the dimming fader, which consists of a unit for each circuit to be controlled on a common drive is moved either by a handwheel or by means of a motor drive to position No. 2. It can be seen, therefore,

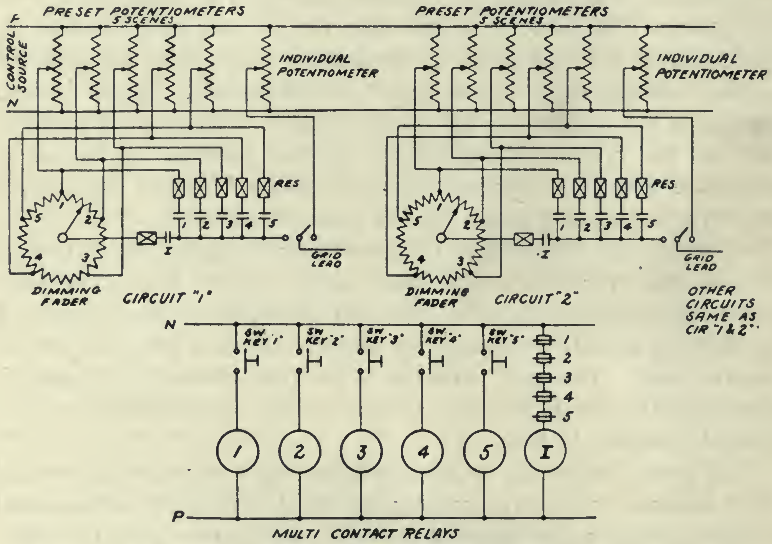

FIG. 1. Schematic diagram of scene flashing control thermionic type theater switchboard.

that since point No. 1 of the dimming fader is connected to the slider of preset potentiometer No. 1 and is therefore at the same potential as its preset for this scene, and since point No. 2 is connected to the slider of preset potentiometer No. 2, there is a gradual transition from the potential set for preset No. 1 to that for preset No. 2. This gives a gradual change on the potential impressed on the grid circuit of the tube unit, and, therefore, a proportional change in the lighting circuit.

A similar operation is also performed to transfer from scene No. 2 to scene No. 3. It is, furthermore, possible with this type of equipment to set up the scenes not in use for additional effects without affecting the scene in progress.

The purpose of the scene flashing equipment is to allow the operator to transfer immediately from the effect that may be set up from one scene to the effect set up for any other scene and have all the lighting circuits come to the desired preset intensity. This is accomplished by means of the relays, *1*, *2*, *3*, *4*, *5* and *I* which operate to disconnect the grid lead from the scene fader and connect it to the preset potentiometer associated with the relay selected. Thus the potential which has already been set up on this potentiometer is applied to the grid lead of the tube unit and a corresponding intensity of the lighting circuit results. When any other relay is operated, the relay previously closed is automatically disconnected by means of the switch keys, which are interlocked.

In order to obtain color master operation of any of the circuits, as has been previously described, the pilot switch is thrown to the color master position. This transfers the lead to the positive end of the control potentiometer from the positive bus and connects it to the sliding arm of the color master potentiometer. Thus it may be seen that the voltage on all the potentiometers connected to this particular color master is varied by moving its sliding arm. Consequently, a proportional change in the voltage impressed on the sliding arm of the individual potentiometers is obtained, which results in a proportional change in the lighting intensity of the circuits connected to these controls. Thus, if one of the circuits connected to this color master is at full brilliancy, a second at $^3/_4$ brilliancy, a third at $^1/_2$ brilliancy, *etc.*, should these circuits be dimmed out by the color master they would start dimming at the same time, and proportionally change, so that they would reach the black-out position at the same time. This is in contrast to the operation of the standard interlock type of color master in which a similar operation would result in the circuit at full brilliancy being dimmed until it corresponded to the one at $^3/_4$ brilliancy, at which point the second circuit would interlock with the color master and both these circuits would travel until they reached half brilliancy, where the third circuit would interlock and finally all would black-out together. This often results in a spotty effect and is undesirable. By using an electrical color master rather than a mechanical color master, a proportional dimming effect is accomplished as previously described.

In order to obtain grand master control, the pilot switch on the color master section is transferred from the hot-bus position to the grand master position which connects the circuits on the color master to a master generator. By varying the voltage on this master

FIG. 2. Thermionic lighting control console, Severance Hall, Cleveland, Ohio.

generator, the potential impressed on the color master is varied, thus causing a proportional change similar to that previously described for the circuits connected to the grand master.

Motor operation is provided for the dimming fader in the Los Angeles theater so that it is possible for the operator to change from one effect to another simply by pushing a small telephone switch starting the motor drive. This motor drive is so provided with limit switches that it will travel to the succeeding scene at which point it will stop, and will not start again until the operator pushes the "start" button.

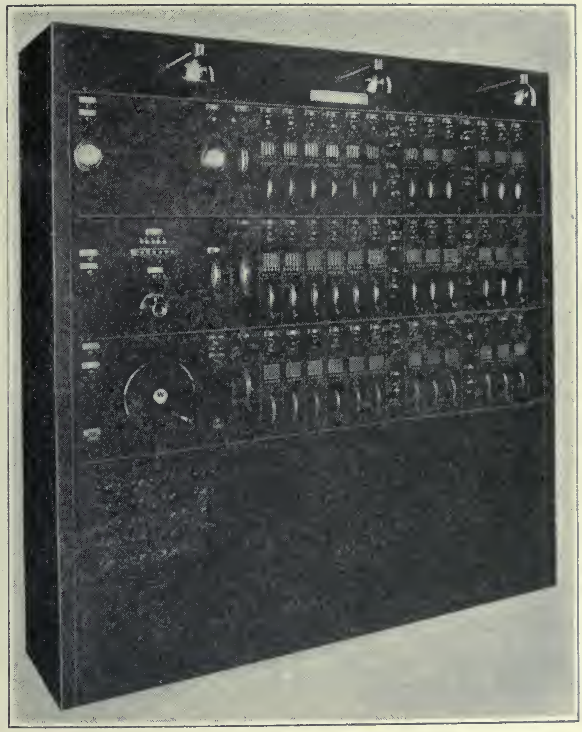

FIG. 3. 5-Scene thermionic control board for stage lighting control, Los Angeles Theater, Los Angeles, California.

This allows an easy means of obtaining remote control of the intensity of all the lighting circuits in the theater. In the old type of multi-preset board it was possible to obtain remote control scene changes, but it was impossible to preset the intensities, as it was necessary for the operator to set the dimmers beforehand or to change their setting when transferring from one effect to the other. By using the thermionic tube control, it is possible to preset the dimming as well as to preset the circuits which are to be used and, furthermore, to obtain remote control of these circuits if it is desired. This is of special advantage in motion picture houses where it is desirable to control the light from the projection room and at the same time have a switchboard on the stage floor which can be used in case of stage presentation work.

In the Los Angeles theater, the remote control board at the stage floor allows the stage switchboard operator to have full control of the color masters for the auditorium circuit, and in addition to this allows him to change the lighting effects on the auditorium for five presets which had previously been determined by means of the switchboard located in the projection room. Furthermore, by means of the color masters, it is possible for the operator to dim out any particular color from any scene that had previously been preset, thus giving a very flexible control.

The previous description is typical of this type of control. Due to the rapid development in the art, at least one other scheme has already been conceived. Instead of a grid-glow type tube, a vacuum tube of rather large plate capacity is used and a motor generator set supplies 500 volts d-c. to the plates. The output is regulated by grid control of these tubes. That is, the 500-volt supply from the generator is connected in series with the vacuum tube and the d-c. coil of the reactor. Thus, by varying the impedance of the vacuum tube by change of grid potential, the amount of direct current that is allowed to pass through the d-c. coil of the reactor is changed. The control equipment, that is, the potentiometer set-up is practically a duplicate of that used in the Los Angeles theater, the new developments affecting the tube units rather than the control.

Another advance has been in the method of control by means of which it is now possible for a switchboard to be built wherein the operator may change from one scene to any other scene and get a gradual fading effect from the one to the other, or to obtain a flashing effect as previously described. The Los Angeles theater was built prior to this development, so that it was necessary to fade from one scene to the next succeeding scene. The new development allows a much more flexible control due to the fact that in stage presentation work it is often desirable to repeat an effect; with this type of control it is possible to do this as often as is desired, and to fade into this effect from any other that may be in progress.

Another interesting development that has recently been brought forth, the first application of which is for the control lighting of the Buckingham Fountain in Chicago, provides a continuous preset pro-

FIG. 4. Reactor and thermionic unit rack, Los Angeles Theater, Los Angeles, California.

gram which is laid out in advance for an evening's performance. This is accomplished by means of an insulating track on which there has been drawn a conducting path. This moves and is continuously in contact with a potentiometer similar to the control potentiometers for the tube units. By varying the location of the conducting strip on the moving track, a variable preset potential is obtained which correspondingly changes the output of the tube unit, and a change in the intensity of the lighting circuit results. While this is developed for floodlighting control it may be used for such an application as varying the lighting of a theater according to a definite program for the overture. It could also be used for providing a light change program for the patrons at the time between the opening of the house and the beginning of the performance. This program is motor driven, and can be started and allowed to run for a definite period of time after which, by means of a transfer relay, the control can be transferred back to the regular stage switchboard for use in connection with the picture or the stage presentation.

In summarizing it may be said that the application of thermionic tubes to theater dimming has made possible a stage board giving the following very desirable features:

(1) Presetting of intensity for any desired number of scenes.
(2) Proportional dimming.
(3) A light compact board using telephone switches, thus insuring ease of operation with added assurance of proved reliability of this type of equipment.
(4) Low control voltage (less than 50 volts, d-c.) allows use of telephone cable for control wiring.
(5) Remote control easily added.

In fact, the field of application of tube control to lighting is in its very infancy, and due to the rapid development in tubes, as we have witnessed in the past in the radio field, a great deal may be expected of this type of equipment.

A PORTABLE NON-INTERMITTENT CINÉ PROJECTOR*

Summary.—*A portable projector made by the Établissement Gaumont Franco-Film Aubert is described. The projector is of very small weight and is arranged for carrying in a case. The film moves with a constant motion past the axis of the light source and the projection lens, the image being maintained stationary upon the screen by a combination of the movement with an optical "compensator." It is claimed that due to these features, wearing of the film has been very much reduced and the motion is extremely silent in operation. The article describes briefly the optical principle of the motion, how the principle is applied, and the construction and assembly of the apparatus.*

The "Simpliciné" is a ciné projector for standard film, self-contained and complete, yet small enough in bulk and weight to be portable. The whole projector is enclosed in a metal casing and can be carried easily on a sling strap. Its erection is almost instantaneous and its manipulation so simple that no special experience is required for its use.

The chief importance of this machine, particularly so far as the non-professional user is concerned, is that it employs the principle of constant movement projection. The film moves with a uniform motion across the axis of the light source and the projection lens. This is a vital difference from the usual intermittent projector, in which a Maltese cross or other mechanism is used to drag the film into position and then bring it momentarily to a standstill in the gate of the machine. In the new projector the image is kept stationary on the screen by means of a special combination of the movement with an optical device termed a "compensator." One greater advantage of such a system is the very much reduced wear on the film perforations owing to the elimination of the violent and repeated tugs to which films are subjected in ordinary types of projectors. Film is said to last five times as long when it is run in this continuous manner. To this advantage may be added the not less important one that absolutely silent mechanism can be obtained when all the moving parts are given nothing but continuous rotary movement, as is the case in the "Simpliciné."

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* Translated from *Revue d'Optique*, **10** (April, 1931), No. 4, p. 178.

The Optical Principle.—Fig. 1 represents a film moving in a downward direction and carrying a series of images *1, 2, 3, etc.* Imagine that in front of these images is a series of similar lenses O_1, O_2, O_3, *etc.*, each having its focal point in the plane of one of the images, and suppose this chain of lenses to move in a direction parallel with the film and at the same speed. If the beams of parallel light so formed meet a fixed lens C the images of the different elements of the film will be superimposed in the focal plane of this lens. Indeed, if we consider an element formed by an image on the film and the corresponding lens, the image of a point of this element given by C will have its position, in the focal plane of C, determined solely by a straight line passing through the optical center of C and parallel to the straight line joining the given point in the element to the optical center of the corresponding lens. Now this straight line as it moves remains parallel, consequently the final image is fixed. This is true

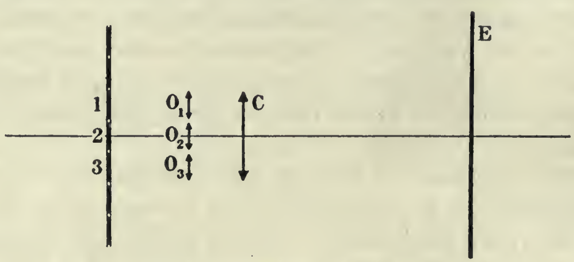

FIG. 1. Diagram illustrating the optical principle.

for all images of the points of the element of the film. The straight lines joining corresponding points of the element to the optical centers of the corresponding lens being parallel, the images of successive elements are superimposed in the focal plane of C. Hence the projection screen E is made to take the position of the focal plane of C and focusing for various distances is obtained by providing a set of lenses C of different focal lengths.

How the Principle Is Applied.—The realization of this principle in actual fact has been achieved in the following manner: The lenses are set round the periphery of a cylindrical drum T (Fig. 2), which is free to turn on its axis. T is made to rotate by the fact that the film catches a tooth D formed on the drum and carries T round with its own movement. The lenses therefore move at the same speed as the film. Light passing through the illuminated film reaches the lenses O after traversing a prism P (Fig. 2), which is formed integrally with the fixed axis of the drum. This prism has two reflecting surfaces M_1 and M_2 set perpendicular to one another. The system thus produced is that indicated in Fig. 1, with the difference that the film and the lenses do not travel in a straight path but follow curves of the same radius. This difference has a practically negligible effect on the quality of the images, assuming that the film is illuminated only over the length of two images. This means that two images and two only of the chain of lenses are actually utilized, film elements and lenses which have any appreciable inclination to the normal being kept out of action. Furthermore, the projected image shows

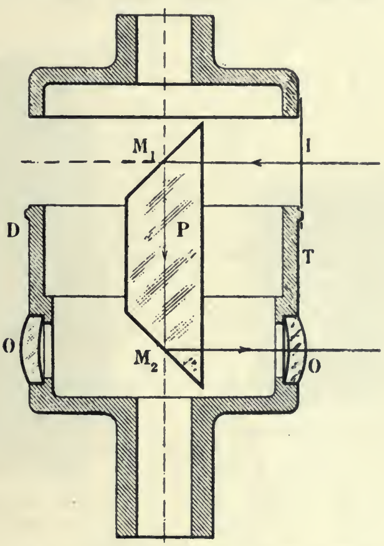

FIG. 2. The construction of the drum carrying the lenses on its periphery.

its maximum illumination at the moment at which the corresponding lens has its axis coincident with the axis of projection, and the effect of this is to reduce greatly the aberrations of the images thrown by adjacent lenses which are slightly inclined. This mechanism is exceedingly simple: it consists of a single component moving with a continuous rotary movement at low speed—80 revolutions a minute for a projection speed of 16 pictures a second. Wear is therefore reduced to a minimum and the running is quite noiseless.

The Projector Described.—The "Simpliciné" has been given the form of a rectangular case, the top and side of which are formed with hinged swinging sections which are raised vertically for use. All the mechanism is then made visible.

The feed-reel, *3* (Figs. 4 and 5), with its pulley, *4*, is then fixed on this raised portion of the casing. The film passes under the feed sprockets, *5*, and on to the drum *T* carrying the compensating lenses; then on to the toothed sprocket *6*, the take-up reel *7*, rotated by its driving pulley *8*.

Masking the film on the screen is effected thus: when the lever, *9* is pressed downward, the roller, *10* is pushed up between the two pressure rollers, thus raising the film and raising the roller, *11*. If the pressure on this lever is released, the roller *11* returns into contact

FIG. 3. External view of projector.

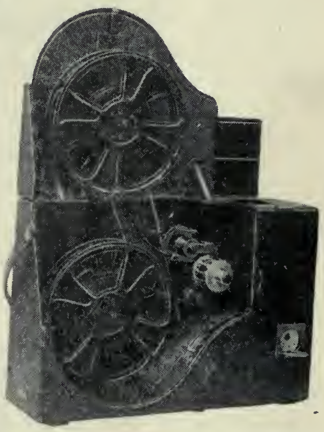

FIG. 4. View of projector opened for use, showing internal arrangement.

with the drum, and the loop formed by the film is taken up by the movement of the drum. The importance of the formation of this loop is that in this operation the film advances by one perforation. Masking is thus effected by the displacement of the image by an amount equal to a quarter of its height.

Motor Drive and Lighting.—The driving parts are carried on a fixed aluminum platform and can be removed as one unit from the box. This block consists of an electric motor, *12;* a pulley drive, *13*, reversible for rewinding; and a transformer, *14*, to feed the lamp *15*. In front of this assembly, against one of the panels of the box, are mounted side by side two rheostats, for the lamp and for the motor, with finger controls, *16* and *17*, for their adjustment; and an ammeter, *19*, for the control of the lighting system. A plug let into the casing provides for the connection of the apparatus to a source of electric power.

The lamp used is a 225-watt Phillips, taking 30 amperes, at $7^1/_2$ volts. The beam is of about 525 cp. in a horizontal direction perpendicular to the tungsten filament. The lamp is conical in shape and works upside down in order to avoid the blackening of the bulb around the filament. The lamp is suitably supported and adjusted. The optical system includes a two-lens condenser *25*, and spherical mirror *26* in line with the axis of the filament.

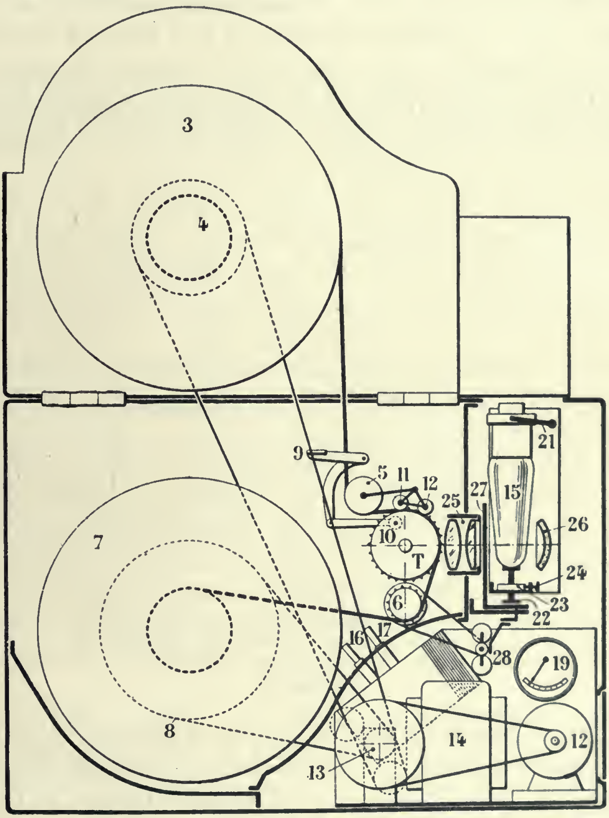

FIG. 5. Diagram of internal arrangement.

As a safety device there is a wire gauze, *27*, which is arranged to come into place automatically between the light source and the condenser when the film is stationary. This takes place by a centrifugal action. Its effect is to protect the film from any dangerous degree of heating without restricting the light unduly when the machine is used for still projection from selected pictures.

As regards focusing, the apparatus possesses five collimating lenses *C* (Fig. 1), arranged on a rotatable disk, and by means of these the image can be focused on a screen at any distance from 6 to 32 feet. The milled edge of this disk projects through the casing at the side so that it can be rotated by the finger, and a spring detent sets it in accurately centered position whichever lens is in action. A

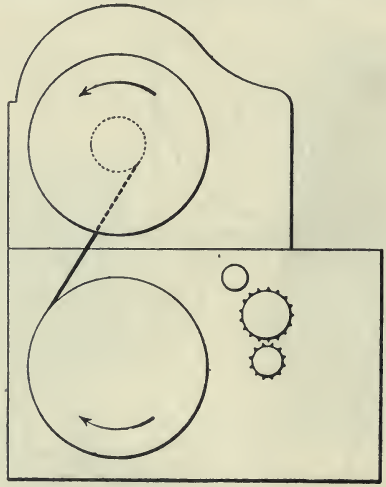

FIG. 6. Showing the method of rewinding.

rectangular window in the front wall of the apparatus, made to allow the beam to pass, is fitted with two sliding covers adjustable vertically to cut off parasitic images which would otherwise be thrown on the screen.

Re-winding at the end of the projection is very simply carried out. The film is released from the drum and from the guiding sprockets, so that it runs as shown in Fig. 6. An adjustment is then made, to allow the take-up reel to turn freely on its axis and to fix the feed-reel to its axis. The full take-up reel thus becomes the feed-reel, and *vice versa*. The motor, running just as in projection, then rapidly re-winds the film, leaving it ready to project again.

COMMITTEE ACTIVITIES

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

The Projection Practice Committee wishes to direct attention to what it considers one of the foremost causes of waste and monetary loss suffered by the motion picture industry, namely, the mutilation of positive prints. This mutilation not only results in a considerably shortened life of the individual print, which is serious enough in itself, but in addition to this, it is impossible to obtain the optimum screen results, which are so highly important in creating the proper illusion so necessary to the motion picture play. Both picture and sound are affected by mutilation of film.

It is generally understood that the mutilation of film is frequently due to the maladjustment of projector parts, wearing of projector parts, accumulation of emulsion during projection, excessive oiling of projector or leakage of oil, and careless handling of film. The Projection Practice Committee is of the opinion that there is urgent need for the establishment of standards dealing with the various tensions to which the film should be subjected during projection, the clearances of adjacent projector parts and sound apparatus, allowable tolerances, and the amount of wear projector parts may suffer without impairing the quality of the picture or causing mutilation of film.

The committee, therefore, plans to conduct a thorough investigation which will be nation wide in scope, with the view of obtaining all necessary data for submittance to the Society for the purpose of adopting such standards. In order to accomplish this, the committee requests the earnest coöperation and support of the Society as a whole, as well as of associated individuals and organizations. Their assistance will be needed as this work will be of considerable magnitude and should, when completed, prove invaluable to the industry.

The Committee wishes also to call attention at this time to the lack of uniformity in the processing of prints, which constitutes another

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

serious loss. In regard to the processing of film, there seems to be no standard for this work at the present time. One producer uses a certain method of processing film; another producer simply waxes the margins of the print; and a third producer does not process the print at all. This condition works a hardship on all concerned, inasmuch as it frequently happens that the producer who has processed his product suffers by reason of the fact that the theater uses unprocessed film at the same time. This evil adversely affects both the sound quality and the quality of the picture.

It is well known that with unprocessed film there is a tendency to accumulate emulsion at the tension points in the projector. Formation of emulsion greatly increases the tension applied to the film and imposes a strain on the sprocket holes. Occasionally a positive print is irreparably damaged during its first projection. The Projection Practice Committee recommends that a thorough investigation to find the best method or methods of processing film be conducted by a designated committee of the Society so that such methods may be recommended as a standard for the industry.

Unless such a standard is adopted, generally accepted, and put into use by the producers of film, the industry will continue to suffer the great loss now occasioned through faulty (or the lack of) processing methods, and such benefits which should accrue through the adoption of the standards relating to projector tensions, adjustments, *etc.*, would be largely nullified. In the opinion of the Projection Practice Committee, such a work is one of the most important contributions the Society could make to the industry.

RESOLUTION

The Projection Practice Committee wishes to include in the records of the Society a statement of its appreciation of the splendid work and coöperation which President Crabtree extended to this Committee and, also, for his realization of the important role which practical projection plays in the motion picture industry.

Through President Crabtree's foresight, initiative, and efforts, a committee to deal with the practical problems of projection was formed for the first time in the history of the industry, and specific problems greatly in need of attention and correction were brought to the light of day and taken under consideration.

Therefore, we, the Projection Practice Committee, gratefully acknowledge what President Crabtree has done for the craft, for the Society, and for the industry at large, and extend to him our thanks and a vote of confidence in his conduct of the affairs of the Society.

HARRY RUBIN, *Chairman*

THAD. C. BARROWS	R. H. McCULLOUGH
G. C. EDWARDS	P. A. McGUIRE
SAM GLAUBER	RUDOLPH MIEHLING
J. H. GOLDBERG	F. H. RICHARDSON
CHAUNCEY GREENE	MAX RUBEN
HERBERT GRIFFIN	H. B. SANTEE
JESSE J. HOPKINS	L. M. TOWNSEND

DISCUSSION

MR. McGUIRE: For quite a few years I was one of those who vigorously protested against the neglect of projection by this Society, but no longer have I any cause for complaint as we have our own Projection Practice Committee and it is up to ourselves to make good. In discussing the Report of the Projection Practice Committee it is not my intention to complain or criticize, but to offer some suggestions which I hope will be helpful to the motion picture industry and a benefit to the Society of Motion Picture Engineers. I ask you to be patient because much of what I will say is to be of a somewhat general nature and, perhaps out of place in the proceedings of this Society. But most of the papers and much of the discussion of the Society are more or less incomprehensible or relatively unimportant to some part of the membership of this organization. In order to deal only with subjects which would be of interest to everyone it might be necessary to hold a hundred conventions or divide the meetings into an equally large number of groups. In its proceedings, the Society of Motion Picture Engineers must give some attention to invention, development, manufacture, maintenance and operation, the electrical, chemical, and mechanical divisions of the industry, visual and sound recording and reproducing, and always theory and practice. These are rough classifications, but give a general idea of the vast field the Society must cover.

The Society of Motion Picture Engineers is not a scientific body seeking abstract truth, but a technical organization with a very definite commercial background. When we lose sight of the fact that we are part of the motion picture industry we fail to realize the true purpose of the Society. It, therefore, seems to me that anything the Society can do to render a practical service to the industry should result in the organization receiving increased support. The benefits that the industry has derived from the Society of Motion Picture Engineers have not always been recognized because they were often of an extremely indirect and intangible nature. The fact that the Society has for many years focused attention upon the technical side of the motion picture industry and to some extent has won the interest of non-technically minded executives is in itself a great achievement. The executives of this industry have never given the Society adequate support, and I believe that the producers and exhibitors have contributed more to a single activity of another organization in this field than they have to the Society of Motion Picture Engineers in its entire history.

The Society is facing new conditions and it is desirable that the service which it renders the industry should be more direct and more obvious. If this can be done, the Society will receive increased support and be in a better position to carry on its important work. This organization is in a particularly strong position to secure technical data regarding the cause and prevention of film mutilation. Various attempts have been made to get this information, but there is good reason to believe that the results have not been entirely satisfactory.

Someone has said that "science is common sense made exact." The Projection Practice Committee will conduct a scientific survey, collecting the facts systematically and thoroughly, and present them in an authoritative report. When this is done definite action should result and the Society will have rendered a service comprehensible in terms of dollars and cents.

The work we are undertaking, however, will involve considerable time and expense, and should receive adequate support from the Society as well as the industry. It is an unfortunate fact that the industry does not take proper interest in the collective thought developed by such an organization as the Society of Motion Picture Engineers. Progressive projectionists in this organization, and their own projection societies, are constantly giving their own time to do valuable technical work without receiving the least recognition from the executives of their own firms. Conceding that this is a period in which executives are very properly insisting upon economies, it nevertheless seems unwise to ignore totally all the collective effort for the betterment of the industry.

Back of the artistic side of the motion picture industry is a vast technical field whose work offers infinite opportunity for flaws and failures. Motion pictures provide entertainment and education through chemical, mechanical, and electrical processes. What the public pays for is not the product of a single commercial organization, and it is important that the Society of Motion Picture Engineers should bring this to the attention of the industry—emphasize the interdependence of the various departments and point out the need for coördination. In all work which is not of a competitive nature the industry benefits tremendously from the collective thought developed in such organizations as the Society of Motion Picture Engineers. I sincerely hope that a way will be found to encourage and finance adequately the efforts of the Projection Practice Committee to find the cause and prevention of film mutilation. The men on this Committee have the technical and practical experience to do the work. Their report should result in a tremendous saving through prevention of waste and the improvement in screen presentation.

PRESIDENT CRABTREE: I indorse Mr. McGuire's remarks one hundred per cent. Of course the world was not made in a day. But it is encouraging that the producers have shown a much greater willingness to do things for us at this Convention than at any time previously.

Will Mr. Griffin give us a few details as to how the stoppages occurred in the projection room?

MR. GRIFFIN: There was only one cause, Mr. President, and that was the processing. Emulsion, or whatever was on the film, supposedly to prevent its "seizing up" during transit through the mechanism, did not prevent it. In some cases it was wax, and in some cases something else.

PRESIDENT CRABTREE: Where did it seize?

MR. GRIFFIN: In the gates. It can seize anywhere in transit, wherever there is tension—at the picture gate or the sound gate. This time it happened to be at the sound gate. It is not the fault of the manufacturer of the equipment, because one can run a film through that has been run two or three times, and properly processed, and it will not cause any trouble at all. We could have run the film through without stopping; it was a new print, however, and we wanted to save it. And in as much as it was not a very serious matter to stop the picture here, as would have been the case in a theater, we stopped it. But the sound was terrible in some cases, caused by a piling up of the wax, behind the film, thus changing the thickness of the scanning beam.

PRESIDENT CRABTREE: Was this a new machine?

MR. GRIFFIN: It was not new in the sense that it had never been run before. Films had been run through it on different occasions, but the equipment to all intents and purposes is new.

PRESIDENT CRABTREE: In the case of two metal surfaces, one of which is polished to an extremely high degree with rouge, and one which is not polished, the polished surface will not pick up as much gelatin or emulsion as the rougher one. I was wondering, therefore, that if this machine had been a little older, would the trouble have occurred?

MR. GRIFFIN: The finishes on all parts that come into contact with film are finished with rouge, and I believe that RCA uses crocus-cloth for polishing. I don't know of anything better. The surfaces are highly polished and burnished,

MR. SUMNER: I happen to be an exhibitor, and this report of the Committee was very interesting to me. We happen to run a theater that is called a "first subsequent run;" that is, we run after the key point in this district, which is Boston. I have attended a number of the conventions, and have heard the reports from the various specialists in the studios; and I realize the great amount of thought and work that is put into the pictures, the great mass of work that has been done to accomplish perfect sound, and so forth. And yet, when these prints get to the theaters, the greater part of that work has been ruined by improper handling of film. As an exhibitor, I wish to state that I believe that the work that has been begun by this Committee is most important. I want to urge them not to stop with the problem of processing film. They must go much further than that.

In spite of the noiseless recording system, the prints reach the theaters so dirty and scratched that the work of noiseless recording has almost gone for naught.

I think this Committee is one of the most important factors in the organization and I want to urge that it be given all possible support in its work.

PRESIDENT CRABTREE: I should like to ask Mr. Griffin: Was the accumulation of emulsion due to friction along the perforations, or at some portion of the picture area? In other words, is it necessary to process the entire surface of the film, or merely the edges of the perforations?

MR. GRIFFIN: For projection purposes it is necessary only to process—or lubricate, as it may be called—the edges of the film in the sprocket hole area.

PRESIDENT CRABTREE: Was the film in question lubricated or "processed?"

MR. GRIFFIN: I cannot answer that. I do not know either the processes or who does the processing. I only know what occurs during projection.

MR. FAULKNER: Four different prints caused the trouble, and each one of the four had four different applications and four different kinds of chemicals on them. The gathering of emulsion on three different prints that I looked at was identically in the same spot, showing that no matter what caused it to gather, it did so in exactly the same place on the film. I did not see the fourth print but the sound quality and the way in which it behaved were similar.

As Mr. Griffin says, as far as passing the film through a projector is concerned, it is only necessary to lubricate the margin of the film. The emulsion that is on film, unless the metal parts with which it comes into contact are lubricated, is quite likely to stick. Therefore, the film is lubricated for the purpose of keeping the tension shoes lubricated.

Mr. Rubin asked me to present to you his idea that "processing" is an incorrect term to use for this process. He wants to find a name for waxing, treating, processing or "whatnot," and to standardize that name. I went to a dictionary and ran down every name I could think of. I have a great number of them, none of which I think would be appropriate, except perhaps "treatment" or "finishing" or the like. "Processing" is used to indicate anything that may happen to film from the time it is printed to the time it is developed for screening.

PRESIDENT CRABTREE: Why not use the word "conditioning?"

MR. FAULKNER: Some of the names I accumulated are: hardening, completing, seasoning, curing, impregnating, finishing, duratizing, dura-proofing, inuring, toughening, preserving, protecting, treating, perfecting treatment. None of these I think would be satisfactory except perhaps "conditioning" or "treating." I do not like "processing," nor does Mr. Rubin.

MR. MCGUIRE: I ask you not to exaggerate the importance of "processing" merely because it has received special attention in this discussion. It is a serious problem, but we shall have other important subjects to consider in our efforts to find the cause and prevention of film mutilation. There has been much talk in the past about film mutilation and various organizations have dealt with it rather unsuccessfully.

The Projection Practice Committee is starting out with the idea that there seems to be an evil which is called film mutilation, but that it knows absolutely nothing about its cause and prevention. We hope to be able to gather some data in the next six or twelve months, which will save the motion picture industry a tremendous sum every year and greatly improve the quality of screen presentation.

MR. J. CRABTREE: I think a little more attention to the projector is what is necessary. I often project green film, and find that as long as the projector is kept in shape, little trouble is experienced. Mr. Faulkner pointed out that last night the accumulation occurred in the same spot in each case, which goes to show that there is a high spot somewhere. One cannot expect lubrication to take care of all high spots. Eliminate the high spots, and the lubrication won't be so necessary.

MR. GRIFFIN: I must take exception to that. I don't know under what conditions Mr. Crabtree projects his prints, but I defy anybody to take a piece of green film off the drying rack and project it under conditions existing in the theater today and not have it seize up, no matter how well the projector is designed.

PRESIDENT CRABTREE: Are you speaking now of a film to the edges of which wax has been applied?

MR. GRIFFIN: Mr. Crabtree said he would use it without treatment—right out of the laboratory. It is not waxed there. Now, waxing is not the solution, apparently, because the wax peels off and rolls up. With the old silent machines, waxing was all right. Today we have sound. The wax rolls off, gets in the sprocket holes, and is carried to the sound gate, where it either leaves the film or raises it off the sound gate.

PRESIDENT CRABTREE: You are speaking of the old method of waxing with solid wax?

MR. GRIFFIN: Yes.

PRESIDENT CRABTREE: You should use a solution of wax in a solvent. It is only necessary to put on a layer of wax a millionth or so of an inch thick, to provide the necessary lubrication.

MR. GRIFFIN: I have seen, in cases where the film is put on a rewinding device, two pieces of tallow right at the sprocket holes, over which this film is drawn. The projectionist should be taught not to do a thing like that. We must find a proper means of treating the film so that during projection under high amperages it does not seize in the tension parts of the projector.

PRESIDENT CRABTREE: Of course, Mr. Crabtree is not projecting under the high amperages that you speak of.

MR. FAULKNER: When the film comes off the drying cabinets and is projected for inspection, felt runners are used in some places, and I know one laboratory that does not use them. They never scratch film, but it is due to the fact that there is no heat on them.

MR. GRIFFIN: We supply thousands of different types of runners to the laboratories of studios, and I know how they work. They use a Mazda lamp, and very little light.

PRESIDENT CRABTREE: I happen to have done a considerable amount of research on the lubrication of film. Our researches have shown that if you have even the merest trace of wax or oil or grease or any lubricant, on the film, it makes a tremendous difference in the ease with which it passes through the projector. To date we have not found that any special processing treatment is any better with regard to lubrication.

REPORT OF THE PROJECTION THEORY COMMITTEE

SUBCOMMITTEE ON LITERATURE

At the Spring Convention at Hollywood a report was made of the activities of the Projection Theory Committee. A subcommittee to examine the literature of the subject was formed, consisting of C. Tuttle, F. K. Moss, and H. P. Gage, *Chairman.* The present plan of this Committee is to prepare a tutorial paper on the progress of the optics of motion picture projection, based principally on the papers published by of the Society of Motion Picture Engineers, but also referring to significant papers in other publications.

A letter from F. K. Moss states, "I have devoted some time in surveying the literature on the effect of motion pictures upon the eyes. As I progressed in my survey it became increasingly apparent to me that available data on the effect of motion pictures upon the eyes were largely negative in character. In other words, pictures made according to the best of modern practice had little if any observable deleterious effect upon the eyes. In the past, when pictures presented excessive brightness contrasts, unsteadiness and flicker, there was no doubt that they were the cause of ocular strain and fatigue. These objectionable characteristics seem to have been reduced to a point where they cease to be important in the better grade of pictures.

"I also approached the problem more or less directly from the viewpoint of general physiological optics. Such an analysis indicates, for example, that the brightness contrasts on the screen and with the general surroundings, are not of such an order as to induce unusual degrees of ocular fatigue. Hence the conclusions reached by scientific considerations and those resulting from actual experience are in agreement. Since the subject is largely one of eye-strain or 'eye-fatigue' which has never been satisfactorily measured, a quantitative discussion is impossible. In brief, these effects upon the eyes become important in cases where projection is faulty."

Mr. Tuttle under date of April 28 sent a list of forty titles containing significant information on the subjects of Illumination, Optics, Projection Angle, Mechanics of Projectors, Aberration of Lenses, Projection under Special Conditions, and Visual Angle.

Subcommittee on Literature
H. P. GAGE, *Chairman*
F. K. MOSS
C. TUTTLE

DISCUSSION

MR. MATTHEWS: In connection with the work of the Progress Committee, it is worthy of mention that a considerable amount of information has been published on the subject of visual fatigue in motion picture theaters, in the *International Review of Educational Cinematography*. A series of measurements were made of a great many school children in theaters in Italy, giving data that might be considered by the Committee. There is a series of four or five articles in this publication.

MR. MURRAY: Does the work of the Committee include a search of the literature in regard to the psychological effects involved in the projection of motion pictures in color?

MR. GAGE: Mr. Moss is studying the literature dealing with the effects on the eye. The Committee is considering more generally the possible deleterious effects rather than the whole group of psychological effects, which constitutes such an unlimited field that little would be accomplished if it were to be considered in its broadest aspect.

MR. MURRAY: I have heard complaints that colored pictures produce eye fatigue that I have not heard in connection with black and white. Have these been considered by the Committee?

PRESIDENT CRABTREE: In the case of the old two-color additive Kinemacolor pictures, I would say that they caused fatigue. With modern two-color subtractive pictures fatigue may have been caused by the fact that some of the pictures were out of focus. They lacked definition, and the person viewing them did not know whether it was his eye that was at fault or the picture. He assumed that his eyes were at fault, and strained them in trying to focus the picture.

I asked for a vote the other day as to whether the colored pictures we saw one evening this week caused any annoyance or eye-strain, and no one said that they had any effect—they did not seem to notice any difference between the effects produced by the colored and by the black-and-white pictures. Perhaps at this time, if any one has thought it over and has the courage to say it gave him annoyance, he might care to say something about it.

MR. J. CRABTREE: During the showing of the picture I thought I should be able to view it to the end, but I had to close my eyes. When the next black-and-white picture was projected, the annoyance entirely disappeared. Checking with other people, no one else to whom I spoke seemed to have had the same experience. Apparently it was merely an idiosyncrasy. But the irritation was undoubted in my case.

MR. FALGE: Is it not true that with color in general, it is harder to focus on some colors than on others, and that one experiences certain visual effects with pictures in the blue and red?

Another factor which is a function of eye-strain is the size of the picture. The magnetoscope pictures, if viewed throughout an entire show, would be very hard for those seated in the front rows, as their eyes have to chase back and forth across the picture as in a three-ringed circus. Does not the addition of color to the picture in general cause a reduction of its brightness? And from the standpoint of lighting, it usually follows that a decrease in brightness is less harmful to the eyes than an increase. And aren't we back to the same subject we were on a minute ago, that we have not enough brightness in our pictures today, and that that is harmful to the eyes?

PRESIDENT CRABTREE: We are talking of annoyance of a much higher order of magnitude than what you have in mind.

MR. BURNETT: In color photography, it has been known for a long time that the red colors are very harmful to the eye, while the green colors are not. In most of the colored pictures that I have seen the reds have been predominant, causing a great deal of strain on eyes which have not been strong enough to stand it. I do not think that this effect was as conspicuous the other night as heretofore.

Eye-strain can be also considered from the standpoint of brightness; but it is the reds, I think, that cause the greatest trouble in color photography, as far as eye-strain is concerned.

ABSTRACTS

Supply and Cost of 16-Mm. Film for the Home. F. S. IRBY. *Electronics*, August, 1931, p. 48. An analysis of the various factors that contribute to the cost of 16-mm. films for sound pictures in the home. The author considers that if such films are to reach more than a very limited class market, the rental cost to the consumer should not exceed $2 for a four or five reel feature picture. The library must anticipate liquidation of the cost of the film in from twenty to twenty-five rentals, which means that the cost of the film to the library must not exceed $10 to $12 per reel. A. C. H.

Light-Valve Sound Recording. J. P. LIVADARY. *Electronics*, August, 1931, p. 54. The third and final installment in a series of articles dealing with the frequency distortion introduced by the finite width of the slit in recording. This article is concerned chiefly with a mathematical analysis of the distortion introduced in the light valve method of recording. In the conclusion, the author summarizes the results of this and the preceding articles by comparing the various methods of recording that have been studied; namely, the glow lamp method, the single ribbon light valve method, the double ribbon light valve, and the variable width method. He concludes that "from a practical standpoint, all three systems are capable of high-grade recording, and any difference such as we have shown will not become very apparent or objectionable until such time when the film grain noise is suppressed and sound recording systems are capable of commercially reproducing frequencies up to 10,000 cycles or over. Until then all three systems will be competing on practically equal terms." A. C. H.

Dynamic Loud Speaker Design. J. E. GOETH. *Electronics*, August, 1931, p. 66. A very elementary account of the magnetic circuit of dynamic loud speakers. A second installment of this article will appear in a later issue. A. C. H.

A Rapid-Record Oscillograph. A. M. CURTIS AND I. E. COLE. *Electronics*, August, 1931, p. 70. An oscillograph of the string galvanometer type that is especially designed for the study of transient phenomena. A. C. H.

Noiseless Sound-on-Film Recording. GEORGE LEWIN. *Electronics*, September, 1931, p. 102. The author discusses the theory of noiseless sound-on-film recording by the light valve. The subject will be treated from a practical standpoint in a subsequent issue. A. C. H.

Dynamic Loud Speaker Design—II. J. E. GOETH. *Electronics*, September, 1931, p. 112. The second and final installment of an article concerned primarily with the magnetic circuit of dynamic loud speakers. A. C. H.

Stage Equipment: An Outline of Modern Practice. W. L. TANN. *Theater Management*, **27**, December, 1931, p. 6. Essential stage equipment in an average sized theater presenting straight pictures or pictures and stage performances is described and illustrated. Modern advances in fire protection by asbestos curtains and steel smoke pockets are pointed out. Various mechanical contrivances for enlarging the screen to permit the showing of wide films are discussed. A notable advance in design of stage equipment is the silence with which the intricate mechanism operates. E. P. J.

Room Noise Reduction for Improved Sound Reception. V. A. SCHLENKER. *Theater Management,* **26,** November, 1931, p. 3. Describes tests conducted to determine the effect of extraneous noises on sound reproduction. Illustrates outside noises in typical theater before and after acoustical treatment of vestibule, lobby, foyer, and exit doors. An oscillograph trace of three bands of noises recorded simultaneously in the street, lobby, and foyer of theater under discussion reveals that while high and middle frequency bands are effectively silenced by entrance doors, bands of low frequency enter the theater practically undiminished.

A chart showing the effect of various sensation levels expressed in decibels above minimum audibility of the human ear is discussed. The painful effect produced by fader manipulation to produce audibility of picture sound above room noise is indicated. E. P. J.

The Use of Rochelle Salt Crystals for Electrical Reproducers and Microphones. C. B. SAWYER. *Proc. IRE,* **19,** No. 11, November, 1931, p. 2020. A brief history of the use of piezo-activity for acoustic uses is followed by a description of a cheap method of production of Rochelle salt crystals, used in the author's experiments. The principle of opposition was used. Two Rochelle salt sections are cemented together so that upon application of an electrical field, one section tends to expand and the other section tends to contract, thus amplifying the resultant motion. The method of cutting Rochelle salt crystals for this work is explained. Brief descriptions of Rochelle salt microphones, loud speakers, and phonograph pick-ups are given. The Rochelle salt development has the following outstanding advantages.

(1) Cheapness and simplicity.
(2) Long life.
(3) Flexibility of design.
(4) Generation of high voltages in input circuits.
(5) Directly matched with output tubes in output circuits.
(6) No necessity for an exciting field. A. H. H.

Trans-Lux Rear Stage Projection. W. MAYER. *Theater Management and Theater Engineering,* **26,** No. 22, October, 1931, p. 3. A non-technical discussion of the Trans-Lux system of rear stage projection as installed in theaters. The history of the system, various problems encountered and their solutions, and a description of the present installations give a concise outline of Trans-Lux. By means of special lens and optical systems, no changes in the projector and sound head mechanisms are necessary. Standard film is used and is threaded in the projector in the standard way. The average distance between screen and projector is $13^1/_2$ feet. A. H. H.

Moving Coil Telephone Receivers and Microphones. E. C. WENTE AND A. L. THURAS. *Bell Telephone Tech. J.,* **X,** No. 4, October, 1931, p. 565. A description of a moving coil head receiver and a microphone. The mechanical construction is based on using light-weight materials for moving parts, thus giving greater response over the frequency range. Theoretical and actual response are compared. The sensitivity of the moving coil microphone was found to be about ten db. higher than that of the condenser microphone. A. H. H.

Playing Light on a Thermionic Organ. W. C. Fulton. *Motion Picture Herald,* **104,** No. 13, September 26, 1931, Section 2, p. 12. A description of a unique lighting switchboard, built for the Severance Memorial Hall in Cleveland. The major innovation in the lighting system is the switchboard, built along the lines of a console of a modern organ. Controls for 4000 lighting combinations of 110 load circuits are at the finger tips of the operator. Included are a four scene preset control, proportional control, remote control of intensity, and interconnection of circuits. The system is based on the thermionic type of lighting control. The control apparatus for each circuit requires a dimming reactor, a conventional vacuum tube, two grid glow rectifiers, and a system of control potentiometers. The lamp load current flowing in the a-c. coils of the reactor, is directly dependent on the d-c. saturation current flowing in the d-c. coil of the same unit. As the direct current increases, the iron core of the reactor becomes saturated alternating current increases. The direct current is supplied by a pair of grid glow tubes whose output is controlled by the plate current of the vacuum tube. The plate current of the vacuum tube is in turn controlled by varying the bias on its grid. All the above apparatus is placed at a remote point from the control console. The control circuit of the vacuum tube grid is brought to the console. By means of selector switches, potentiometers, *etc.,* any or all circuits in the hall may be controlled at will. Circuit diagrams and pictures clearly show the operation of this installation. A. H. H.

Audible Frequency Ranges of Music, Speech, and Noise. W. B. Snow. *Bell Telephone Tech. J.,* **X,** October, 1931, No. 4, p. 616. A description of tests to determine the maximum frequency range necessary for perfect or nearly perfect reproduction. With the aid of experienced listeners, and using a series of filters, varying degrees of cut-off were tried. It was found that frequencies between 80 and 8000 cycles were necessary to give good quality. Although rather indefinite as to the advantages of using frequencies outside this range, it is believed that the most nearly perfect quality is obtained by reproducing the full audible frequency range. A. H. H.

The Development of the Microphone. H. A. Frederick. *Bell Telephone Quarterly,* July, 1931, p. 164. An interesting history of the early experiments leading up to the present design of microphones. Dr. Page in 1837, Sullivan in 1845, Bourseil in 1854, Reis in 1861, Helmholtz in 1863, and Varley in 1870, made contributions to the development of the microphone. The experiments of Dr. Alexander Graham Bell, begun in 1874, are described in more detail. In 1877, Edison patented a transmitter of the varying resistance type, using a button of solid carbon or plumbago. The granular carbon design was first used in 1885. The condenser type and the piezoelectric crystal type are of more recent design. The difficulties of developing the carbon microphone are described in detail. It is interesting to note that minute granules of carbonized anthracite coal were first used by Edison in 1886. This source of carbon is still used to a great extent at the present time. A. H. H.

The Effect of Humidity upon the Absorption of Sound in a Room, and a Determination of the Coefficients of Absorption of Sound in Air. V. O. Knudsen, Jr. *J. Acoustical Soc. of America,* **III,** No. 1, Part 1, July, 1931, p. 126. It is shown that the absorption of sound in air for frequencies above 2000 cycles is appreciable. This effect is great enough to affect very appreciably the calculation of the reverberation time and absorption in a room for frequencies of 4000 cycles and above. The absorption of air becomes less as the humidity increases.

An idea of the magnitude of the effect may be obtained from the following statement. "Thus, if a tone of 4096 d.v., in the form of a plane parallel beam, were used for long range signaling there would be, at a temperature of 21° C. and a relative humidity of 44 per cent, an attenuation of 9.8 db. per second, or about 46 db. per mile. On the other hand, the attenuation would be less than 1 db. per mile for a frequency of 512 d.v." Furthermore, it appears from this data, that a reverberation chamber with perfectly reflecting walls would have a reverberation time of no more than about six seconds for a tone of 4096 d.v. if the humidity of the air in it is 44 per cent or less.

Theoretical formulas are deduced. The method used in separating the effect of the absorption in air and that at the surface of the rooms was to take comparable data in two rooms of different sizes but with the same boundary material, namely, painted and varnished concrete. This yields sufficient data to separate the effects. Even at 4096 d.v. the absorption of the painted concrete was about 0.02 and practically independent of humidity as long as condensation did not occur.

W. A. M.

A Critical Study of the Precision of Measurement of Absorption Coefficients by Reverberation Methods. P. E. SABINE, JR. *J. Acoustical Soc. of America,* **III,** No. 1, Part 1, July 1931, p. 139. The data presented include a comparison of absorption coefficients obtained at the Bureau of Standards and by two methods at the Riverbank Laboratories on identical samples of each of four materials. It is concluded that normal experimental errors in measuring absorption coefficients may easily be 3 or 4 per cent, that probably an error of 10 per cent in the coefficients would not appreciably affect the acoustic properties of an audience room; and the actual computation of the reverberation time in a room is a matter of approximate estimate rather than precise determination. W. A. M.

The High Intensity Arc for Motion Picture Projection. F. PATZELT. *Kinotechnik,* **13,** September 20, 1931, p. 344. Measurements and graphs were made of the light distribution of an "Artisol 75" projection lamp with high intensity carbons and with ordinary carbons. The average brightness of the entire crater of ordinary carbons 14 mm. in diameter at 35 amperes and 45 volts was found to be 140 Hefner candles per sq. mm. Copper-coated high intensity carbons 11 mm. in diameter were found to have a brightness of 357 Hefner candles per sq. mm. at 75 amperes and 45 volts. The variation in the brightness of high intensity carbons with different amounts of current was also measured. It was found that carbons of small diameter require higher current densities than larger carbons to attain the same brightness. The effect of changing the relative positions of the carbons was studied, and it was found that greater brightness was attained with the axis of the negative carbon in line with the center of the positive carbon than with the axis of the negative carbon opposite the lower edge of the positive carbon. The variation of the brightness at constant current with varying length of arc was found to be small. It is stated that a 25-degree inclination of the axis of the negative carbon to the axis of the horizontal positive carbon is the most favorable. It is concluded that the difficulties in the use of high intensity carbons are compensated for by the increased illumination. M. W. S.

Safety Film. K. BRATRING. *Kinotechnik,* **13,** July 20, 1931, p. 237. In its mechanical properties, such as resistance to wear and damage, cellulose acetate motion picture film base is considered inferior to cellulose nitrate base. In view of the universal precautions against fire in the projection of professional motion picture films, it is considered that the low inflammability of cellulose acetate film is sufficient cause to justify the increased expense attendant upon its use in theaters. For schools, homes, and other places where proper safety precautions for nitrate film are not taken, cellulose acetate film should undoubtedly be used. It is thought that nitrate support constitutes no great hazard when used for amateur roll films and film packs, or for professional portrait films. For x-ray films, the introduction of cellulose acetate support is viewed with favor. M. W. S.

The Phillips Reproducing Set. *Kinemat. Weekly*, **172**, June 4, 1931, p. 61. The sound equipment in the Phillips set is a pedestal mounted at the left-hand side of the projector; and a flexible shaft coupling driven by the motor is connected with the projector flywheel. An integral gear shift permits the use of either sound-on-film, sound-on-disk, or silent operation. The sound head of the projector employs a curved gate which is said to prevent film buckle. A high emission photoelectric cell (18 microamperes per lumen) is used at present but a gas-filled caesium cell is being investigated for future use. The speed control is ingenious, the electric control being effected by rotating make-and-break cams, one driven by the projector motor and the other by a constant-speed motor. When the contact is made on both cam switches, a resistance is short circuited. The period during which this resistance is short circuited, therefore, depends upon the relative positions of the two cams. The cams revolve at approximately 80 rpm. The fader used in the set gives a logarithmic change. The projection room amplifier consists of a single stage which supplies current to the main amplifier which may range in capacity from 20 to 200 watts with speech levels of 10 to 45 watts, respectively. L. E. M.

A Continuous Motion Picture Projector. M. Huc. *Bull. soc. franç. phot.*, **73**, June 1931, p. 128. A newly designed single oscillating mirror type of continuous projector is described. The principle involved is one in which the film passes over a cylindrical drum having an aperture through which the single frame is projected upon an oscillating mirror, which in turn reflects it into the objective of the machine. During the movement of the film over the aperture, the adjacent frame is isolated by a moving window behind the aperture, which moves with the same angular velocity as the film. When the projection phase is terminated, a shutter in front of the objective masks it during the return of the mirror and window. The light from the illuminating sources does not fall directly on the film but is interrupted and reflected by a 45-inch mirror which is fabricated of a metal capable of absorbing a large percentage of the heat rays, thus protecting the film. All gears and cams are encased in oil, where possible, thereby minimizing noise. It is claimed that a projector as described is capable of projecting a film 3000 times without injury to the film. Drawings are included. C. H. S.

Faith in the Title. F. Slip. *Filmtechnik*, **7**, May 2, 1931, p. 6. Although titles have been replaced temporarily by the use of sound, they have a place in certain classes of films, such as teaching films. Correctly composed titles may also be of value in the presentation of certain sound films. During a study of correct methods of title composition the maximum title width of 19 mm. has been selected as desirable with the height accordingly proportional. The background should preferably be dark and the letters light. The type must be simple, clear, and attractive. The optimum length for the title has been investigated from a consideration of (1) length of the lines, and (2) number of letters. A useful table is given showing length of the lines, number of letters, length of the title, and length of the film per line of title, assuming projection at the rate of 24 frames per second. L. E. M.

Motion Picture of the Eclipse of the Moon. F. Albrecht. *Filmtechnik,* **7,** May 2, 1931, p. 1. On April 2, 1931, the first motion picture of a total eclipse of the moon was photographed at the Trepton observatory in Germany. With the usual motion picture camera the image of the moon is far too small and even with a teleobjective of 30 cm. The image is only 3 mm. in diameter. In the successful motion picture an $f/10$ objective of 65 cm. focal length was used, mounted on an Ernemann E camera. The camera and lens were secured in place on the 21-meter Trepton telescope. Positive film was employed and exposures of $^1/_4$ to $^1/_2$ second were made, using a blue filter with the teleobjective operated with a 35-mm. opening. The camera shutter opening was increased to 160 degrees at the beginning of the eclipse and decreased to 90 degrees as the eclipse passed. Single frame exposures were made at intervals of 5 seconds, thus giving for the $3^1/_2$ hour time a length of film which, when projected at the rate of 24 frames per second, occupied $1^1/_2$ minutes. L. E. M.

Television Demonstration at Broadway Theater. *Film Daily,* **57,** October 23, 1931, p. 1. A television demonstration was given at the Broadway Theater, New York, for two weeks beginning on Oct. 22, 1931, a 10 by 10 foot screen being used. The receiving disk revolved 900 times per minute and a projection system projected the images on the screen. The sending station was located a short distance away in the Theater Guild Studio. G. E. M.

ABSTRACTS OF RECENT U.S. PATENTS

The views of the readers of the JOURNAL *relative to the usefulness to them of the patent abstracts regularly published in the* JOURNAL *will be appreciated. Favorable views are of particular interest. In the absence of a substantial body of opinion to the effect that these patent abstracts are desired by the membership, their early discontinuance may be considered.*

1,821,930. **Film Feeding Mechanism.** M. COUADE. Sept. 8, 1931. A film feeding mechanism for projectors in which a claw engages the perforations in the film and intermittently moves the film in accordance with the operation of a cam mechanism which imparts angular movement to the claw. Adjustments may be made for determining the length of stroke of the claw by adjusting the eccentricity of the driving cam mechanism which engages the claw.

1,821,946. **Film Feeding Mechanism.** F. H. OWENS. Sept. 8, 1931. A sound and motion picture apparatus including mechanism for intermittently moving the picture films in front of the projection lens system while continually moving the sound record portion. The shutter for the light beam has a peripheral groove thereon for defining a belt wheel which is engaged by the drive belt. A manual adjusting means is provided for properly positioning the shutter. There is a lost motion connection between the film moving mechanism and the parts of shutter by which the shutter may be selectively adjusted under manual control before being operated under automatic control.

1,822,057. **Composite Photographic Sound Records.** F. H. OWENS. Sept. 8, 1931. The method of making a composite photograph sound record from different sources of sound such as a song with orchestra accompaniment and with the addition of some special instrumental features such as bells and the like wherein a plurality of photographic sound records are synchronously converted into electric impulses. These impulses are received for modulating the intensity of a single recording lamp. The modulated light rays from the lamp are photographed upon the sensitized film. By this process it is possible to produce a sound record by selecting desirable portions of previous sound records and thereby construct a program of highly entertaining qualities.

1,822,183. **Light Slit for Recording and Reproducing.** D. A. Whitson. Assigned to Whitson Photophone Corp. Sept. 8, 1931. A light slot for a sound recording and reproducing system in which a guide block is disposed adjacent the film. The guide block has a wide slot and a communicating narrow slot. The sound record is passed over the wide slot. There is a lens in the bottom of the wide slot and in contact with the sides and bottom of the slot for focusing radiations to pass through the slots on the strip. The purpose of the lens slot is to concentrate the light at maximum intensity upon the film at the same time that protection of the slot against the accumulation of dust or foreign matter is effected.

1,822,350. **Arrangement of Perforations in Cinematographic Films.** J. H. JARNIER. Sept. 8, 1931. A motion picture film which is perforated laterally of the picture frames instead of in two rows on opposite sides of the picture frames.

Claws are used to shift the picture frames intermittently before the projector. The structure of the film is such as to increase the resistance of the film against tearing at the lateral lines of perforations. Rectangular perforations are provided in the transverse spaces between the images wherein the ratio of the number (N) of transverse perforations to the width (L) of the film having a specific resistance to rupture by traction λ is determined by the formula:

$$N = \frac{L\lambda}{p - a\lambda}$$

in which a is the width of the perforations, p the resistance to rupture for the width a in such a way that the resistance to tearing of the line of perforations engaged is the same as the resistance to rupture by traction of the spaces separating them, this resistance being the maximum.

1,822,528. **Moving Lens Cinematograph Machine.** W. E. JOHN. Sept. 8, 1931. A motion picture camera or projector having a continuously moving film and a series of loose lens carriers moving with the film. The loose lens carriers move through a closed circuit including a straight guide in which they are exposed, and curved guides, one at each end of the straight guide; the circuit between the curved guides being completed by a driving and conveying member in the form of an internally toothed and pocketed wheel. The separate lens members are brought into alignment with the optical path through the camera by driving means connected with the lens carrier. The lens carriers slide longitudinally around the guide which defines the path of movement for each of the lens members.

1,822,551. **Lens Shifting Mechanism for Projecting Machines.** A. TONDREAU. Assigned to Warner Bros. Pictures, Inc. Sept. 8, 1931. A system of lenses which may be shifted in a projection machine to enable an instant change of magnification on the projection screen without loss of focus. An attachment is provided carrying lenses which may be first set in focus and which may be operated to bring either one lens of a certain magnification or another lens of a different magnification into the optical path. The lens carrier is provided with individual supports for the different lens members, allowing independent longitudinal adjustment of the different lens carriers.

1,822,865. **Glow Discharge Tube for Recording.** T. W. CASE. Sept. 8, 1931. A glow discharge tube for recording variations in light intensity upon film. A bulb is provided for enclosing a non-thermionic anode and a cathode. An atmosphere of helium is provided within the bulb at such a pressure that a concentrated glow is provided about the negative electrode with a voltage not substantially greater than 400 volts d-c. across the electrodes. The cathode has a photoelectrically activated coating comprising barium actuated for electron emission by the said glow concentrated about the cathode. The device is designed to produce response of the glow in terms of light emission according to variations of electrical impulses produced in a sound control circuit.

1,822,932. **Combination Recording and Reproducing Stylus Head.** M. H. LOUGHRIDGE. Sept. 15, 1931. A stylus head is arranged to support both a recording and a reproducing stylus with respect to a wax record of a phonograph. The stylus head may be shifted to bring either the recording or reproducing stylus into engagement with the phonograph record. A switching mechanism is provided for controlling the connection of the styluses to an amplifying system.

When the reproducing stylus engages the sound record, the input circuit of the amplifier is connected with the stylus. When the recording stylus is placed in engagement with the sound record, the magnetic windings thereof are connected with the output circuit of the amplifier for cutting a groove in the record in accordance with the sound vibrations impressed upon the input circuit of the amplifier.

1,823,243. **Method and Apparatus for Lapping Color Film Embossing Rollers.** O. WHITTEL. Assigned to Eastman Kodak Co. Sept. 15, 1931. A method of lapping lenticular film embossing rollers which comprises providing a cylinder with a plurality of fine guide lines, turning the cylinder, and lapping the cylinder with a plurality of wires, a fine lapping compound being used on the cylinder. The embossing roller is used for operation upon color motion picture films. The lenticular areas or elements formed in the film are extremely minute as the distance across these elements may be from 0.0015 to 0.002 of an inch.

1,823,245. **Film Winding Device.** O. WITTEL. Assigned to Eastman Kodak Co. Sept. 15, 1931. Winding device for motion picture film in which a reel is provided with a pair of concentric hub members. One hub member is slidably carried by a flange disposed in one side thereof. The two hub members are separated by sliding the flange on one hub. The structure of the film winding device is such that the film may be drawn from an inner convolution of a supply reel and wound on an outer convolution of a take-up reel. The construction of the reel is such that the film is properly aligned on the reel without rewinding.

1,823,246. **Method of Tinting Film for Use in Sound Reproduction.** A. A. YOUNG. Sept. 15, 1931. A method of tinting the picture areas of a photograph film in which the sound record portion is preserved untinted while preventing shrinkage of the film by applying to the picture areas of the film a dye dissolved in a solution comprising a solvent for the film and the dye and a non-solvent for the film which has the property of reducing the rate of evaporation of the solvent whereby the tendency of the film to buckle is eliminated. The dye, which is applied to the picture areas of the film, is dissolved in a solution containing from 5 to 10 per cent of acetone, from 70 to 75 per cent methyl alcohol, and the remainder triacetin.

1,823,349. **Producing Fade-in and Fade-out of Photographic Sound Record.** S. C. CHAPMAN. Assigned to Electrical Research Products, Inc. Sept. 15, 1931. The sound record is chemically treated for reducing the end portions of the sound record progressively varying lengthwise of the film. The reproduced sound will thus gradually increase in volume from silence to the normal volume of the record, vary normally with the record till near the end when the volume of the sound will gradually diminish to silence.

1,823,355. **Telescope Framing Device.** L. S. FRAPPIER AND E. BOECKING. Assigned to International Projector Corp. Sept. 15, 1931. Projecting machine for photographic sound records wherein a microscope is supported in the path of a scanning ray in such position that the ray can be observed while adjustments are being made to secure the proper characteristics thereof. A prism is positioned in the path of the light rays to deflect a portion of the light at right angles into the microscope in order that the sound record may be analyzed.

1,823,400. **Photographic Film Copying Machine.** L. HORST. Assigned to Sirius Kleuren-Film Maatschappil, of Bosch en Duin, Netherlands. Sept. 15,

1931. A machine for copying two color films and more particularly a machine of this kind in which the pictures are transferred from one film to the other by means of mirrors and objectives provided in duplicate. Two sources of light are provided, each of which is separately regulable, for timing the degree of copying of the individual part pictures.

1,823,462. **Photographic Camera.** K. MORSBACH. Assigned to Siemens & Halske, Aktiengesellschaft. Sept. 15, 1931. The film refill which is supplied for the camera is carried by an interchangeable cassette which coöperatively engages a film guide channel located in the interior of the camera behind the objective lens. There is a guide plate carrying the window for the image, permanently located behind the objective and in its focus. There is a pressure plate independently mounted on the cassette. When the camera is refilled, any differences in the focal lengths of the objectives of different cameras are compensated by the pressure plate and the guide plate so that equal operation of cameras which are not uniform is obtainable.

1,823,737. **Sound-on-Disk Motion Picture Projector.** CHARLES L. HEISLER. Assigned to General Electric Co. Sept. 15, 1931. A motion picture projector which includes a projector housing mounted adjacent a phonograph turntable. The driving motor which operates the projector also drives the phonograph turntable so that the film and the record may be operated in synchronism. The arm which carries the phonograph pick-up is pivoted adjacent one side of the record table and permits the phonograph pick-up to be moved over the area of the revolving record.

1,824,294. **Sound and Picture Film Matching Means.** FREEMAN H. OWENS. Assigned to Owens Development Corp. Sept. 22, 1931. A method which permits the accurate repair or splicing of separate film strips, one of which carries the picture record and the other of which carries the sound record to maintain synchronism between the picture and the sound wherein an insertable film section is provided attachable to the broken ends of the film. The insert is provided with a sound record and images adjacent the sound record, the images being partial duplicates of the images on the picture film. The splicer finds it very easy and convenient to judge accurately the length of the insert by simply matching the two films by observing the partial duplicates of the images on the insert and fitting the sound strip in to match the sound on the film. That is to say, a guide is provided on the insertable sound strip so that the splicer is advised accurately as to where this sound should occur on the sound film in order to match accurately the images on the picture film.

1,824,417. **Treating Sound Records Produced by Splicing.** A. T. TAYLOR. Assigned to Metro-Goldwyn-Mayer Corp. Sept. 22, 1931. The method of splicing a film carrying a sound record to prevent audible clicks and foreign noises at the splice marks as the film passes the light path. The ends of the broken film are cemented and then a patch in the form of a half-cycle sine wave cemented over the adjoining ends of the sound record. This sine wave patch has a frequency below normal audibility and an amplitude equivalent to the width of the sound record so that there is no extraneous sound created as the splice passes the sound reproducing aperture.

1,824,446. **Producing Motion Pictures in Color.** E. L. PEARSON. Sept. 22, 1931. A projection screen is arranged for rotative movement in timed relation to the rotation of a color filter at the projection machine. The projector is arranged to project successively images through the different colored filters upon the moving projection screen from which the picture may be viewed and through which the images are produced. By shifting the relative positions of the projector and the projection screen to project successively the images upon the portions of the projection screen corresponding to the particular filters upon which the images are produced, an effect upon the eye of colored motion pictures closely portraying in color and motion real animated objects is produced.

1,824,709. **Camera for Taking Cinematographic Pictures.** A. L. V. C. DEBRIE. Sept. 22, 1931. View taking apparatus comprising two parts, namely, a front part containing the film driving device, the shutter, and the optical arrangement and a rear removable part which can be secured instantaneously to the front part and which contains a feeding storing box wherein the unimpressed film is disposed together with the film guiding devices, the transmission gear, and a second storing box into which the impressed film is wound up. The latter box can be the same as the feeding box or else both boxes can be made separate. The operator can thus be provided with several rear parts ready for use which he may secure to the front part of the apparatus according to the requirements. The result thereof is, besides the advantage already mentioned, a saving of time which is of great interest in the case where the taking of the complete scene which is to be cinematographed requires a length of film greater than what can be contained in one single storing box.

1,824,731. **Picture Transmitting System.** D. M. MOORE. Assigned to General Electric Co. Sept. 22, 1931. A picture receiving system in which the light is modulated in accordance with the shading of the successive elemental areas of the picture transmitted. A screen is provided and there are a plurality of rotatably mounted mirrors arranged to reflect successively the modulated light to produce a trace on the screen. The mirrors are rotated continuously in one direction at different speeds with a lens system arranged between the mirrors. The mirrors are each mounted on the shaft of the associated driving means in such manner that the mirrors are inclined at an angle to the axis of the driving shaft so that rotation of each of the mirrors produces a scanning operation over the area of the receiving screen.

1,825,078. **Incandescent Electric Lamp for Projection Apparatus.** J. MARETTE. Assigned to Pathé Cinema Anciens Établissements Pathé Fréres. Sept. 29, 1931. A glow lamp is directly centered in the optical path of a projection machine by means of a ring member which is secured over the base of the lamp and serves to center the lamp accurately in its support for accurately directing the maximum amount of light through the projection path.

1,825,121. **Lamp Holder.** F. H. OWENS. Assigned to Owens Development Corp. Sept. 29, 1931. A plurality of separate lamps are mounted on a carrier which may be laterally shifted to move any one of the lamps successively into a predetermined operative position. There are stops provided on the lamp supporting base to limit the movement of the lamps to selected positions. The lamp holder may be moved through a shaft member to the outside of a lamp housing.

1,825,122. **Objective for Color Photography.** A. OSWALD. Assigned to Keller Dorian Colorfilm Corp. Sept. 29, 1931. An objective lens system for color photography employing films having a goffered base wherein the lens system is made up of a plurality of different elements; a diaphragm and a collimator film. The several elements of the optical system are so arranged that the pupil of emergence of the objective is in the anterior focal plane of the collimator lens, the aberrations introduced by the collimator lens being corrected by compensating aberrations introduced into said objective.

The objective is anastigmatic and is constituted by the three spaced elements and by a collimating lens located in the vicinity of the focal plane of the objective. The objective of this invention follows Petzval's law—

$$-P = \Sigma \frac{\phi}{\eta}$$

and in calculating these objectives in view of increasing the sharpness of the marginal images, P is left with a negative value suited to the extent of the field to be represented; when calculating an objective of this sort intended to be provided with a collimating lens, the residual value ascribed to P will therefore have to be increased by varying the quantity $\phi\eta$.

1,825,142. **Motion Picture Film Magazine.** W. A. BRUNO. Assigned to Clarence W. Fuller. Sept. 29, 1931. A protective housing for films wherein the film is supported for avoiding breakage or other injuries. A plurality of film carrying reels of considerable diameter are provided so that the film may be stored in the magazine, without sharp bends. The reels are constructed to engage the film near its marginal edges only, the cylindrical surfaces of the reels being concave or otherwise centrally disposed to prevent contact thereof with the central portions of the film. Power means are provided for driving the reels for storing the film in the magazine while preventing scratching or other abrasion to the picture frames on the film.

1,825,253. **Synchronous Camera Mechanism.** A. F. VICTOR. Sept. 29, 1931. A camera having means for controlling and synchronizing the motion and arresting the movement of the feeding devices with respect to the shutter. A cam coöperating with an abutting arm is provided in association with the rotatable shutter by which the shutter may be brought to rest by moving the arm. By withdrawing the arm from the path of the cam the shutter may be rotated under control of the drive mechanism. The movement of the shutter with the film feeding devices is synchronized. The shutter is provided with additional devices that coöperate with control mechanism so that when the latter is released to return to normal, the stoppage of the film is momentarily postponed until the shutter is in position in front of the exposure aperture, whereupon the movement of all mechanism is arrested. This is accomplished in such manner that it positively insures the proper positioning of the shutter in front of the aperture at the moment the movement of the film ceases and the stoppage is made without jar to the camera.

1,825,254. **Intermittent Feed for Motion Picture Apparatus.** A. F. VICTOR. Sept. 29, 1931. A mechanism for intermittently feeding a film through a camera or projection machine which includes a shuttle that is reciprocated by a continuously rotatable cam. The shuttle is hinged upon the end portions of lever arms that are pivotally mounted upon the housing of the camera or projector. Means are provided for adjusting the pivoted ends of the arms toward each other in such manner that any noticeable wear between the cam and the parts engaged thereby may be taken up by means of a simple adjusting structure. The fulcrums of the lever arms are supported in a "floating" pivot because the pivotal members are not actually secured to the camera or projector but are carried upon suitable rocker-arms which themselves are pivoted on the support or housing. The operation of these rocker arms is similar to the action of a cam or cams engaged with the lever arms.

1,825,340. **Electroöptical Cell.** N. DEISCH. Sept. 29, 1931. A Kerr cell is used for electrically modulating a beam of light. One electrode of the Kerr cell comprises a frame having an opening comprising the active space thereof and a plurality of flexible ribbon-like division members dividing the opening into a plurality of light passages, the flexible ribbon-like members being secured to said frame and held taut across said opening. Electrostatic stresses impressed on the cell operate to modify the light passing through the divisions of the cell.

1,825,529. **Sound Pipe Reproduction from Photographic Films.** R. KOLLER. Sept. 29, 1931. A motion picture film is combined with an air control band which moves synchronously with the motion picture film. The air control band moves over a tracker board for controlling the supply of air to various sound pipes for the reproduction of sound appropriate to the pictures. Synchronization of the sound with the pictures is obtained by virtue of the interconnection of the moving band with the picture film. Various forms of pipe organ valves may be operated by allowing the air to pass through predetermined apertures in the moving band.

1,825,486. **Scanning Disk.** A. O. TATE. Sept. 29, 1931. The apertures in a scanning disk are arranged in reverse spirals, one of the spirals beginning at the outer edge of an image and ending at the inner edge thereof and the other of the spirals beginning at the inner edge and ending at the outer edge. The adjacent apertures of the spirals are disposed the same radial distance from the center of the disk so that the images are scanned twice in succession. Each of the apertures is bounded by arcs of concentric circles and by radii of the disk. The objects of the arrangement of the scanning disk apertures are to eliminate the inconvenient restrictions with respect to the area available for use as scanning space as defined by the distances between the open ends of the spirals, to provide means whereby an object may be scanned laterally by intermittent light beams or pencils which maintain perpendicularly a continuous, rhythmic, undulatory movement through the period of revolution of the disk; to provide means whereby the total area of the scanning space may be varied with respect to its dimensions; and to provide means whereby an object may be scanned with one revolution of the disk a plurality of times.

The scanning disk is divided circumferentially by a plurality of radial lines to form circumferential divisions and is divided radially by a plurality of concentric circles to form radial divisions and may be conveniently plotted by the following formula, in which:

A represents the number of circumferential divisions of the entire disk;

B represents the number of radial divisions included within the scanning area;

C represents the number of circumferential divisions between successive apertures; and

D represents the number of times the scanning area is scanned in one revolution of the disk and also the number of spirals in the system.

The following equation represents the relationship of the above quantities:

$$A = BCD$$

This equation may be solved for C or B as follows:

$$C = \frac{A}{BD}; \quad B = \frac{A}{CD}$$

By assuming the various constants of the disk, the apertures may be conveniently laid out in accordance with any desired scheme by following the above formula so as completely to scan the image any desired number of times for each revolution of the disk.

1,825,487. **Scanning Device.** A. O. TATE. Sept. 29, 1931. An endless belt is provided with a staggered series of apertures. The belt is looped around a multiplicity of guide drums and is driven by rollers at opposite ends of a frame structure, so that the apertures are moved successively across the field of a lens system for scanning an object within the field of the lens. The object is scanned in lines from bottom to top or top to bottom. The band is approximately 160 inches in length and has approximately 80 apertures therein, each spaced from the adjacent aperture at a distance of 4 inches.

1,825,497. **Light Projection Display Apparatus.** T. WILFRED. Sept. 29, 1931. A polysided screen consisting of a plurality of upright differently faced concave sides meeting in thin edges is provided for a display surface. There are light projecting means spaced outwardly in front of each of the concave sides, the several projecting means being adapted to project coöperatively upon the respective adjacent concave sides to produce an ornamental light display for attracting the attention of a spectator. The projection apparatus is used in various forms of floodlighting architectural displays.

1,825,598. **Process for Producing Combined Sound and Picture Films.** H. VOGT, J. MASSOLLE, AND J. ENGL. Assignors by mesne assignments to American Tri-Ergon Corp. Sept. 29, 1931. The sound and picture records are photographed on separate film strips to form separate negatives. The negative picture record is photographed upon a portion of a sensitized film not exposed to the sound record. The negative sound record is photographed on the same face of the sensitized film but on a portion thereof not exposed to the picture record. By the separation of the sound record from the picture record, a film record combining both of these records can be produced without subjecting either record to conditions of overexposure or underexposure.

(Abstracts compiled by John B. Brady, Patent Attorney, Washington, D. C.)

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SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting of the Board of Governors held at the Waldorf-Astoria Hotel, New York, N. Y., on December 10th, consideration was given to the establishment of new committees which would expand to a great extent the scope of activities of the Society in directions which have so far not been adequately investigated. Among the new committees considered was one to deal with non-theatrical home equipment, a committee on the development and care of film, a Museum Committee whose duty it will be to gather historical pieces of motion picture apparatus for purposes of exhibition in suitable depositories, and a committee on the preservation of film.

It was decided that the S. M. P. E. Fellowship, created through the generosity of Mr. George Eastman, is to be established at the University of Rochester. Its administration is to be left to the Projection Theory Committee, the object of the Fellowship being to conduct investigations on problems particularly concerned with or cognate to the motion picture art.

Much discussion was held concerning the financial operations of the Society for the fiscal year and on the general matters of entrance fees, dues, and subscription rates.

SPRING, 1932, CONVENTION

The Board of Governors decided that the names of the cities, New York, N. Y., and Washington, D. C., be placed upon the ballot which is to be mailed to the entire membership for voting upo tnhe location of the Spring, 1932, Meeting.

NEW YORK SECTION

A meeting of this section was held on Wednesday, December 9th, in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, N. Y. Mr. H. A. Frederick of the Bell Telephone Laboratories repeated his paper entitled, "Vertical Sound Records; Recent Technical Advances in Mechanical Records on

Wax," which was presented at the Swampscott Convention on October 7th. The demonstration which accompanied the paper included considerably more elaborate apparatus than that which was used at the Swampscott Meeting. Following Mr. Frederick's presentation Mr. Leopold Stokowski, director of the Philadelphia Orchestra, addressed the meeting, presenting from a musician's standpoint some of the problems of recording. The meeting created considerable interest, more than seven hundred and fifty people attending in spite of the inclement weather.

The next meeting of the Section is scheduled to be held about the second week in January. Announcements will be mailed to all members enrolled in the Section. Those whose names are not on the mailing list of the Section, but who wish to receive information concerning the meetings, should communicate with the general office of the Society.

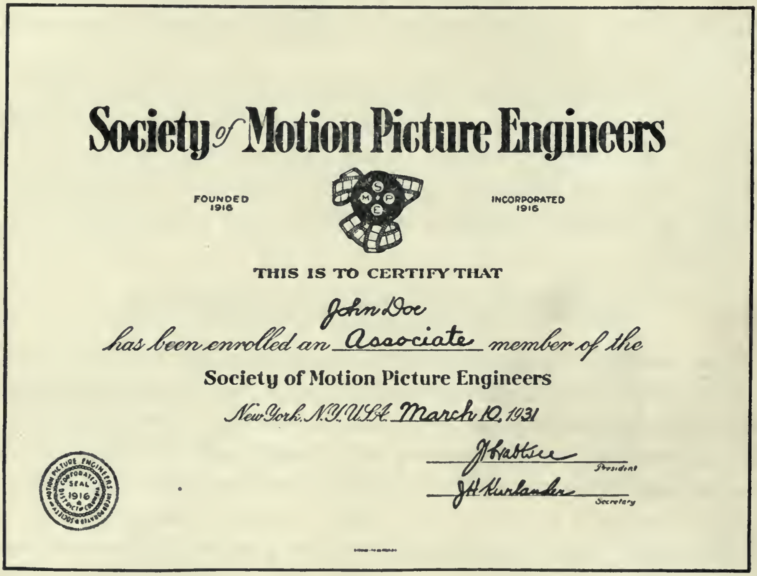
PROJECTION PRACTICE COMMITTEE

At a meeting of the Projection Practice Committee held on November 24th, a program outlining the work to be conducted by the Committee during the current year was formulated, being particularly directed toward the recommendation of standards of tolerances and clearances of projector and sound parts, and the determination of the degree of wear of projector and sound equipment which can be allowed without impairing the quality of the projected picture or damaging the film. A study of the methods of so-called processing, or the treating of finished positive prints to prevent damage during the first showing of the film is to be included in the work of the year. It is felt that there is a need for more perfect methods which will completely eliminate the shedding of emulsion or the accumulation of oil and wax in the projector, due to the film.

At a second meeting of the Committee on Tuesday, December 15th, further discussion of the problems of tolerances and clearances in projector and sound parts was held, particular attention being paid to the points at which tension of the film and wearing of the parts occur. The problem of the specifications desirable for projector apertures was also discussed at some length, and the work on this problem, although not completed, is recommended for the study of the Standards and Nomenclature Committee of the Society.

MEMBERSHIP CERTIFICATE

Associate members of the Society may obtain the membership certificate illustrated below by forwarding a request for the same to the General Office of the Society at 33 W. 42nd St., New York, N. Y., accompanied by a remittance of one dollar.


Society of Motion Picture Engineers

FOUNDED 1916 INCORPORATED 1916

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John Doe

has been enrolled an Associate member of the

Society of Motion Picture Engineers

New York, N.Y. U.S.A. March 10, 1931

President

Secretary

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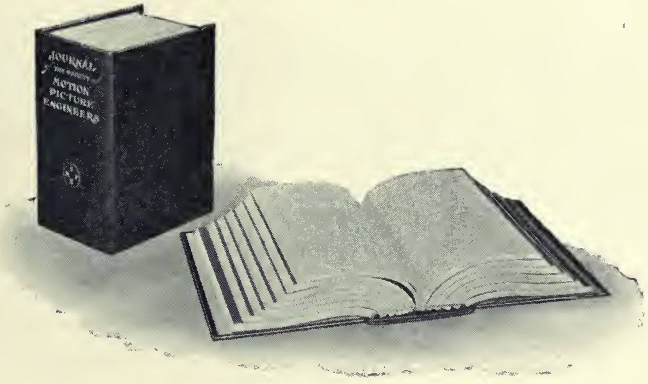
There is mailed to each newly elected member, upon his first payment of dues, a gold membership button which only members of the Society are entitled to wear. This button is shown twice actual diameter in the illustration. The letters are of gold on a white background. Replacements of this button may be obtained from the General Office of the Society at a charge of one dollar.

JOURNAL BINDERS

The binder shown in the accompanying illustration serves as a temporary transfer binder or as a permanent cover for a complete year's supply of JOURNALS. It is made of black crush fabrikoid, with lettering in gold. The binder is so constructed that each individual copy of the JOURNAL will lie flat as its pages are turned. The separate copies are held rigidly in place but may be removed or replaced at will in a few seconds.



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BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted. The cost of all the available *Transactions* totals $46.25.

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Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.50 each, a complete yearly issue totalling $18.00. Single copies of the current issue may be obtained for $1.50 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society, 33 West 42nd Street, New York, N. Y., and should be accompanied by check or money-order.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII **FEBRUARY, 1932** **Number 2**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

VERTICAL SOUND RECORDS*

RECENT FUNDAMENTAL ADVANCES IN MECHANICAL RECORDS ON "WAX"*

H. A. FREDERICK**

Summary.—*This paper describes recent progress which has been made in laboratory studies of mechanical records of sound cut on a wax disk. Both theoretical and experimental investigations indicate that a phonograph record, cut with vertical undulations instead of the more usual lateral undulations possesses fundamental advantages. The principal improvement comes from a marked increase in the volume and frequency range over which faithful reproduction may be obtained. A higher volume level can be recorded for the same groove spacing and speed. More playing time can be provided with a given size of record and volume level since, for these conditions, both the groove spacing and speed may be reduced. Improvements in methods of processing the stampers and in the record material give a large reduction in surface noise and hence a corresponding increase in the volume range. With these improvements the frequency range which can be reproduced satisfactorily can be extended nearly an octave to 8000 to 10,000 cycles. Other improvements incidental to the improvements noted above are great improvement in the quality of reproduction obtainable directly from a soft "wax" record and a great extension in the life of the hard record.*

At the convention of this Society held at Lake Placid in the fall of 1928, data were presented showing that a very good frequency characteristic could be obtained in recording and reproducing by means of the "lateral" disk recording system.[1] The data presented at that time had to do chiefly with the response-frequency characteristics of the elements which entered into that system. The information then available, however, about non-linear distortion was somewhat limited. That discussion, in addition, did not attempt to cover the limitations imposed by background noise commonly called "surface" or "needle scratch."

In most commercial uses of lateral records, surface noise has imposed very serious limitations. In many cases this noise has been

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

(Repeated at a meeting of the New York Section, December 9, 1931, at New York, N. Y.)

** Bell Telephone Laboratories, New York, N. Y.

suppressed by the use of so-called "scratch" filters. These have effectively quieted the reproduction but only by the sacrifice of an important portion of the recorded band of frequencies which are above 3000 to 4000 cycles. Investigations have been carried on to determine the fundamental causes and the characteristics of the surface noise in order that, with a better understanding, it might be more effectively reduced and without such a sacrifice.

In addition to the limitations imposed by surface noise, other studies have indicated that, with the available reproducers for lateral cut records, the needle point may fail to follow the center of the groove accurately when the curvature becomes too sharp, and may skid from side to side by varying amounts, depending on the record and the characteristics of the reproducer being used. Studies have proceeded

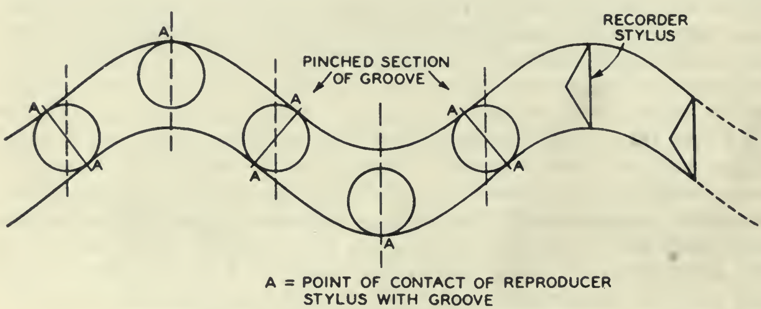

FIG. 1. Distortion in a lateral groove.

relating to the physical characteristics necessary in a reproducer in order that it may faithfully follow a groove. These studies have led us to expect superior performance from a groove cut with vertical undulations than from one with lateral undulations. These records are similar in principle to those used by Mr. Edison. With the lateral groove there is distortion due to the fact that the sound is recorded with a chisel-shaped stylus and reproduced with a round stylus; also that in reproduction the bearing point of the stylus against the groove shifts forward and backward as the needle rounds a curve. These effects are illustrated in Fig. 1. With vertical records the first of these effects, sometimes called the "pinch" effect, is absent, but a shifting of the bearing point of the reproducing stylus forward and backward occurs if a round stylus is used. It is doubtful if a chisel-shaped reproducing stylus or a stylus with an elliptical point can be justified due to the increased cost and complication, and in consideration of the rather small amount of distortion which this would eliminate. Some qualitative idea of what takes place with vertical undulations may be gained from Fig. 2, in which a sine wave is shown together with the resulting positions of the stylus point. For a given stylus tip radius and for a given recording level this effect increases with frequency.

This failure of a stylus point to follow a vertical record with great accuracy is, of course, due to the finite length of the stylus point along the groove. A fact which relieves this situation is that speech and music and most other sounds which we are interested in recording contain much less energy in the high than in the low frequency range.[2]

Frequency analyses of surface noise have been made using a variety

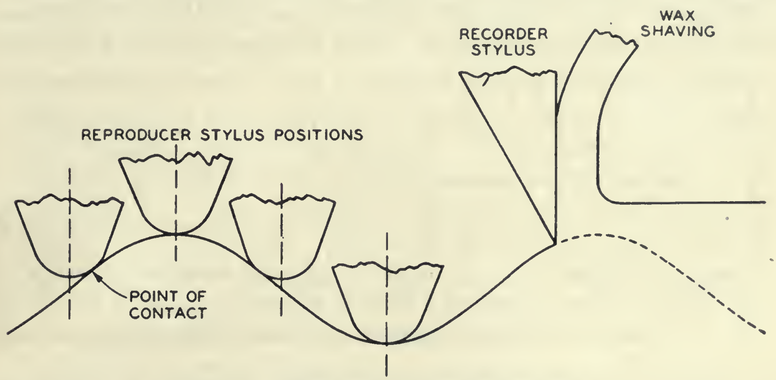

FIG. 2. Distortion in a vertical groove.

of reproducers and record materials. In general, these frequency characteristics have been found to be very largely influenced by the characteristics of the reproducers, but do not show any marked differences as between lateral and vertical recordings. Frequency charts of surface noise taken with a vertical reproducer having a very flat frequency characteristic over the audible range have shown the surface noise to be relatively richer in high frequencies. The distribution of surface noise energy below 10,000 cycles from a cellulose acetate pressing is shown in Fig. 3. The amount of recorded sound energy in the low frequency range, *i. e.*, below about 2000 or 3000 cycles, however, is large relative to that in the higher frequency ranges. Moreover, the characteristics of many lateral reproducers have been such as to accentuate surface noise between 3000 and 5000 cycles. Hence the use of "scratch" filters for the elimination of the high frequency components of the surface have made a large effective reduction in noise without any material loss in loudness of the sounds of interest. The loss in loudness at the higher frequencies has also reduced the audible distortion due to poor traction and, although the loss of the higher frequencies is serious, it has been held by many that the end has justified the means. Surface noise is probably caused by a more or less random distribution of impulsive shocks on the needle due to minute irregularities in the record. It has been common practice in lateral recording to use record material containing a certain amount of abrasive in order to grind the needle to fit the groove. The irregularities due to the abrasive would logically be expected to produce a scratchy noise of much the character with which we are all familiar. A 5000-cycle note of the same loudness as a 10,000-cycle band of surface noise using a reproducer with a flat characteristic would have

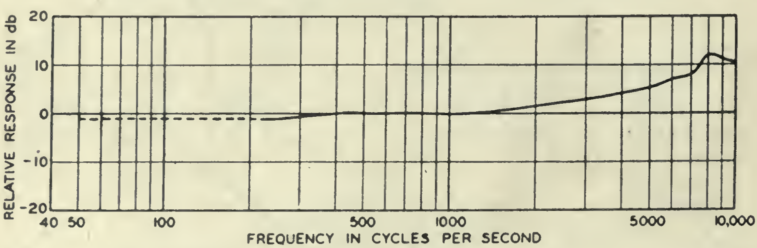

FIG. 3. Energy distribution of surface noise from a cellulose acetate record.

an amplitude of only about 0.000001 inch. In order to reduce the surface noise to the point where it is no longer troublesome, it appears necessary to eliminate irregularities at least down to this order of magnitude. It has been found that, if the usual abrasive record were replaced by an unabrasive record pressed of a very clean homogeneous material such as cellulose acetate, the surface noise caused by the record material itself would be greatly reduced. Such a change, however, by itself, has been found to give a comparatively minor improvement; for, when this cause is moved well into the background, other causes of surface noise of practically the same order of magnitude as that due to the abrasive of a shellac record become controlling.

The next process which it has been found necessary to improve has been that of rendering the surface of the original wax electrically conducting. The usual methods of graphiting or brushing with fine electrically conducting powders have been found unsatisfactory.

Recourse has therefore been had to one of the earlier methods used in phonograph practice, namely, cathode sputtering[3] of the wax. This method was not devoid of difficulty, however. With the best sputtering technic the usual thick "waxes" are heated to such an extent as to injure or destroy their finely engraved surfaces. By using a very thin layer of wax flowed on a metal surface it is possible to keep it cool during the sputtering operation. It is thus possible to apply an extremely uniform, smooth, and tenacious surface of metal of adequate thickness in a very few minutes. This can be electroplated by the ordinary methods, and the electroplate used for pressing the final record. By using this thinly flowed wax, it is possible to obtain a surface texture which is extremely smooth and homogeneous and which is also free from the mechanical strains incident to shaving the waxes by the methods previously commonly used. In addition, waxes of this type possess obvious advantages in ease of transportation, ruggedness, *etc.* When the noise due to the two causes discussed above has been removed or largely reduced, a third source of noise is apt to become prominent. This involves the reaction of the wax shaving on the recording stylus, which appears on the final record as "clicks" when the shaving breaks or is removed in a non-uniform manner. It has, however, been found possible by suitable design to provide a recorder, stylus, and suction arrangement such that the shaving is removed in a very smooth stream, thus eliminating this type of noise to a large extent.

It has been common practice in the past to provide duplicate stampers by electroplating the first stamper or "master" to obtain a negative metal record. This in turn has been plated to provide the duplicate stamper. A convenient and quick alternative method is provided by sputtering and plating a suitable pressing made directly from the "master."

These improvements in the methods of engraving and processing, and in the final record material are more or less applicable to either type of recording, lateral or vertical. Their full value, however, can only be realized provided full advantage may be taken of the increased frequency range which greater quietness permits. It is possible to take advantage of this improvement to effect other improvements or economies rather than to use it all in the one direction of decreased noise. In amount, the reduction in surface noise from that of present commercial records will differ depending on the frequency range reproduced.

If a blank groove record, made with the improvements noted above, is reproduced by a reproducer which is uniformly responsive up to 10,000 cycles, the surface noise is 20 db. below that of an old type record reproduced in the same manner. If, however, all frequencies above 5000 cycles are eliminated in each case, the difference is 15 db. If now the noise of the new record reproduced to 10,000 cycles is compared with the old record reproduced to 5000 cycles only, which is the comparison of greatest practical interest, the difference in noise is about 15 db. In addition, it is possible to take advantage of the fact that most sounds to be recorded contain less energy in the high frequency range than in the medium or low frequency range, and to record the higher frequencies at a level somewhat higher than normal. In reproduction these higher frequencies are then correspondingly reduced by the reproducing amplifier or circuit. It is thus found that a further reduction of about 10 db. in surface noise can be obtained, the amount depending somewhat on the high frequency cut-off of the reproducer or circuit. This effect occurs chiefly between 5000 and 10,000 cycles.

The "volume range" for any particular frequency band is usually considered to be the difference in decibels between the loudness of the surface noise and the loudness of the maximum recorded sound which the record can accommodate when reproduced faithfully over this frequency range. With the lateral records of the past, reproduced to 5000 cycles, this volume range may be stated as about 25 to 30 db. This figure obviously will differ somewhat for different cases, depending on the character of the sounds recorded and on the degree of excellence obtained with the recording and processing methods throughout. With vertical recording the reductions in surface noise described above increase the volume range for a 5000-cycle band of frequencies to from 50 to 55 db. For 10,000-cycle reproduction the volume range is 45 to 50 db. Obviously, these new facilities open the door for very great improvements in fidelity of reproduction and for the reproduction of many effects not possible in the past. In many cases it means that the surface noise may be reduced to inaudibility.

Lateral records have usually been cut with a stylus having a tip radius between 0.002 inch and 0.003 inch. The angle between the two sides has, in this country, commonly been about 90 degrees. The groove has been 0.002 inch to 0.003 inch deep and about 0.006 inch to 0.007 inch wide. The groove spacing has been 0.010 inch to 0.011

inch so that the uncut space between blank grooves has been 0.003 inch to 0.004 inch. If one groove is not cut over into the next, the maximum amplitude which can be used is limited to about 0.002 inch. If the usual loudness of the record is to be maintained it is necessary to maintain this spacing between grooves.

With vertical records it has been found desirable, particularly where a very loud record is to be made, to use a recording stylus with approximately the same tip radius as previously used with lateral records, but to reduce the divergence between the sides of the stylus above the tip. In addition, it has not been found necessary to provide any clearance space between grooves. In fact, it has been found entirely satisfactory to have the side of one groove cut consistently into the next. It is therefore entirely feasible to increase the number of grooves per inch from the usual 98 to between 125 and 150, at the same time that the recording level is increased. When using this recording stylus with the lesser divergence for cutting a record with 125 to 150 threads per inch, it has been found desirable to make the groove about 0.007 inch wide and about 0.003 inch deep. The maximum amplitude may, under these conditions, be increased about 4 db. It has been found possible, however, to obtain satisfactory results with most waxes even though the normal depth of the groove is increased to as much as 0.004 inch to 0.006 inch. In this case, the recorded level may be increased 6 db. This increase in the recording level obviously increases the volume range by a like amount. If occasionally, due to a loud crash of sound, the recording stylus completely leaves the wax, the reproducer will still "track" satisfactorily; that is, continue in the correct groove. The corresponding situation with a lateral record where one groove cuts into another is, of course, fatal since in such a case the reproducer will usually cross into the next groove. It has been found desirable with vertically cut records to use a permanent reproducing stylus in order to reduce the vibrating mass of the reproducer to a satisfactory value. This stylus point remains sharp in contrast with the old steel needles used with lateral records, and therefore will reproduce satisfactorily undulations of sharper curvature. In other words, for the same amplitudes the linear speed of the record may be reduced. Practically, it may be undesirable to reduce or change the rate of rotation of a record from the commercially used value. It is, however, feasible, to decrease the internal groove diameter recorded on the 33 rpm. record to about 6 inches for a 10,000-cycle frequency range. By the combination of the various elements mentioned above, it is feasible to record for 15 to 20 minutes on a 12-inch record and for 10 to 12 minutes on a 10-inch record. This involves the use of about 200 grooves per inch and a decrease in the recorded level to about the level of laterally recorded records using 98 grooves per inch. Of course, longer recordings can be made in the same space if the recorded level is decreased (more grooves per inch), or if the upper frequency cut-off is decreased (decreased rpm. and inner diameter). However, these changes may introduce tracking difficulties if carried too far and must be well justified by other considerations.

Laterally and vertically cut records drive the reproducer point quite differently. Laterally cut records drive the point from both sides but the point rarely follows the center of the groove with great exactitude. It deviates from the center by amounts chiefly depen-

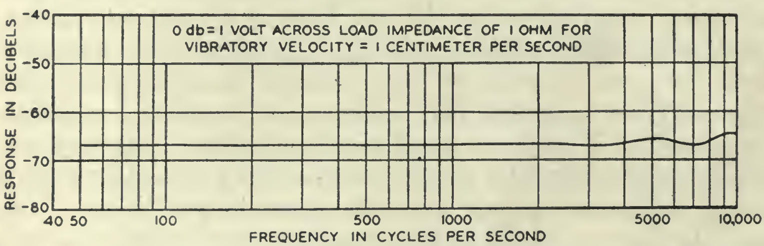

FIG. 4. Response frequency characteristic of an experimental vertical reproducer driven by cellulose acetate records.

dent upon the mechanical impedance of the reproducer. A vertically cut record, on the other hand, drives in only one direction. The restoring force is due chiefly to the elasticity of the supporting structure of the reproducer, the normal restoring force being equal to the total weight on the needle minus the weight of the moving or vibrating part. The stylus point will always remain in contact with the record unless the forces set up by the undulations exceed this normal restoring force. Operation should always be below this limiting condition. This sets definite requirements on the mechanical impedance of the vibrating parts and, unless this condition can be met, reproduction of extreme frequencies by vertical records is impossible. With the vertical reproducers which we have used, the stylus can follow sudden downward motions of the record groove even to accelerations about a thousand times that due to gravity. With laterally cut records, there is no definite limiting condition analogous to the above. However, it appears easier in practical design to reduce greatly the mechanical impedance of vertical than of lateral reproducers. Practical experience has shown that the mass can be so reduced as to reproduce up to well above 10,000 cycles and the stiffness reduced so as to reproduce down to the order of 20 cycles. In fact, there appears to be considerable margin on this score. This makes it possible to reduce the weight with which the reproducer point bears on the record to between 2 and 20 per cent of what has been used with most commercial lateral reproducers. This reduction in stylus or needle point pressure has been found to decrease the wear on the record very greatly, with the result that its life has been considerably increased. Tests have shown that the first few thousand playings cause negligible deterioration, and even several hundred thousand playings do not show excessive wear if the record is properly protected from dust and dirt.

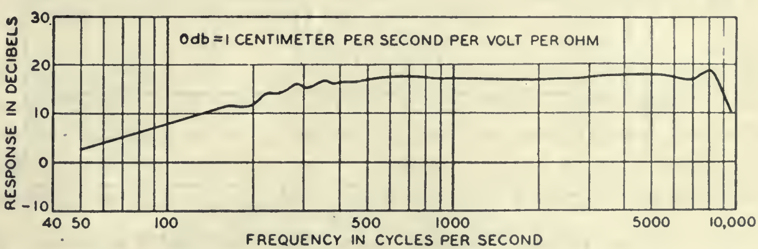

FIG. 5. Response frequency characteristic of an experimental vertical recorder.

A highly satisfactory method of providing a reproducer for vertically cut records has been to use the type of structure with which we are all familiar in loud speaker design; namely, that in which a coil moves in a radial magnetic field. Such a reproducer is simple and sturdy. Its performance is linear over a wide amplitude range; it may be made extremely light and, at the same time, is quite efficient. The coils used have had a diameter of between 0.1 and 0.2 inch, and the total mass of the vibrating system, including the diamond or sapphire stylus, has varied with different models from 5 to 35 milligrams. The total force on the record has been reduced from about 150 grams to between 5 and 25 grams, the lighter structure being used when playing from a soft wax. With the larger of these designs it has been found possible to obtain efficiencies which are comparable with the efficiency of the Western Electric oil-damped reproducer used with lateral records. No difficulty has been experienced due to failure to follow the groove if the reproducer is mounted on a simple pivoted arm, as in the case of lateral reproducers. Due to their very small mass they operate quite satisfactorily even though the record turntable fails to operate in a true plane, and even though the record be considerably warped.

The response of the moving coil vertical reproducer is practically constant over a very broad frequency range. It is shown in Fig. 4, which is the characteristic of an experimental model taken with cellulose acetate pressings.

The design of a recorder for use with vertically cut records involves no fundamentally new problems over those used with laterally cut records which have been described previously.[4] It is still desirable to design the recorder to approximate a constant amplitude characteristic for the lower frequency range and a constant velocity character-

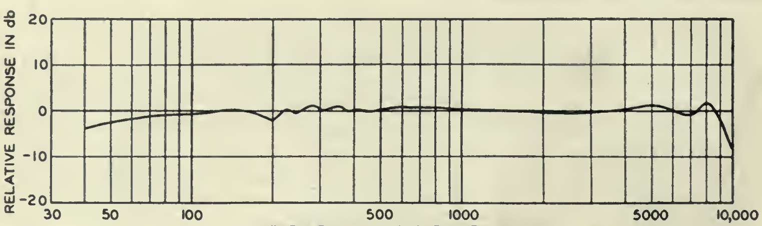

FIG. 6. Over-all response frequency characteristic (recorder + reproducer + network + amplifier).

istic for the higher range. This frequency characteristic has been often shown and is familiar to all. The same recorders which have been used for lateral recording can usually be converted for vertical recording by the addition of a comparatively simple link system and are quite satisfactory if a high frequency cut-off of 6500 to 7000 cycles is acceptable. It is, however, desirable to have a higher high-frequency cut-off. Such a recorder has been used in making many of the records which we have studied. Its frequency characteristic is shown in Fig. 5.

The response of the oil-damped lateral reproducer is greatest at the very low frequencies. Its response decreases with frequency, this decrease in the lower frequency range compensating more or less for the increase of response of the recorder with frequency. Because of the flat characteristic of the vertical reproducer, it has been found desirable to compensate in the reproducing amplifier or circuit for the low response of the vertical recorder at the lower end of the frequency scale. A frequency characteristic for the combination of recorder, reproducer, amplifier, and network is shown in Fig. 6.

It has been found with vertical records that speech is reproduced with considerably improved naturalness and that the word endings, sibilant sounds, *etc.*, are much more distinct. The sounds of the

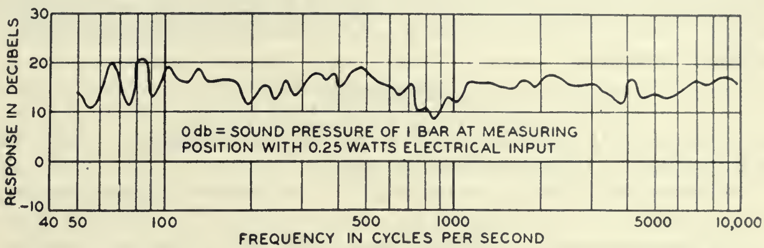

FIG. 7. Response frequency characteristic of combined high and low frequency loud speakers.

different instruments in an orchestra, particularly when playing a loud passage, are reproduced with very great individuality and clarity. Results of this kind are difficult to describe and should be heard to be appreciated fully. If records such as those described are reproduced using various low pass filters, the loss of distinctness due to the elimination of frequencies above even 7000 cycles is easily

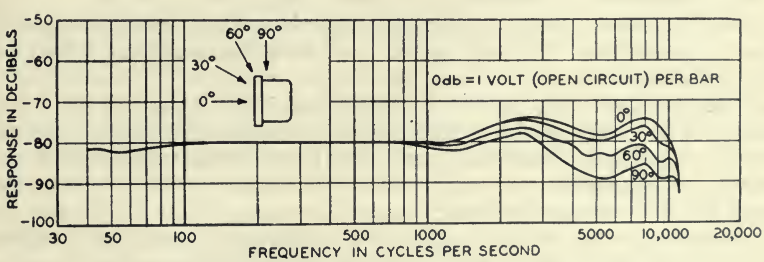

FIG. 8. Field calibration of a moving coil microphone.

noticeable, whereas little or no difference in needle scratch or surface noise may be observed, this being almost wholly absent in all cases. The latter statement holds whether the records contain speech or music or if blank grooves be reproduced. In listening to such records a loud speaker has been used which is essentially flat over a large portion of the range of audibility, its characteristic being as shown.[5]

(Fig. 7.) The reproducer frequency characteristic, as shown in Fig. 4, is essentially flat to 10,000 cycles. A corrective network has been used which compensates for the low frequency droop in the recorder which, at the high frequency end, is, as shown in Fig. 5, essentially flat to 9000 cycles. Thin metal-backed waxes have been used which, after recording, have been rendered electrically conducting by metal sputtering. The moving coil microphone has been used,[6] the characteristic being as shown in Fig. 8. The records have been pressed of cellulose acetate.

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DISCUSSION

MR. RICHARDSON: What is an L. P. filter?

MR. FREDERICK: An L. P. or low pass filter is one that cuts out everything above the particular frequency noted, and transmits everything below this "cut-off" frequency.

PRESIDENT CRABTREE: I think I have pointed out on several occasions that the public has been satisfied to date with the reproduction of speech, but not with the reproduction of music, because of its lack of range, both frequency and volume. This demonstration has shown that the extent to which the frequency range can be covered is excellent.

I am afraid that the range of volume is still inadequate for providing a facsimile of orchestral music. But I think this demonstration shows an epoch-making advance in sound reproduction. I don't believe that I have ever heard a reproduction of a film record that is as satisfying as some of the passages we have just heard.

While I do not predict that the producers will hasten to adopt wax records immediately, this performance will make them sit up and get busy, and either match this quality on film or turn over to the disk.

MR. RICKER: We do not get quite the full benefit of these excellent records in this room. This room lacks in acoustical qualities for a proper appreciation of the magnificent work done.

MR. PALMER: We are always being told that the radio can produce better sound in the home than talking pictures can in the theater. Can Mr. Frederick give us any information as to whether the quality of the music reproduced here, the fidelity of reproduction, is as good as or better than what the best radio receiver can furnish?

MR. FREDERICK: I hesitate to hazard an answer to that, as I am not familiar with the characteristics of all radio receivers. The reproduction of many receivers that I have heard was greatly inferior in quality to the reproduction to which we have just listened, but I prefer to let someone who knows more about that particular field attempt to answer your question.

I think you have been given a very definite picture of what those frequency characteristics mean by listening with the different filter settings. That is why we played the records with filters in and out so much of the time. One has to hear these things again and again, and even then he would have to check up his ears every once in a while, in order to have an accurate appreciation of what they are hearing.

MR. MAXFIELD: Was not the reproduction level of the orchestra record as reproduced here louder than would be heard in the center of the orchestra seats in the theater where it was made? I frequently make tests in that theater, and usually sit in the center of the orchestra. My impression here at the back of the room is that the reproduction of the loud parts is louder than they appear to be in the theater, in fact, a little uncomfortably loud.

MR. FREDERICK: I believe it was.

MR. CARLTON: What type of acetate was used for the new record? What method was used for the production of the cellulose acetate from which the record was made?

MR. FREDERICK: I cannot tell you in great detail. It was a very pure acetate. We obtained it from various sources. Du Pont, for example, has supplied it.

MR. CARLTON: Is it molded?

MR. FREDERICK: Yes, with slightly higher temperatures than are used for most other record materials.

MR. HICKMAN: I believe if the Bell Telephone Company were to present this entire outfit to an average person living in an apartment, and provide an easy means of adjusting the quality of reproduction to suit his taste, you would find that in general he would eliminate all components having a frequency greater than about thirty-five hundred. If the same person were to listen at a hole in the wall leading to an auditorium holding a good orchestra, the hole being disguised by a loud speaker design, he would tell you that the reproduction was rather good but was deficient in low frequency response. As gramophones are getting bigger and bigger, if you produced one big enough for a man to get inside, and let him speak through a speaker aperture, the observer would tell you that it was pretty good but not quite like the human voice. There has grown up, since the reproduction of canned music, a sort of new standard of what is desirable.

Why is it that instinctively we object to what should be the more correct form of recording? I am speaking as a layman—as an enthusiastic amateur musician.

Is it possible that, when the most perfect reproduction has been made, in picking up the sound from the record a high frequency chattering is created which cannot be expressed as harmonics but as a slight disagreeable individuality imparted to the record after, say, a frequency of five thousand, which we would rather have cut out?

MR. FREDERICK: I do not think that your question about reproducing these high frequencies was directed particularly to me or that you expect me to answer about the tastes of people. And I am not sure that I understand your last question.

PRESIDENT CRABTREE: I think Mr. Hickman wants to know why the frequencies above five thousand seem to annoy one in the home.

Recently a friend recommended for my radio a new speaker which had a straight curve up to I don't know how many thousand cycles. I obtained this speaker and compared it with my old speaker, which certainly does not reproduce above five thousand cycles. After repeated tests my observation was exactly the same as Mr. Hickman's—that in spite of the high frequencies, I preferred the low ones. The frequencies higher than about five thousand apparently were annoying, and seemed to irritate the ear. From this observation, it seems that straight line reproduction is not always necessary, but depends on the conditions of the room in which the reproduction occurs and on the tastes of the individual.

MR. HICKMAN: I am not questioning whether the reproduction shall be linear. I am asking why, when apparently the reproduction is most faithful, we do not find the reproduction of the high frequencies pleasing. I want to know whether some particular form of high frequency distortion is introduced in the pick-up, or later on, which is not in the musical record.

MR. FREDERICK: I do not think that anybody knows enough to really answer your question. And I doubt very seriously if a simple answer could be made if anyone did know enough. However, this point is extremely important. When you extend the high frequency range, if there is *any* distortion *anywhere* in the system it may be made audible and distinctly annoying, whereas it was previously inaudible. If the frequency range is to be extended upward a distinctly higher grade of performance must be obtained of all parts of any reproducing system than may seem perfectly tolerable with a lower high frequency cut-off.

The loud speakers so far designed are certainly not perfect. The curves shown in the paper indicate that by far the most jagged and roughest curve of all was that of the loud speaker. It seems reasonable to think that these irregularities, which certainly must mean a certain amount of resonance and "hanging on" of the sounds, must have an effect on the ear.

Now, if we could get a perfect loud speaker—and remember, that a perfect loud speaker means that it must be considered in conjunction with the particular room in which it is used—the results would undoubtedly be greatly modified. The characteristics of a loud speaker will be different in one room from another, and may be quite different in different parts of the same room. But placing ourselves at a particular place in a particular room, and having an ideal loud speaker to project the sound, I personally am convinced that we would, as soon as we were used to it, all vote for as broad a range as we could possibly get, and the most perfect or straight-line reproduction.

The trouble is, as we advance in our halting manner, we often make an improvement which shows up defects which were previously inaudible.

MR. EVANS: Is it not possible that the curves may not tell the complete story?

The curves that we have seen are for continuous tones—single frequencies—and do not take into account transient effects that may exist. If we knew more about transients, might it not be possible to answer the questions that have been asked here?

MR. FREDERICK: I think so. At least, it would take us further.

MR. MILLS: I speak not only as a layman, as some of the others have spoken, but also as one peculiarly inept in music. I have at times attended symphony concerts and orchestral renderings, and suffered from the higher and rasping violin overtones, and from irritating high frequency sounds of brass instruments and cymbals, and it may be that I prefer to listen to a little thirty-five hundred cycle cut-off loud speaker, and interpret its output as music.

But it may be that those who have a wider appreciation of music than I, and a greater discernment, would prefer the more nearly complete reproduction which includes the higher overtones.

I should like to ask Mr. Frederick whether he would briefly summarize four or five points: What is the increased range of loudness which this new record is capable of providing, over and above the previous loudness range? What is the increase in frequency range? What is the increase in time recorded under normal conditions? And what is the increase or decrease between the cellulose acetate record and the normal shellac, in ground noise, at the various frequencies which are important?

MR. FREDERICK: The volume range was stated in the paper as being about twenty-five to thirty decibels for most records. I have called them shellac records. They are not simply "shellac" records, but shellac plus a lot of other technic which accompanies it. The volume range with the type of record demonstrated here lies between fifty-five and sixty decibels, according to the best data we have. The improvement is not due merely to cellulose acetate. It is due to a combination of changes. If one of three or four causes, all approximately equal, is eliminated from consideration, the improvement which will have been made in the total effect is of course fairly small. Our observations have led us to believe that with the old records the noise due to the shellac was somewhat greater than the other noises, but only a few decibels greater. As soon as it was reduced a little the other components of the noise came into evidence.

Regarding the time of recording, I tried to summarize this matter in the paper, but it is difficult to give any simple and definite figure to cover the entire question of playing time. On the older, lateral record, a greater number of grooves per inch was sometimes used. Something has to be sacrificed to do this, but it may be worth while. Edison put out hill and dale records which played thirty or forty minutes. They were not successful because they did not have certain other characteristics which were needed. But as far as playing time is concerned, that is something on which I don't believe you can make any simple statement.

PRESIDENT CRABTREE: For a ten-inch record, how long will a lateral play and how long a vertical?

MR. FREDERICK: The usual ten-inch lateral record will play three minutes, I believe, and on this type we have thought it good practice to make it play ten or twelve minutes.. But if the "game is worth the candle" the time can be made longer. You have to sacrifice something else, however, to do so.

MR. VICTOR: Is there a relation between frequency and volume?

Perhaps the high frequencies carry farther, and perhaps it may be possible to introduce an automatic modulator of some kind for the home, that might tone down the high frequencies to a level that would be more pleasing to the ear.

MR. FREDERICK: Of course it is the easiest thing in the world to get rid of them. The trouble is to get them. High frequencies, I think, are generally found not to carry in distance as well as the low frequencies. A good example of this is furnished by a man making a speech in an open space. As you walk toward him, from a distant point, you first hear the sound of his voice but cannot understand a word. As you get closer, you perceive more of the high frequencies, until, when you get close enough to get the frequencies on which his articulation depends, you can understand what he is saying. This is not simply a matter of how the various components are transmitted, but is also concerned with the fact that the lower frequencies in speech, as in music, are usually very much stronger.

PRESIDENT CRABTREE: What Mr. Victor had in mind was a means of controlling the various frequency components, not to cut them out entirely, but selectively to diminish their volume.

MR. VICTOR: That is right. When a soprano voice comes over my radio I usually reduce the volume.

MR. FREDERICK: If you should go to a concert to hear a first-class soprano, you would not think of doing such a thing. If you should go to hear a first-class orchestra you would not expect to do it. When we do things of that kind I believe we only try to compensate for the faults of the equipment.

MR. RICHARDSON: When I said that the sound was best, according to my judgment, with the seven thousand cycle components included, I did not mean that it was most pleasing, but most natural. A railway whistle, of high frequency, is annoying to everyone. But everyone rather likes to hear a steamboat whistle, which is of low frequency.

Some people enjoy a soprano, but they are the exception. But I do not believe that there is anyone in this room who would not enjoy the sound of a contralto singing "Silver Threads among the Gold" or something of that kind. The sounds are pleasing to everyone. The high frequencies—the soprano, the locomotive whistle—are annoying to the nerves, not to the ear.

MR. SHEA: I think there is a great deal in what Mr. Richardson has said. It is probably true that most sounds which are startling or grating, as some people call them, have a large high frequency content. It seems to be the general experience that for the high frequencies you must have clearer reproduction.

MR. KELLOGG: Quite a little comment seems to have been inspired by the idea that during some of the numbers there was a kind of unnaturalness, particularly where there was fairly complex music—for example, the orchestra. It sounded to me as though it might possibly have been due to some imperfection in the correspondence between input and output—non-linear distortion as we sometimes call it, or it might have been an effect such as one gets when in a room with an orchestra and the reverberation is rather high, particularly in the high frequency range. I should be interested to know in the case of the orchestra recording whether the acoustics of the recording room were such as I have described.

I have another question: The piano was very steady and firm, a condition which obtains only when the turntable is rotating very steadily. A year and a half ago a turntable mechanism was described wherein a great deal of refinement was gone into, to avoid speed irregularities. I should be interested to know whether that type of turntable is used both in recording and reproduction in this case.

MR. FREDERICK: In answer to the first question, as to whether there was not some non-linear distortion somewhere in the system, I do not think there is any question but that there is, but I believe that there was perhaps less of it than we sometimes hear.

The conditions of the pick-up of the sound were not what we should have chosen if we had had a place where we could move the microphone about. A single microphone had to be placed close to the conductor; those conductors to whom I have spoken, and in whose opinions I have great confidence, insist that they cannot judge from the conductor's position what the orchestra should sound like. They have to permit another conductor to rehearse the orchestra, so that they may go out into the body of the hall to get the correct effect. As to turntable speed control, the recording machine was the usual Western Electric Company recording machine. The reproducing turntable was driven by a synchronous motor with multiple belt speed reduction.

MR. MAURER: How abrupt was the cut-off of the low pass filter used in this demonstration?

MR. FREDERICK: The cut-off is quite abrupt. A matter of a few hundred cycles means a great many "db.'s."

MR. THOMPSON: Is this type of reproducer more responsive to vibrations of the turntable, or irregularities of that kind, than is the present lateral pick-up?

MR. FREDERICK: Of course these records would not play on a seventy-eight rpm. turntable, because they were recorded at thirty-three rpm. They are far less sensitive to certain types of irregularity, due to the small mass of the pick-up and the small pressure on the record. We had a record one time that was pressed with a stamper, that had been bent at least an eighth of an inch out of plane, out on one edge, so that there was a big bulge in the record. The reproducer tracked over this without difficulty, and no trouble was experienced in the reproduction in doing so—until the pick-up reached the point where the frame of the reproducer hit the bulge in the record.

As to vibration, I should hesitate to say, because it would seem off-hand that a vertical reproducer would tend to be somewhat sensitive to it. So far as my experience has shown, it has seemed to be certainly no more sensitive to that type of trouble, and my impression is that perhaps it is a bit less sensitive. But I should hesitate to make a definite answer on that.

MR. OLNEY: The question of the frequency range of radio receivers has been raised in the discussion several times, and someone inquired as to how it compared with the reproduction we heard today. There is no comparison between them. In order to reproduce the low frequencies you have been hearing today, a receiver cabinet would have to be the size of the panel you see there, which is out of the question. As far as high frequencies are concerned, the requirements of selectivity prohibit reproduction of anything higher than five thousand cycles. This is a theoretical limit. Practically, the response drops off in the best radio receivers between four and five thousand cycles. In the poorer receivers it may drop off at three thousand cycles. In radio receivers equipped with the so-called tone controls, it may be possible for the user to reduce the cut-off frequency to fifteen hundred cycles. Some persons prefer that.

I do not think it is because they object to a normal amount of high frequencies. Some have claimed that what annoyed them were the frequencies above five thousand cycles. Those frequencies, I believe, are not reproduced by any radio receiving set on the open market today with which adjacent stations can be separated. I believe that one of the difficulties is that most loud speakers used in radio receivers have a very exaggerated response to frequencies in the neighborhood of twenty-five hundred or three thousand cycles; and unless these peaks are suppressed in some manner, the reproduction is bound to be unpleasant.

In commercial receivers, correctly designed, an attempt is made to equalize these defects in the loud speakers. When they are not equalized you will get this impression of harshness in the upper register; but this is not due to the frequencies above five thousand.

MR. VICTOR: I am afraid these discussions will read as if our Society members criticized this performance. I should not like to see the records so appear after such a splendid performance. It is the best I have ever heard.

PRESIDENT CRABTREE: Exactly. But we must not close our eyes to the imperfections. We will never progress if we do not criticize our own work. The man who is satisfied with his own work never gets anywhere.

MR. FREDERICK: I should like to add a comment suggested by something Mr. Victor said, that I may not have properly answered. As the volume level of any reproduced sound is raised or lowered, the quality appears to change, due to the physiological characteristics of our hearing. If it is played too loud the balance is off in one direction, and if it is played softer than in the first place the reproduction is off in another direction, even though the frequency characteristics of the reproducing system, taken either in part or in whole, are entirely flat.

Now, one interpretation of his comment might be that if a person simply must play the reproduced sounds too loudly, he needs to have a certain amount of distortion to make up more or less for what his ear is doing. Of course, I do not think that is the proper thing to do. He ought to endeavor to play the reproduced sounds at the level at which they were originally produced and picked up. If that were done he would not need that kind of a compensating system.

MR. HICKMAN: Mr. Victor put a point for me, that I had in mind. I think that anybody in reading this discussion might imagine that our criticism had been of this demonstration. This demonstration has been the most perfect music I have heard. My own criticism referred to reproduced music in general.

DR. GOLDSMITH: There were two points about this extremely interesting and significant demonstration, which I believe merit consideration: In the first place, comparisons were made to radio. There is no possibility of comparison to radio, because transmitting stations today send out approximately forty-five hundred cycles. The networks of the country carry very little above that. A few stations are going up to approximately eight thousand cycles in transmission. But taking five thousand cycles as the present transmission of radio stations, it is obvious that a wide open receiver, receiving from zero to ten thousand cycles, would get only the upper five thousand cycles of extra noises superimposed on the signal; and a five thousand cycle low pass one would be perfectly justifiable.

If, below that, there are cut out frequencies from five thousand down to three thousand, then reception suffers considerably. A great many people prefer that, however, because they have been working in noisy locations all day, and want to be soothed rather than given an esthetically true reproduction.

Then, a corollary of that is that home conditions are not the same as conditions in an auditorium. If you listen to a great conductor, you discover that the faintest whisper of sound can barely be heard, whereas, the climax following immediately, nearly brings the plaster off the ceiling, if the theater has not been acoustically treated. That condition must not exist in the home for the reason that a radio receiver in the home would be an intolerable nuisance and would start a neighborhood feud. We have to limit the volume range. We have something here that is adequate, indeed, for home purposes, and has the maximum of volume range which is permissible and consistent where people live near each other.

Another feature that we have to take into account is our own reaction when we hear things for the first time, in that we have a habit of reverting to old standards. I remember the first time a certain man, who was quite a capable man in his field, listened to a modern record, and remarked, "That is not good at all. It does not sound like a phonograph." And so we have to be careful. We must remember that we have all made a mental adjustment, a charitable adjustment if you wish, to reproduced music. We have accustomed ourselves to making mental allowances, applying the necessary automatic corrections. And we apply them to something where they are no longer relative.

I regard this as a most impressive demonstration. And throwing a bright light on nature, and holding up a brightly polished mirror to look at nature, is crude, but it is the only way to progress.

One other point, and that is the matter of the capabilities of film records. It is to be hoped and believed that results like this will properly stimulate the production of film records for theater use, which will be of equivalent quality. There is nothing theoretical or impossible about that. The trouble now is not with what is on the film, but the acoustic qualities of the theater.

MR. FREDERICK: I think it would be hopeless to try to summarize all the discussion which has taken place.

I regret that I am not fully familiar with all the facts regarding the transmission circuits of the networks connecting studios to radio stations. I know a great many of them are good to eight thousand cycles, and a great deal of effort has been made to make them good to eight thousand cycles. I think it would be unfortunate and quite incorrect if we should take away with us the impression that the transmission circuits were limiting or will limit radio transmission to five thousand cycles.

(*The following discussion was held on the occasion of the re-presentation of Mr. Frederick's paper, and the address of Mr. Stokowski published on page 164 of this issue of the* JOURNAL, *at the meeting of the New York Section on December 9, 1931.*)

MR. RICHARDSON: One of the worst things we have to contend with in reproduction and projection of sound is dust, both in records and in the film itself.

It will adhere to the film, particularly when a little oil has gotten on the film and will set up heavy ground noise.

It would seem to me that a record of hills and dales would be much more easily injured; it would be more difficult for the projectionist to keep it clear of dust and abrasive materials than a lateral record.

It also seems to me that a sapphire or a diamond point needle running over dust, which unquestionably will collect in the grooves, would have a more injurious effect and set up a greater amount of ground noise than would be the case with the lateral record groove.

Finally, I should like to know what are the limits of range of frequency in conversation and in music.

MR. FREDERICK: As to the effect of dust, our experience with these records has not indicated any particular difficulty. We have taken no particular precautions to avoid trouble. Except where we wanted to play a record thousands and thousands of times, continuously, we have found it necessary to take no special precautions whatever.

As to the limits of speech or music, opinions may differ as to that. If anyone will provide an adequate or an accurate audiogram showing what the upper and lower frequency limits are for his own ear, that will provide the answer to the question. If he is very young and can hear from twenty cycles to seventeen thousand cycles, twenty and seventeen thousand are the limits of his speech and music. If his hearing isn't quite so good and he can hear only from twenty to three thousand, why, that is the limit for him.

(*At Mr. Crabtree's request, Mr. Frederick repeated a record, using only the speakers which reproduced the high frequencies.*)

MR. CRABTREE: Mr. Chairman, I hasten to congratulate Mr. Frederick and his collaborators at the Bell Laboratories on this epoch-making development. The demonstration this evening, especially of the organ, shows how inadequate the present apparatus is and the present theory. I don't know whether Mr. Zukor, Mr. Lasky, or Mr. Harley Clarke were here tonight but if they weren't they should have been, and perhaps it might offer them some hope of getting the people into the motion picture theaters today if they would put on music of this high quality.

MR. SCHENCK: In your opinion, Mr. Frederick, when these high frequency speakers are playing—we haven't been accustomed to hearing frequencies of that order—were those actual reproductions on that frequency band or would you say there was distortion present?

MR. FREDERICK: There is no question that the day of reproducing sound without distortion is not yet here. Surely there is some distortion there. All I should say is that I think there is a little less than I have often heard, and I hope that five years hence there will be still less.

I waver between two feelings on this whole matter. Some days I quite enjoy listening to some of this music, and most of the other days I feel greatly impressed with the fact that we yet have a long, long way to go. This is not perfect and the day of perfection is a long way off.

MR. SCHENCK: We are not accustomed to hearing the high frequencies reproduced, and I am merely wondering whether we jump to conclusions about the distortion at that high frequency, particularly in connection with the orchestral record, wherein it sounded to me as if the cymbals were playing. At one point in the record it seemed almost certain that there was distortion. Following that, it started to clear up somewhat, and I could hear the high frequency instruments such as the cymbals or the bells that you mention.

MR. STOKOWSKI: Those loud crashes are cymbals. But they are cut off at nine thousand cycles. You need at least thirteen thousand, according to our experiments, and perhaps more. That is why they sounded strange.

MR. CRABTREE: What is the thickness of the records, and how are they made?

MR. FREDERICK: These particular records are about a quarter inch thick. They can be made two-hundredths of an inch thick. They are thermoplastic, not like bakelite. Under the application of heat they soften. They were pressed in the usual manner.

MR. WILSON: I would like to ask Mr. Frederick if the sound level, as it appears to the average person sitting here tonight listening to the orchestral record, is approximately what would be expected in an equivalent position in an auditorium listening to the actual orchestra. It is difficult, looking at a bank of loud speakers, to judge whether one is hearing the true level or something considerably above what he would get from the real orchestra.

MR. FREDERICK: I fully appreciate the difficulty you express of judging whether the level is right. Remember, you always hear an orchestra with two ears. The binaural effect changes your impressions always. You also use your eyes when you hear an orchestra and I think that what you see also changes the general impression quite a lot.

The loudness can, of course, be definitely measured and can be compared under different cases. We haven't actually made such measurements in this hall, but it is my impression that the loudness, both in the case of the organ record and in the case of the orchestral record, was fairly close to the original loudness.

MR. EDWARDS: I should like to ask Mr. Frederick about tracking. That is the great handicap of lateral recording, the thing that has given the most trouble in projection.

This is the first time that I have seen a reproducer that hasn't depended for its trackage on a thread and screw.

In the illustration showing the difference between the hill and dale and the lateral recording as placed on the record, I noticed that in the case of the hill and dale recording the wall of the record is cut very much lower than the surface level. Would not a little wear cause a great deal of difficulty in tracking, especially with the free reproducer?

MR. FREDERICK: I don't think I have ever seen one of these fail to track. We have had practically no trouble at all from this. I don't doubt there may be cases where they haven't tracked but I don't remember ever seeing one. That hasn't been one of our difficulties.

MR. EDWARDS: I think possibly the most notable example of detracking in a lateral record was in the picture, *Lilac Time*. In that picture there was a shot in the center of one record, and I think that shot must have cost the producing company a matter of twenty-five thousand dollars for that record because, once played, the next time it went through the wall. It brought disastrous results to everybody concerned.

MR. FREDERICK: Of course, with a lateral record, if an extra broad deviation of the groove occurs there is danger of cutting over into the next groove. With the vertical cut, even when the cutting stylus leaves the wax entirely, we have never experienced any difficulty in tracking. There is some distortion, of course, due to the fact that the top of the wave has been cut off. But it tracks perfectly well. And I think that is a rather important practical advantage of the vertical as opposed to the lateral type of record.

MR. CRABTREE: Might I ask Mr. Stokowski to tell us what is lacking in the music from a musician's standpoint? First of all, is the volume adequate? Do you get the thrill from the reproduction that you do from the actual orchestra? Is it lacking in depth or static effect? Do you notice the lack of perspective in it?

It is only by criticism of this kind, of course, that we can really advance; find out what is lacking and then try to improve it.

MR. STOKOWSKI: As to volume range, it is approximately, in my opinion, the same as in the original orchestra but in frequency there is a departure. The cymbals don't sound like cymbals because, as I said before, they are cut off at about nine thousand cycles and they need thirteen or fourteen thousand. The range between nine thousand and thirteen or fourteen thousand is necessary for several other instruments to give the proper tone color. It is a pity we do not have a word in the English language for timbre. We ought to invent one, because we need technical terms which have an exact significance and are invariable in their meaning.

We have in Philadelphia, in the monitor room (a room, I suppose, about one hundred and twenty feet long, so that there is plenty of space in which the tone can develop), the Bell Telephone Laboratories' loud speaker, different from this one. This is a double speaker; we have a triple loud speaker there, wired from the microphones in the hall. We have usually three, four, or five different microphones in different positions, so we can switch from one to the other.

When we sit in that room, which is soundproof, we don't hear the original. We hear the music only from the loud speaker. And we have there a most wonderful and faithful reproduction of the orchestra. I go in and conduct the orchestra for a time, to get the direct sound of the orchestra. Then I go down the hall about two-thirds of the way and listen to the orchestra from that point, which is the average listening point for the public. Then I go into the monitor room and compare what I hear there with what I heard outside, and it is a very faithful reproduction. From that comparison I notice that if we cut off from about 15,000, as we have done there, down to 9000, we not only cut off those higher frequencies, but there is some relation between those high frequencies and the ones which exist from 9000 downward, and they, too, are changed. The frequencies ranging from one to five thousand should remain the same when the frequency range is cut down to 9000 but, to the ear, they don't remain the same. They are changed in some way. You get a totally different sound. And that is, I think, one thing that will be gained when we have still higher frequencies than this, which we undoubtedly will have, because we already have them in Philadelphia.

MR. RICHARDSON: I believe that this style of recording will meet with trouble in the projection room due to the abrasive effect of dust in the bottom of the groove where the pressure must come from the needle. It must be borne in mind that the conditions in the laboratory and those in a projection room are quite different, particularly in the smaller theaters.

MR. HORNBLOWER: I should like to know whether, in checking the original against the reproduced sound of the symphony, consideration was given to the fact that the symphony orchestra would occupy a stage as large as the one you are standing on, that your base drum would be, say, thirty feet from the first viol, and so on, while in reproducing you get everything within an area six feet square.

MR. FREDERICK: I tried to bring out that point before, that one of the limitations of this type of reproduction is that we are effectively listening with only one ear, picking up with a single microphone, whereas under normal conditions, in a hall, we hear with both ears, and the orchestra is spread out.

We have taken that fact into account in some recording work by placing the microphone at an adequate distance from the orchestra.

In the particular orchestral record which we played here, we were obliged to have the microphone close to the conductor's stand, which we know is an atrocious place for it; but it was impossible to place it anywhere else, and I am quite sure that the record was very much injured as a result of it.

MR. SIMMIONS: Mr. Chairman, I should like to ask Mr. Frederick why the research which has been done at the Bell Telephone Laboratories has been confined to the speaking voice and has not included the singing voice.

MR. FREDERICK: I didn't think it had been.

MR. SIMMIONS: Then very little has been accomplished in regard to the singing voice.

MR. FREDERICK: Of course, in the telephone business our greatest interest is in speech, although we have done some work in other directions. We have played records here of singing voices.

MR. SIMMIONS: I should like to know if the physicist alone can solve the problem of the singing voice, from the physical point of view. In order to carry on this research work I have suggested that there should be three physiologists, three musicians, and three teachers or psychologists—of course, the singing teacher is a psychologist—and then these nine men together could accomplish something in regard to finding out the exact amount of pressure which is necessary in order to produce a beautiful sound.

I would suggest Mr. Stokowski, Mr. Damrosch, and Mr. Bodanski as the three musicians on that research committee. The Academy of Singing Teachers, whom I have approached, suggested that they should select three men from among their ranks. Regarding the physiologists, I have spoken to Dr. Williams of Columbia University and he is interested. I have spoken to Professor Wisluki, who is professor of anatomy at Harvard University, and Dr. Frank E. Miller; and to Dr. Fletcher, Dr. Watson, and Dr. Knudsen, of the University of California.

These men, with the help of the singing teachers, should get together to solve the problem. If they did so I am quite sure the problem of singing in relation to the films would be solved. But as I say it is not a one-man job.

The same standards which have been used in checking the singing could be applied in teaching control of the human voice, so that I should not have to depend on the monitor man when I go on, as Mr. John McCormick does. You know, he said the monitor man changes his voice.

SOUND RECORDING—FROM THE MUSICIAN'S POINT OF VIEW

LEOPOLD STOKOWSKI*

An address delivered before the New York Section, December 9, 1931, following the re-presentation of the paper "Vertical Sound Records: Recent Fundamental Advances in Recording on Wax," by H. A. Frederick, published in this issue of the JOURNAL *on page 141.*

As we listen to music, if I may speak purely from the musical standpoint, we have two kinds of reaction. First, there is the physiological reaction.

When you heard the great volume of tone coming from the organ it thrilled you. It uplifted you. It excited you. I am sure you would find upon analysis, that your heart was beating more quickly, that your blood was flowing more quickly, that your nervous system was tremendously stimulated. That is the physiological reaction.

If you hear a good military band playing in the street, with a really good rhythm, you want to march. That again is physiological.

If you hear very good dance music, you want to dance. Again, the physiological reaction.

The other kind of reaction is the psychological, the emotional. If you hear music of a certain type it arouses in you intense feeling. If you hear music which has very powerful contrasts—very loud, then very soft; very quick, then very slow; and so on—that has a psychological effect on you.

If you hear music which has very rich colors in it, and differences of tone colors, that again has a psychological effect. Melodic form, the flowing up and down of melodies, tunes, motifs—that also has a psychological effect.

There is also a very mysterious thing about music. It is psychic suggestion. I work all day long and every day in music. I experience every day, the whole day, the next day, that week, that month, ten years past, this psychic impression and suggestion that comes from music. So it is with all musicians; we talk about it; we think

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about it; but we don't know what it really is. We feel it vividly, but we don't understand it at all.

That is, to my mind, the most important part of the reaction of the music lover or of any one listening to music. That suggestive power which can carry us into the most remote spheres and realms of feeling and thought, and things that are higher than thought and higher than feeling—that is the important part of music. And in order for this to be done we must have this greater range which we have had demonstrated here tonight; greater range of frequency, of volume, and the elimination of foreign noises, needle scratch, static, and all the noises that we hear in radio. You hear on your radio the dial telephone in the next room; you hear the refrigerator; you can hear all the vegetables in the refrigerator talking to each other; and when the cook takes them out of the refrigerator and puts them on the electric stove and switches it on, you hear that. And so it goes. We must find methods of eliminating all foreign sounds.

When our orchestra plays in Philadelphia, or as we played last night at Carnegie Hall, here in New York, we give out a volume range of about 75 db.; but when we are recording we do so at about 35 db. And I think it is important for everyone connected with music, and the public at large, to know definitely and quite clearly—it is no secret, but quite plain—that when they listen to a record, or when they listen to the radio, they are listening to a sound level of approximately 35 db., sometimes less, sometimes a little more. But when they listen to a symphony orchestra, which is, I think you will agree with me, the most difficult thing to record or to transmit, they are listening to a level of about 75. We must find a way of increasing that 35 to 75 before we really can give the public what it ought to have in the way of expression in music.

That is one dimension, so to speak. Then there is the other dimension, the up and down dimension, the frequency range. When we play as we did last night at Carnegie Hall, in the overtones, or in the fundamentals, we are producing frequencies certainly up to 13,000, probably more. But we know certainly that it is up to 13,000. When you hear a record or when you hear music over the radio, you are hearing frequencies of about 4500, often less, sometimes a little more. The average, however, is about that. You can easily measure it and find out for yourselves whether I am telling the truth or not.

Last Friday night we had a concert in Philadelphia, and after the concert we made a number of tests, in connection with the Bell

Telephone Laboratories, and these are the exact figures we got from those tests:

We asked the first oboe player to play. We were in a room a long way from the room in which he was playing. We had previously arranged everything so that what we heard was an exact reproduction of what was happening on the stage. The oboe player was sitting in the same seat he always occupies during a concert, so that it was an exact reproduction. And we found that he needed frequencies up to 13,000 to express his tone color.

Then we took the trumpet and we found that up to 8000 cycles it gave a satisfactory effect.

The piccolo took up to 6000, and that was a very astonishing thing: that the piccolo, which is a very high pitched instrument, should require up to 6000, whereas the trumpet, which is a lower instrument, requires up to 8000 and the oboe, a moderately low pitched instrument, requires up to 13,000. That is something you couldn't determine without exact experiments like these.

Then we took the violin. It needed up to 8000. The cymbals needed up to at least 13,000, probably more; the tympani, 6000; triangle, 13,000; xylophone, 6000; snare-drum, 13,000.

I was doing these experiments, but the Bell Laboratory scientists were all watching very closely so that there was no chance of exaggeration or mistake. Those are the exact results.

In order to express all this, in my opinion, we must find out what the average living room, with the average curtains, rugs, paintings, and all the things that our wives like to have in our living rooms, which affect the tone, its absorption, and so forth—we must find out what the average living room will take in the way of volume range. We really don't know that exactly, yet. At least, I have never found anybody who did. In my opinion we must know that and we must experiment along that line.

The same thing applies to the average theater in which sound pictures are shown. They vary greatly, and when we record sound, music, or speech, no matter what kind of sound it is, we must have those conditions as nearly as possible invariable. They must be the same, because we record in a certain way, to project the sound in a certain way, and then if the projecting instrument and the hall or room in which it is sounding is different in each case, a different effect will be produced in each case.

This is the place, in my opinion, where standardization is very desirable. In many other things in life, such as thought, emotion, *etc.*, it is very undesirable to have standardization. But it is important for us to see clearly where standardization is necessary and I think it is necessary here.

It is the same with frequency characteristics. This hall has certain frequency characteristics; your living room where you play your radio, where you play your gramophone, has frequency characteristics. In producing our music for the gramophone or for the radio we should know roughly what is going to be the frequency characteristic of the place in which it is going to be played or the whole thing will be distorted.

In my opinion the gramophone and radio are twin brothers. There is often a certain antagonism between those who follow one god and those who follow the other god. But they are fundamentally the same, and they help each other very much.

For instance, we broadcast our concert last Saturday night. Forgive me if I speak about what we are doing. I do it with a definite purpose, not to be personal or to boast in any way—far from that—but I want to tell you tonight about my own direct experience, not what I have read in books or what someone has told me, but what I have tried by experiment. I think that is the only thing that has any value.

When we were recording last Saturday night, for example, we sent this music out. We asked the public to send us criticisms. That is what we want. We want them to tell us what is wrong about the broadcast, because we honestly want to make our broadcasting better and better all the time. Those criticisms came in, hundreds of letters and telegrams, telling exactly what those people felt was not good about this thing.

That is one method we have of checking. Another one is that during the performance someone is recording the concert in the concert hall where we are playing, and of course the connection between the microphone and the recording instrument is close and can be well taken care of, so that it is in good order and we have good reproduction.

Then the selection is sent over the air, and in the laboratory in New York someone is again recording, over the ether.

So that we are using those three methods of checking our performance and comparing them one with the other. First is the criticism from the public—what we want is the reaction of the average man in the average living room who is listening to our broadcast; we want to know how it impresses him, and we are receiving that information through the letters. Then we have the recording in the academy, and the recording over the ether in New York. By comparing those three things we get a fairly clear idea of what is wrong and how perhaps we can improve.

People often say when they listen to music, especially modern music, "That isn't music." For example we recently produced an opera called *Wozzek* and one of the music critics wrote this in his newspaper (as I say, this was a very modern work, different from other works, extremely original): "This department is organized to criticize music. *Wozzek* is not music. Therefore we shall say nothing."

But what is music? What are the limitations of music? There are people who think that the *Last Rose of Summer* is the summit, the highest peak of music. Well, it is a very beautiful melody. I enjoy it very much when it is well sung or well played. But there are other kinds of music, too. A little bird singing in the forest is producing very marvelous music, and a different kind.

What are the limitations of music in sound? Personally, I think one sees, as music progresses and has wider and wider horizons, that its limitations are becoming less. We are seeing it in a bigger and bigger way all the time. And ultimately it may be that we will think that all sound is music. All sound has something to which we can respond.

The sound that comes from that little machine* down there I should call music because it has a definite frequency. It has definite duration, and it has a very interesting rhythm if you will listen to it. The narrow-minded musician would say, "No, that is merely a noise."

But, I think, for the sake of the motion picture with sound, with tone, which is going to be an ever and ever more important type of art, that we have to think about what is sound, and what is music, and what are the limitations of music; and we have to take in more and more of sound, the sounds of nature, like the wind going through the trees The sound of the sea has a most interesting rhythm if you will take the trouble to listen to it. It has very deep, strange sounds, which are quite extraordinary. The sounds of the birds are marvelously beautiful as Wagner has shown in *Siegfried*.

There are all kinds of sounds in nature which are interesting and

* The stenotype machine.

which we wish to reproduce in tone films. The machine has very interesting rhythms if you listen to it with an open mind, not with the nineteenth century narrow-minded view, but with the view of today, which takes in more of life. All this will come, in my opinion, in the tone film, and then music will not be a narrow thing. It will extend itself until it takes in all sounds.

I said a little while ago that we must standardize certain things. I think a great battle is coming in the world between standardization and non-standardization, individuality. It is coming in all planes. It certainly is coming in the field of economics. I believe it is coming in the things in which we are interested, in sound, in science, in photography, in light, and I am watching it with great interest.

For example, my orchestra, I notice, plays differently every day. We play the same music; we rehearse it, say, for five days in succession. That is what we do every week. We rehearse every morning—Monday, Tuesday, Wednesday, Thursday, and Friday—the same music. Friday afternoon we play it in the concert. But every day the men play differently. Each day one can draw from them a different quality of tone and a different volume of tone.

This is going to be the great question: whether we shall standardize that or whether we shall allow it to be free and individual. Certainly, when we record it we standardize it. We must. We fix that day's impression on the disk, and send it out to the receiving apparatus as a standardized thing. But when we play it in the concert it is unstandardized. It is different every day. Emotionally, it is also different. That is something for us to think about, and I believe it will be years before we get any results on that.

I believe that this tremendous development that has been going on in sound in the last six or seven years through the radio, the gramophone, *etc.*, will lead to something that is very desirable.

At the present time, when a composer hears in his inner being some music, he desires to make it permanent, that impression that is going on within him, so he takes a paper and pencil, and writes down marks on the paper to preserve that melody, those harmonies, those rhythms. Then the singer or the player comes and reproduces those sounds. The composer listens and he says, "That is not at all what I intended."

We have that all the time. He composes something for the orchestra. We play the notes that he has written and he says, "That is totally different from what I intended."

Why is that? It is because the method of writing sounds on paper is tremendously imperfect.

If a painter wishes to paint a picture he takes his canvas and his colors; he puts his colors on the canvas where he wishes them. He makes his design, his relativity of color to color or form to form, and when he finishes it and he is satisfied; that ends the matter. It is complete.

But when Beethoven or any composer composes a symphony and writes it on paper, he has only half completed the process. It must then be given to the orchestra. They play it and he is dissatisfied, because it doesn't reproduce his idea, because our method of notation is so imperfect

I see in all this development something new coming. I believe it will be only a few years before the composer will paint directly in tone. He won't write down his impressions on paper. He will express them through frequency, through volume, and through duration. In that way he will express his ideas exactly, and not with the imperfections we now have. That is almost possible today, and through electrical production of tone, such as we get through the Theremin instruments and others which are being developed now, that will soon be possible and will be a very desirable thing.

What is the ideal for us who are scientists, or engineers, or musicians or photographers, or producers of tone films? What can we do in the future which is greater than what we are doing now? A great deal, in my opinion.

We may communicate with someone by telephone. We can talk to someone over the telephone. We can communicate ideas. We can come to understandings about ideas. We can talk for a long time on the most intricate, complex subjects, and make decisions and have a discussion. But when we combine sight and sound, through the tone picture, we can communicate much more, not only ideas but emotions and suggestions of things which are not completely said but which are conveyed in a more subtle way. We can suggest on levels of consciousness higher than thought, and feeling, and imagination, and all those strange things that go on in our nervous system which make our inner life so complex and so rich. Above all, these things for which we have words we all know perfectly well there are other things. We have no names for them, no words for them, but they exist. They are part of our daily experience. Especially do we feel those things through the finest type of music. Music of the higher type expresses just those things. And it is through the tone film that we can very richly and completely express that, and it is through radio, and eventually television that we can project those things through space all over the world.

That is the magnificent ideal, something quite supreme, toward which we must all work. We must not be satisfied to stand where we are at present, which is about a half-way point toward that thing.

The development of the radio, the gramophone, of photography and reproduction of sound has been perfectly miraculous during the last six, eight, or ten years, but there is far more yet to be done. Let's admit that frankly, and let's work for that immense ideal which is possible.

ON THE ASSIGNMENT OF PRINTING EXPOSURE BY MEASUREMENT OF NEGATIVE CHARACTERISTICS*

CLIFTON TUTTLE**

Summary.—*The theory of photographic tone reproduction, though specific for ideal cases, cannot always be applied in the determination of printing exposure for motion picture negatives. A statistical study of the correlation of various optical characteristics—maximum transmission, minimum transmission, and total frame transmission—with the required exposure has been made. Of the possible measurements to be made, the value of total frame transmission seems to be the best criterion of printing exposure. The apparatus used in making the measurements is described and the data obtained are presented graphically.*

PRESENT PRACTICE IN PRINTING EXPOSURE ASSIGNMENT

In motion picture finishing laboratories, one of the problems which must be considered is the assignment of printing exposure to each scene of negative of which a print is desired. The usual type of printer operates at constant speed, thus fixing the time of exposure. Compensation for differences in negative density is made by varying the intensity of the light incident upon the negative. In practice, a series of intensity steps is provided either by control of resistance in series with the printing lamp or by the setting of an opening in an optical diaphragm. Before a negative is printed its correct printing intensity must be selected and the light source must be regulated to give this intensity.

Methods for selecting the best printing exposure vary somewhat in different laboratories. In some instances, a tablet sensitometer is used as described by Jones and Crabtree.[1] In this method, a print of the negative scene is made through a density step tablet. The steps, each the size of a single frame, have been calibrated to correspond with those of the printer light-change board. The resultant positive after processing is inspected visually and a se-

* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Communication No. 470 from the Kodak Research Laboratories.

** Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

lection of the best exposure is made by an expert judge of print quality.

More frequently the assignment of printing exposure is made directly from the negative. A negative "timer," who by virtue of long experience and particular aptitude has become adept at judging negatives, is able to assign the proper printing exposure to a series of negative scenes merely by visual inspection. In the timing of negatives used for release prints, the initial results obtained by the timer are, of course, subject to correction after the projection of a trial print.

The author has never had the opportunity to gather any data concerning the waste of time and material occasioned by errors in the initial timing of a negative. It is probable, however, that such waste amounts to a negligible per cent of the total processing cost on release pictures, and it is probably true that the present methods of exposure assignment are entirely satisfactory where a large number of prints are made from a single negative.

If a single print is to be made from a negative, if speed is desired in the production of a first print, or if the services of an expert judge of photographic quality are not available, assignment of printing exposure on the basis of a measurement of the optical characteristics of the negative may be desirable. These practical considerations and the obvious interest of the question in the theory of tone reproduction have suggested the value of a study of the relation of the optical characteristics of motion picture negatives and their required printing exposures.

NEGATIVE CHARACTERISTICS AND PRINTING EXPOSURE

The rigid theory of tone reproduction is specific on the subject of required printing exposure. To reproduce with perfect accuracy the brightness relationships existing in the object by an equivalent series of tone relationships in the picture requires, first, a negative in which the total range is included on the straight line portion of the H & D characteristic curve. Given such a negative, a perfect print must translate the negative density range into positive density values lying in inverse order on the straight line portion of the positive characteristic curve. For the thinnest perfect positive, which for efficient projection would seem to be the thing desired, the printing intensity, according to the tone reproduction theory, is given by the following:

$$\log I = \log E_{P\ \text{min.}} - \log t + D_{N\ \text{max.}}$$

where I = intensity incident upon the negative.
t = time of exposure.
$D_{N\ \text{max.}}$ = maximum negative density.
$E_{P\ \text{min.}}$ = minimum exposure for positive—the exposure for the lowest density on the straight line portion of the characteristic.

In practice, many negatives, probably most of them, are not perfect in the sense just described. The printing operation also is usually a compromise, and throughout the literature we find numerous suggestions as to practical criteria for printing exposure.

Hurter and Driffield, the pioneers of quantitative photography, make the following statement in one of their early papers:[2] "We first of all measure the highest density of the negative...and knowing the inertia of the plate (positive) we take care that the exposure shall be such that behind the highest density of the negative the plate shall receive an exposure at least equal to the inertia." Since the inertia is defined as the intersection of the extended straight line portion of the characteristic curve with the log E axis, it is evident that an exposure equal to the inertia will not give a density lying on the straight line portion of the positive characteristic.

Driffield, in a later paper,[3] modified this criterion. He suggested that the printing exposure be computed as the antilog of the average of maximum and minimum negative densities multiplied by the geometrical mean of the exposure range of the positive. This procedure bases the printing exposure on the transmission of the middle tones of the negative.

According to this criterion, a negative with a range of density greater than can be accommodated by the linear portion of the positive characteristic would give a print in which shadow and highlight would overlap shoulder and toe of the positive characteristic to the same extent. Since that time a number of others have recommended the use of a similar criterion of printing exposure.

One authority quoted by Renwick[4] considers the total range of the print and not the relationship between tones to be the important thing, which is equivalent to saying that printing exposure is in no way critical so long as a given maximum contrast is obtained.

F. C. Tilney,[5] speaking for the artist, remarks, "There seems to be one thing only in matters of tone that is absolute, and that is the correct relation of one tone to another in the same picture whatever the key adopted." Translated into photographic parlance this statement may be taken to mean that the straight line portion of the characteristic curves only should be used and that the locating of negative density values with respect to the log E axis of the positive is unimportant so long as this condition is fulfilled.

If we may be permitted to apply the practical photographer's axiom for negative making—"Expose for the shadows and let the highlights take care of themselves"—to the making of the positive, we should do well to base our judgment of exposure on the transmission of the thinnest (or shadow) portion of the negative.

L. A. Jones'[6] discussion of tone reproduction, which is based upon a knowledge of the limitations of photographic materials, fixes the printing exposure at the value which will give a "just perceptible" density (0.008) for the highlight portion of the negative. This procedure insures gradation throughout the highlights of the picture.

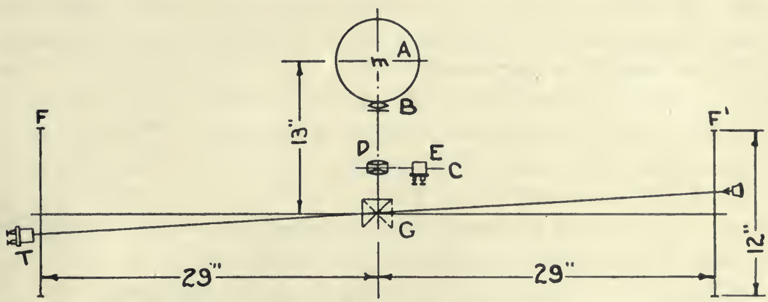

FIG. 1. A projection densitometer for the measurement of motion picture image characteristics.

The foregoing comments indicate that there are some differences of opinion regarding the assignment of "best printing exposure" from a consideration of negative characteristics. It is hoped that this fact will supply an excuse for the statistical treatment of a problem which does not appear amenable to purely theoretical solution.

MEASUREMENT OF OPTICAL CHARACTERISTICS OF A NEGATIVE

Apparatus.—Three characteristics of a negative—minimum transmission, maximum transmission, and total transmission—are readily measurable. Any one of these, or a combination of two, might be expected to give some correlation with the required printing exposure. To facilitate the measurement of these three values for a large number of motion picture negatives the instrument shown diagrammatically in Fig. 1 was constructed.

Referring to this figure, a monoplane filament lamp, A, in a suitable housing is imaged by lens, B, in the plane, C. In the plane, C, a sliding carrier containing a lens, D, and thermopile, E, may be so positioned that either the lens or the thermopile receives the filament image.

Over the condenser lens, B, is placed a rectangular mask with an opening the size of a single motion picture frame. The aperture is supplied with a spring gate so that a motion picture film may be readily inserted and framed in the opening.

When the lens, D, is in position an image of the motion picture frame may be formed either at F or at F', depending upon the position of the totally reflecting prism, G. This prism may be rotated about a vertical axis through its hypotenuse face to either of the two positions shown in Fig. 1. The plane at F' is provided either with a ground glass screen for viewing the image or with a sheet of bromide paper for making a permanent record of it. A stylus back of the plane F' may move either in the vertical or horizontal direction so that it is possible to indicate any area of the image. The movement of the stylus in the plane F' is mechanically linked to the movement of the Moll thermopile in the plane F. Thus, if the stylus is positioned at an area of the image corresponding, say, to the most dense portion of the negative highlight, the thermopile is brought automatically to an identical position with respect to the image which is projected on F by the rotation of the prism.

The thermopile is connected to a Leeds and Northrup high sensitivity galvanometer (17 mm./μv.) which is provided with an Ayrton shunt. Two readings are required in the making of a transmission measurement: A value for zero density, and a second value of the amount of light which has passed through the area of the negative to be measured. For the first value, the motion picture frame is removed from the beam by sliding the whole aperture plate and gate assembly horizontally in a pair of gibs. It is possible with this instrument to read transmission values as low as 0.1 per cent with an error less than 5 per cent, while higher transmission can be read to a much higher degree of accuracy.

Procedure Followed to Obtain Data.—Through the courtesy of a number of studios on both the west and east coasts, about 1000 clippings from release picture negatives were obtained. A wide variation in subject-matter and composition was represented by these samples. From each of the negatives a sensitometric tablet[1] print was made to be used subsequently in the determination of required printing exposure.

A single frame of each scene sample was registered in the gate of the motion picture densitometer. With the thermopile, E, centered with respect to the frame, a measurement was made of the percentage of light transmitted by the whole frame of the negative. It should be noted at this point that the measured value of trans-

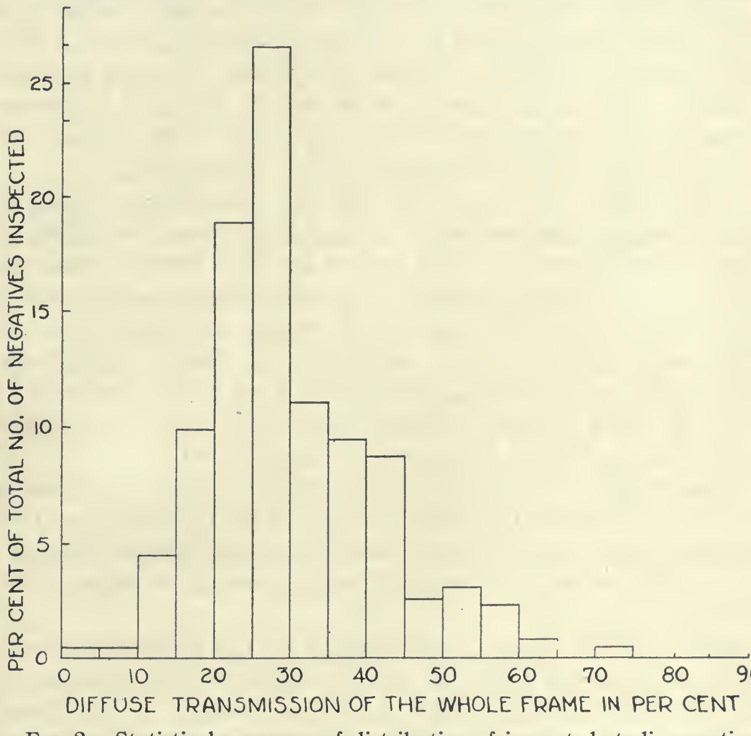

FIG. 2. Statistical summary of distribution of inspected studio negatives according to the whole frame transmission. The areas represent the comparative numbers of negatives to be found within each region of transmission.

mission so obtained is a specular value, and therefore is not identical with the diffuse transmission value. This matter must be considered in an application of the data to the contact printing problem.

In order to make measurements of the transmission of the densest and thinnest portions of each frame, the lens, D, was used to project an image of the negative magnified 10 times. With the prism, G, positioned to throw this image on the ground glass at F', the areas selected for measurement were designated by the indicator stylus, the movement of which automatically positioned the thermopile to receive the identical area when the prism was rotated through 90 degrees. The blackened receiver of the thermopile covered a circular area 1.0 centimeter in diameter which corresponded to a circle on the negative film of 1.0 millimeter diameter.

In the measurement of the total transmission of the large number of negatives, it soon became apparent that the great majority of professionally photographed and processed scenes occupied a relatively small portion of the possible transmission range for printable negatives. The data presented graphically in Fig. 2 is of interest in that it indicates the remarkable uniformity of the product of a number of studios so far as average density is concerned.

In the plotting of Fig. 2, the specular transmissions obtained directly from the galvanometer readings have been transformed to diffuse transmissions* to make the results more directly applicable to the contact printing problem. The figure shows the distribution of the per cent of the total number of scenes measured among various regions of transmission. It is seen from this figure, for instance, that 50 per cent of professional negatives have a total transmission of from 20 to 30 per cent and that about 95 per cent have a transmission between 10 and 60 per cent—a range of but 6 to 1.

An expert judge of print quality working from the sensitometric tablet prints assigned the printing exposure for the 1000 negatives. An analysis of his results showed that the required printing intensity range for 95 per cent of the negatives also covered a range of only 6 to 1.

Because of this great preponderance of the available samples within these narrow limits of printing exposure and transmission, it was decided to select a limited number of negatives distributed

* The author has shown in a previous paper[7] that the relation between specular and diffuse density is of the form $D_{\parallel}$ (specular density) $= KD_{\#}^{M}$ (diffuse density). For motion picture negative film $K = 1.37$ and $M = 1.088$, approximately. In computing the value of diffuse density of picture negatives from the specular density in this manner there are three possible sources of error: (1) The constants given apply to a truly specular optical system; (2) the values of the constants vary somewhat for different emulsions; (3) in substituting a value of $D_{\parallel}$ in the exponential relation one must assume that the density is uniform which is, of course, not the case with a motion picture image. It is believed that none of these errors is of any great importance for the type of data to be presented.

more uniformly throughout a greater printing range rather than to encumber the graphical presentation with data for the entire group. The table summarizes the data for the selected series.

TABLE I

Table Showing Characteristics of Group of Motion Picture Negatives

Scene Number	Total Specular Transmission	Total Diffuse Transmission	Maximum Specular Transmission	Maximum Diffuse Transmission	Minimum Specular Transmission	Minimum Diffuse Transmission	Ratio Maximum to Minimum Transmission	Printing Exposure M.C.S.
1	57.0	69.0	69.0	80.0	17.0	28.0	2.9	1.03
2	56.0	68.0	69.0	80.0	12.0	22.0	3.6	1.03
3	41.0	55.0	62.0	74.0	7.8	15.0	4.9	1.67
4	34.0	47.0	62.0	74.0	5.9	12.0	6.2	1.67
5	30.0	44.0	48.0	62.0	6.9	14.0	4.5	2.28
6	29.0	42.0	57.0	71.0	6.2	12.0	5.9	1.67
7	25.0	38.0	49.0	62.0	3.8	8.3	7.5	2.28
8	20.0	32.0	46.0	60.0	15.0	25.0	2.4	1.03
9	17.0	28.0	40.0	54.0	5.1	11.0	4.9	2.65
10	12.0	21.0	26.0	39.0	4.8	10.0	3.9	3.64
11	11.0	20.0	18.0	29.0	4.8	10.0	2.9	2.65
12	11.0	20.0	19.0	31.0	1.0	2.8	11.0	3.64
13	8.0	15.0	17.0	28.0	1.1	3.1	9.0	5.05
14	7.8	15.0	26.0	39.0	0.9	2.5	15.6	3.64
15	6.9	14.0	13.0	22.0	1.6	4.2	5.2	5.05
16	6.5	13.0	11.0	20.0	0.8	2.7	7.4	5.05
17	6.5	13.0	15.0	25.0	0.5	1.6	15.6	5.05
18	6.5	13.0	12.0	22.0	0.3	1.1	20.0	5.05
19	4.6	9.8	...	...	...	...	...	9.55
20	3.2	7.2	5.5	11.0	0.2	0.9	12.2	13.60
21	3.0	6.7	2.4	5.7	0.4	1.2	4.7	7.70
22	2.5	6.0	2.7	6.5	0.17	0.8	8.1	13.60
23	2.4	5.9	2.1	5.1	0.4	1.2	4.2	13.60
24	2.4	5.8	3.7	7.8	0.3	1.1	7.1	13.60
25	1.8	4.6	1.6	4.2	0.16	0.8	5.2	25.00
26	1.6	4.1	...	...	...	...	...	13.60
27	1.5	4.0	1.9	4.8	0.4	1.2	4.0	31.60
28	1.5	4.0	1.1	3.1	0.07	0.3	10.0	25.00
29	1.3	3.4	0.7	2.0	0.1	0.4	8.0	19.00

This table is probably self-explanatory with the following brief enumeration of the methods of obtaining each column of figures. Column 2 gives the ratios of galvanometer deflections with and without each negative scene in place. In this case a lens in the plane of the frame forms an image of the densitometer lamp on the thermopile and the reading is, therefore, a specular measure of the transmission of each whole frame. In column 3, the values of specular transmissions have been converted to diffuse transmissions as explained in the preceding footnote. Column 4 gives the specular transmission of the least dense area in each scene. Column 5 shows these same values converted to diffuse transmissions. Columns 6 and 7 give similar data for the specular and diffuse transmissions of the densest negative areas. Column 8 lists the ratios of the values

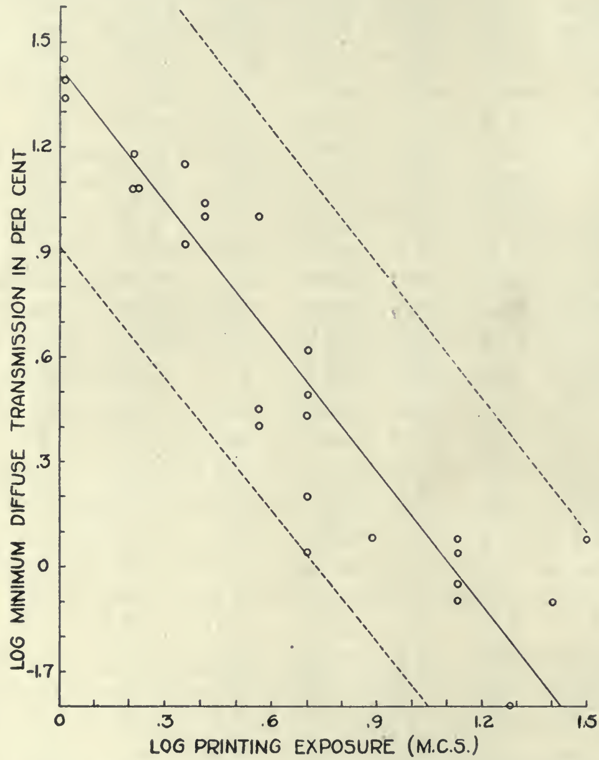

FIG. 3. Relation between $\log_{10}$ of required printing exposure and $\log_{10}$ of minimum negative transmission, diffusely measured.

of column 5 to those of column 7. These ratio values are of interest in a consideration of the exposure scale of the positive material which is to be used. The final column is the result of the expert's judgment concerning the printer step required to print each negative scene, the positive being developed to a gamma of about 1.6. These data are given as the exposure in meter candle seconds which would be required to print each scene. A calibration of the printer to which the "required step" data applied was made by methods of photographic photometry, the procedure for which has been previously described by the author.[8] The intensity factor of the exposure was measured by its photographic effect on positive film compared to the effect of a source operated at 5000 degrees K.

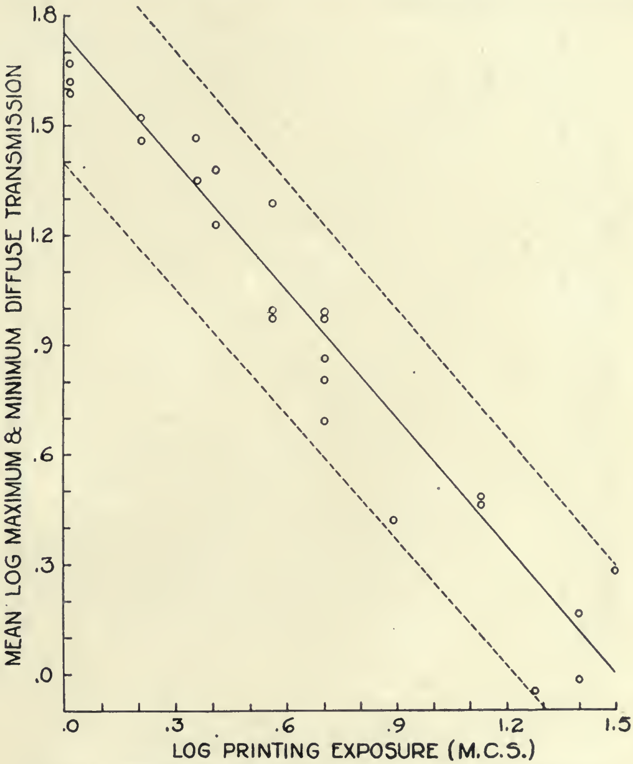

FIG. 4. Relation between $\log_{10}$ of required printing exposure and the mean of the logs_{10} of maximum and minimum negative transmissions.

In Figs. 3, 4, 5, and 6, $\log_{10}$ of required printing exposure as selected by the expert is shown as the abscissa axes. Figs. 4, 5, and 6 test the various printing exposure criteria which have been enumerated in the early part of this paper. In Fig. 3, $\log_{10}$ of minimum negative transmission is plotted. This tests the exposure criterion suggested by Hurter and Driffield[2] and by Jones.[6] If some definite highlight density is to be produced in the print to make the best positive we must assign any departure of the points from a straight line of unit slope to the uncertainty of the judgment of the expert.

The criterion suggested by Driffield[3] is tested in Fig. 4. If we suppose that an average of highlight and shadow negative densities is to be rendered by a definite positive density this data should define a straight line of unit slope.

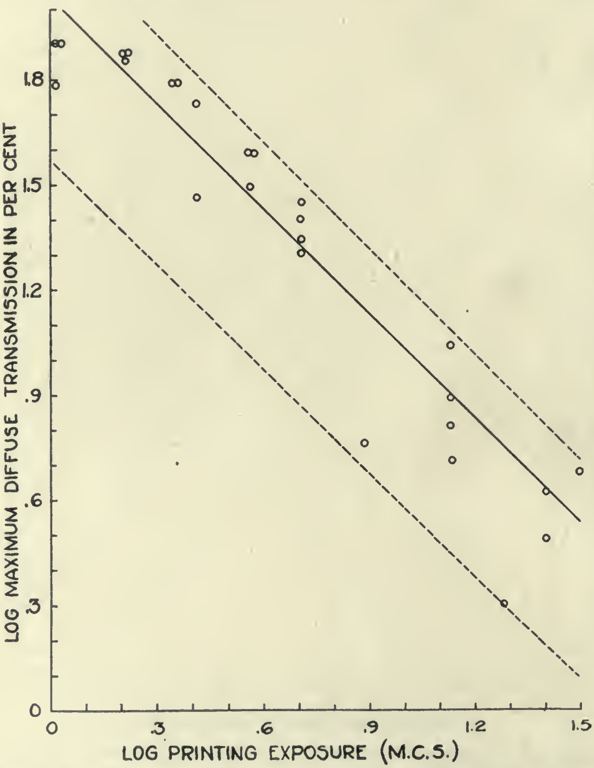

FIG. 5. Relation between $\log_{10}$ of required printing exposure and $\log_{10}$ of maximum negative transmission.

Fig. 5 shows $\log_{10}$ of maximum transmission, suggested by the photographer's rule of exposure and Fig. 6 indicates the correlation to be expected from a measurement of total frame transmission.

A value of total transmission can, of course, be determined much more readily than can the value either of minimum or maximum transmission. From the point of view of convenience and speed it would be the best measurement to make for the assignment of printing exposure. It seems possible that some total transmission measurement other than for the whole frame might give even better results and still have the advantages of speed in making the determination. It is possible, for instance, that the accuracy might be increased if only the foreground of the picture were measured, thus

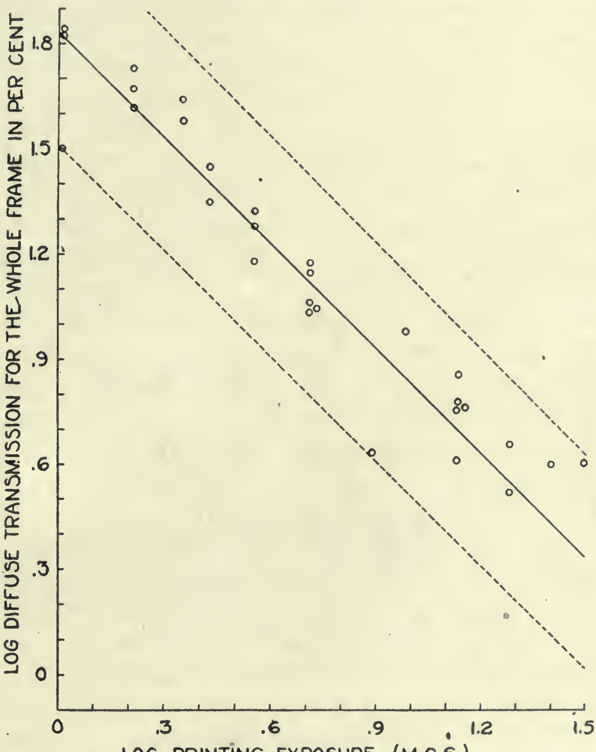

FIG. 6. Relation between $\log_{10}$ of required printing exposure, and $\log_{10}$ of total negative transmission.

leaving the area usually occupied by sky in exteriors and ceiling in interiors out of consideration. This alternative was tried but the results obtained were disappointing. The correlation of this measurement with required printing exposure was not nearly as high as was the whole frame transmission value.

A second alternative was tried using a circular mask of 0.75 inch diameter centrally located with respect to the film frame.

This idea was followed out on the supposition that the center of interest, and therefore the area most desirable to measure, usually occupies an area toward the frame center. In the case of these measurements, the correlation was somewhat better than that shown by any of the other measurements. It should be pointed out,

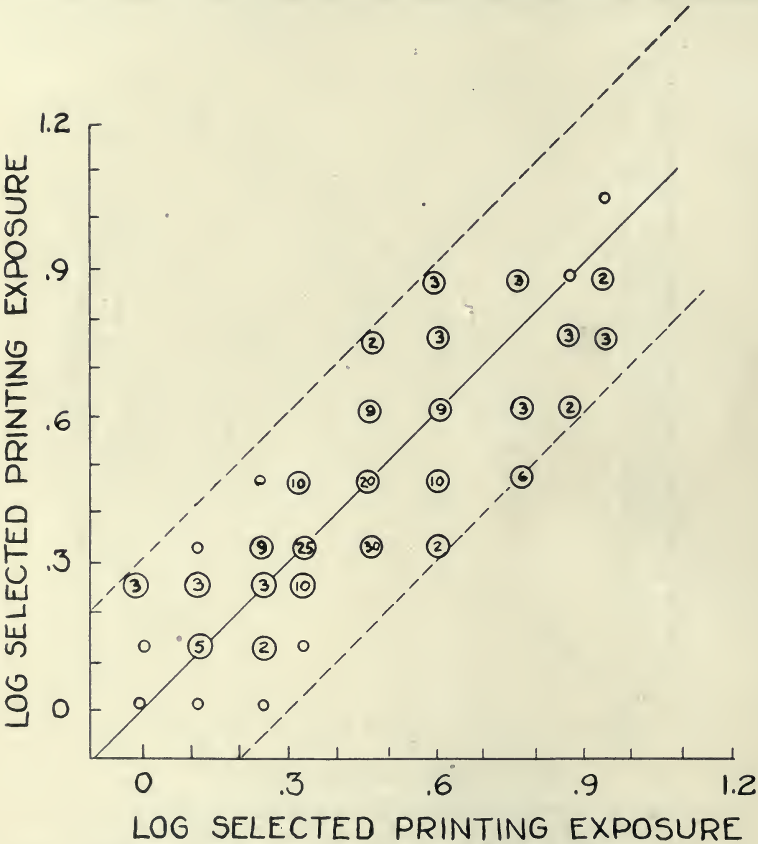

FIG. 7. Relation between $\log s_{10}$ of printing exposure as selected by two expert judges of print quality.

however, that, while statistically the central area measurement may give the best correlation, the occasional errors due to grouping of the subject interest at the edges of the frame may be of greater magnitude than would ever occur in case the whole frame were measured.

Certainty of Exposure Assignment by Visual Judgment.—In considering the data of Figs. 3 to 6, it should not be assumed that the value of required printing exposure chosen by the expert for each negative scene is the "correct" value. Undoubtedly, at least in the case of some scenes, this value may vary somewhat and still result in passable prints. It has already been suggested that the judgment of printing exposure is regarded as somewhat of an art by the motion picture profession. If this is the case, it may be that such factors as personal taste of the observer, and conditions of the observation play some part in the selection.

While it is difficult to arrive at any decision on this question of how accurate is the work of the negative timer, the following set of data may throw some light on this matter. In our own processing laboratory two individuals have had considerable experience in assigning printer exposure from inspection of sensitometric tablet prints. These two persons work interchangeably and it is generally agreed that both are expert judges of print quality.

After the first timer had completed his work with the tablet prints the second was given the same set of prints and asked to assign the printing exposures. The diversity of opinion which is indicated in Fig. 7 is rather surprising. The two axes of the graph are used for the log of printing exposure assigned to the series of negatives by the two experts. If the agreement in all cases had been perfect all of the points would lie on a straight line of unit slope.

The figure represents data for 180 scenes. The numbers in the circles show the number of scenes which determine the location of each point. For only 64 scenes is the agreement of the two observers perfect. The remainder of the observations is distributed throughout an area which is enveloped by the two dotted lines. To include all the scattered points these lines are drawn at positions ± 0.3 in $\log_{10} E$ removed from the mean straight line. This means that, at least in the case of some of the scenes estimated, there is a printing exposure tolerance equal to a factor of two or one-half. The statistical method does not reveal the presence of some scenes in which conceivably there is very little tolerance in printing exposure.

DISCUSSION OF RESULTS

Accuracy Demanded in the Selection of Printing Exposure.—The wide tolerance in the choice of printing exposure which is suggested by the data of Fig. 7 is surprising in view of the known facts concerning existing practice in the commercial laboratories. Consider for a moment the usual light change scale of the production laboratory printer. Few of them are calibrated to accommodate an intensity range of more than ten or twelve to one. This range is split up into twenty-odd steps and the average magnitude of a step is between 10 and 15 per cent. A printing exposure tolerance, such as that indicated in Fig. 7, would correspond to plus or minus perhaps half a dozen such steps. The experts in the laboratories presumably work to a tolerance of plus or minus one printer step. The author is in no position to express an opinion concerning the desirable accuracy of printing exposure assignment but merely wishes to present the following facts which may have some bearing on the question.

In column 8 of the table are given the transmission ratios, maximum to minimum, of the studio negatives which were examined. These ratios vary from 2.9 to 20.0. It is probable that 20 is an extreme case. Special precautions[9] must be observed to obtain a lens image brightness ratio for highlight to shadow of more than 25 to 1.0. With negative developed to a gamma of 0.5 or 0.6, the transmission ratio will seldom exceed 15.0. Since the average positive material at a gamma of 2.0 has an exposure scale of approximately 60 to 1.0 there would appear to be a latitude in printing exposure of two or one-half from the mean value without making use of the toe or shoulder of the positive characteristic. In other words, positives which would render the negative tones perfectly could be made from most negatives throughout a four to one range of printing intensity. Such positives would differ from each other only in average transmission.

The amount of light reflected to the audience from the screen is known to differ in various theaters. The public at present sees motion pictures under so many different conditions in different theaters, that it seems quite possible that within wide limits the average transmission of the positive is a matter of small consequence.

Choosing the Negative Characteristic to Measure.—Whether or not measured values can be as satisfactory as expert judgment in assigning printing exposure, it is conceivable that there may be applications in the processing laboratory for a quick approximation of exposure such as would be afforded by a densitometric method. With this end in view we can consider the relative merits of the criteria tested in Figs. 3 to 6.

The relations between printing exposure, E, in meter candle seconds and negative transmissions in per cent obtained from Figs. 3, 4, 5, and 6 follow:

(1) $E = \frac{12.9}{T_{\text{min.}}^{0.79}}$ in which $T_{\text{min.}}$ is the diffuse transmission of the negative highlights.

(2) $E = \frac{33}{T_{\text{average}}^{0.89}}$ in which T_{average} is the geometrical average of the diffuse highlight and shadow transmission.

(3) $E = \frac{107}{T_{\text{max.}}}$ in which $T_{\text{max.}}$ is the diffuse transmission of the negative shadow.

(4) $E = \frac{67}{T_{\text{total}}}$ in which T_{total} is the diffusely measured total transmission.

The measurement of minimum negative transmission has little to recommend it. The possible error which would follow its use (roughly indicated by the distance separating the dotted lines) is greater than that for the other suggested values. The dotted lines which designate the area required to include all points are 0.8 in log E apart. This separation corresponds to an exposure factor of 6.3 which means that a departure of 3.1 times in exposure from the value picked by the expert might be made. The relation involved is exponential, which means that a linear calibration curve between opacity ($1/T$) and required exposure could not be used. In addition to these objections, there is the fact that the lower the transmission value the more difficult is the measurement to make and the greater is the probability for error in the measurement.

The other suggested criteria appear to be almost equal in that the maximum departure from the visually selected printing exposure would be by a factor of about two or one-half. The geometrical mean of maximum and minimum transmission, which gives slightly better correlation than the other criteria give, is probably ruled out as a practical measure of required printing exposure because two selected areas would have to be measured and a computation made before this value could be applied.

There is no question but that the value of total frame transmission is the most readily applicable to the speedy determination of printing intensity. In many instances, no doubt, exposure assignment on the basis of a total transmission measurement would be considerably in error. In any number of conceivable cases where the object of principal interest occupies a relatively small portion of the frame against a background of a markedly different transmission, the total transmission will not give an indication of the best printing exposure. In scenes where special effects are to be obtained by over- or underprinting no generally applicable method of printing intensity evaluation by measurement is conceivable.

The value of a measuring method used either alone or to supplement the judgment of an expert is a matter which must be decided upon evidence gathered under practical conditions of operation.

It is certain that there is waste of some time and material with the present methods of printing exposure assignment in the making of first prints. Only extensive trials of the possibilities of exposure assignment by measurement can decide as to its relative merits.

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UTILIZATION OF DESIRABLE SEATING AREAS IN RELATION TO SCREEN SHAPES AND SIZES AND THEATER FLOOR INCLINATIONS *

BEN SCHLANGER **

Summary.—*The aim of this paper is to establish a relation between the bodily posture of the viewer, the size and shape of the picture, and the architectural form of the theater in all its details. The present type of theater floor is compared with the reversed type described in a previous paper in order to show how the latter type of floor permits placing a greater number of seats within the desirable seating areas than the present type. An analysis is made also of the effect of reversing the floor on the ability of the viewer to assume a comfortable bodily posture. Definite angles of sight specified by the various tilts of chair backs found necessary for comfortable posture are shown. Several forms of theaters of various seating capacities and screen sizes are described in order to show the broad application of the theories involved in reversing the pitch of the orchestra floor.*

The principle of reversing the slope of the orchestra floor in theater structures, as presented in a previous paper, suggested the possibility of correcting many of the faults of present-day theaters. Bodily posture in seating, vision, projection angles, accessibility of various levels, and construction costs are all affected. Further study of this new principle in planning theaters has resulted in the development of definite relations between the various functions that contribute to the practicability of the whole. Study has also brought out the fact that this new principle is not only applicable for improving the present form of the theater, but also for deriving from it many new forms more adaptable to motion picture exhibition. (Fig. 1.)

A complete analysis of bodily posture has been made in connection with this new principle. Certain maximum and minimum pitches of chair backs and floor slopes have been arrived at, and measurements have been made of the vertical range of vision which can be obtained while sitting against differently pitched chair backs.

Practical projectionists have verified the need of lessening the angle of projection. This need has been recognized, and has been answered

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Architect, New York, N. Y.

in these studies by establishing a maximum angle of ten degrees to the center of the screen from the lens center. In most cases the angle will be less, varying from ten degrees to a perfectly horizontal line of projection. In existing theaters the projection angle is often as great as thirty degrees or more. Regardless of the size or seating capacity of a theater, the reversed floor principle of planning requires no angle of projection greater than ten degrees.

It has been found that the enlarged screen can be more easily accommodated in a theater structure if the reversed floor principle of planning is applied; and that it would be impossible to install an enlarged screen in the present type of theater without incurring a

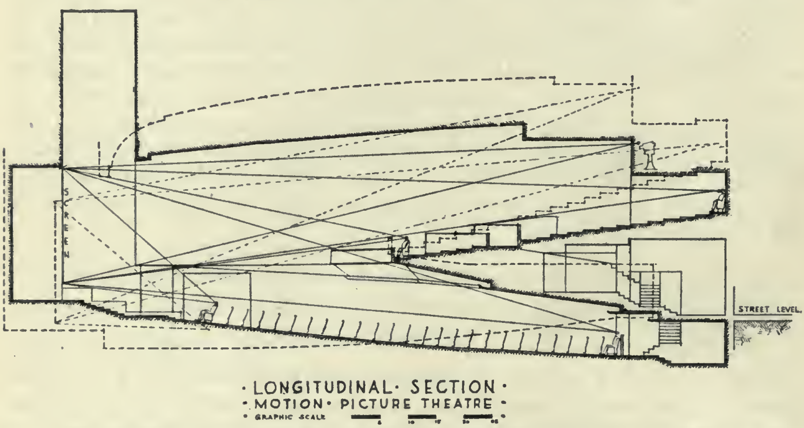

FIG 1. Longitudinal section of the present type of motion picture theater as affected by the use of reversed floor.

great waste of structure area and inefficiency in seating arrangement, resulting from the failure to utilize the areas most valuable for comfortable vision. The difficulty of using an enlarged screen in present theaters has already evidenced itself, and is partly delaying its popular adoption. Balcony obstructions, and the difficulty of obtaining a complete and comfortable view of the higher screen are serious impediments, which may be overcome by the use of the reversed floor.

The practicability of applying the reversed floor principle to variously sized and proportioned plots of ground has been given special attention, the object always being to obtain a maximum number of "good" seats within a minimum area. Many different adaptations of the reversed floor principle have been devised to fit the peculiar conditions of various theater projects. The feasibility presents itself of placing a part or the whole of a theater auditorium above or below the portions of a structure which may be used for other purposes. It therefore becomes important to design a theater auditorium so that it will not require too much valuable area in the vertical sense. Thus, the remaining portions of a structure above or below the theater may provide an additional income which, in turn, results in a reduced rental for the theater itself. The use of the reversed floor permits constructing a theater within a limited height, where it would be impossible to include a theater planned according to present practices.

A revised building code for the city of New York, affecting theater structures, is about to be put into effect. The committee revising this code has taken into consideration the possibilities of the reversed floor by providing for its development in the wording of the

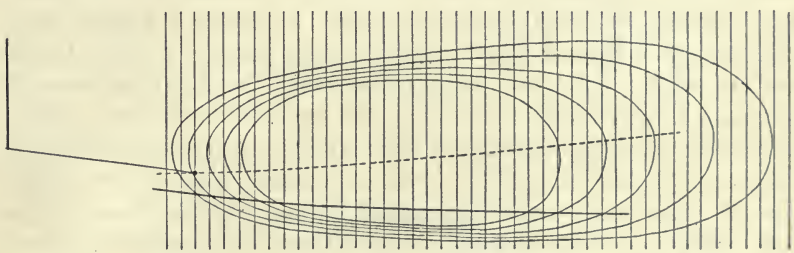

FIG. 2. Chart for determining, in the vertical sense, the desirable seating areas.

code. The revised code will permit the construction of a theater auditorium, having a capacity of more than 600 seats, directly beneath the portions of a building used for other purposes. This is already permitted in many other building codes.

For the purpose of making possible better vision, smaller projection angles, and reducing the cubage of the theater structure, a very intensive search has been made to ascertain which of the physical areas are most valuable as seat locations in relation to the screen, the object being to use these areas only for seating arrangements. The present system of theater planning necessitates the utilization of portions beyond these valuable areas, thus causing large projection angles, distorted vision from high balconies, unnecessarily large construction costs, and the payment of excessive rentals for space which not only has no value to the exhibitor, but which also creates conditions highly unsuitable for motion picture exhibition.

For these reasons the present method of theater planning results in unscientific and uneconomically built structures. If original construction and maintenance costs can be reduced, at the same time giving to the theater patron the comforts and surroundings due him, there is little doubt as to what the effect on the box-office will be.

A chart showing the location of the desirable areas has been developed. (Fig. 3.) These areas have been found by determining how much above and below, and how far from and how near a fixed screen, a spectator may sit, maintaining a comfortable bodily posture, and obtain a view of the entire screen. The spectator should be seated in such a position that the picture on the screen will appear at a level which is most imitative of the level from which natural surroundings are viewed in real life. Still another determining factor in locating these valuable areas is that it is more natural to sit low and lean slightly backward against the chair to obtain a higher view, than it is to sit high and lean forward to look down at a screen below the eye level. For these reasons, therefore, the desirable areas of seating are limited to levels below the top of the picture. While both the reversed orchestra floor slope and the present orchestra floor slope come within the desirable areas, the present slope of floor, which rises up away from the screen, causes all upper levels of seating to come within the areas undesirable for natural and comfortable viewing. The reversed orchestra floor slope has a much smaller pitch downward than the present type of floor has upward. The present type of floor eats into the valuable areas unnecessarily, while the reversed floor hugs the lower region of the desirable areas, leaving the remaining valuable areas for additional seating levels.

A method of adjusting the level of the screen, the levels of the various eye lines, the distance between the eyes and the screen, the slope and inclination of the various levels of seating, and the pitches of the backs of the seats has been developed, keeping a definite relation between all the elements involved. (Fig. 3.) Formulas have been evolved to define the position of the screen in relation to the slopes required for the orchestra and balcony levels. The shape and size of the screen are also a definite part of the calculations. Given the shape and size of the screen, and the distance between the screen and the nearest seat (which should equal the width of the screen, for perfect horizontal vision), the vertical distance between the level of the nearest seat and the level of the bottom of the screen is determined.

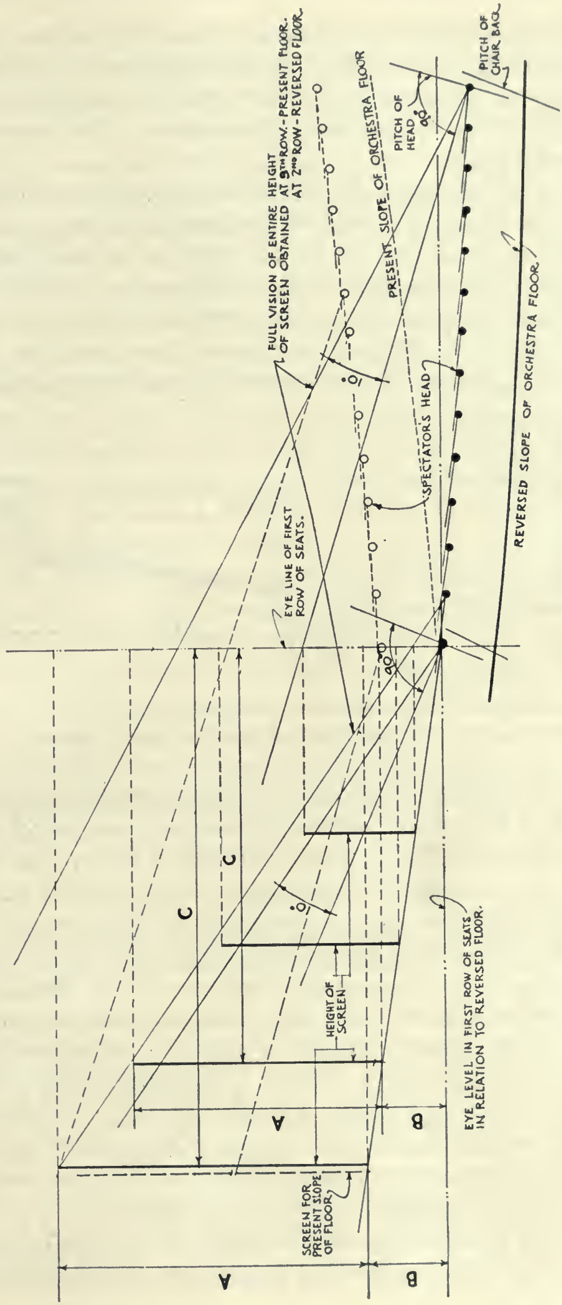

FIG. 3. Diagram for determining screen level, sight lines, distances, slope of floor, and pitch of seats.

This distance determines the slope of the orchestra floor and the pitches of the chair backs. The resultant slope is a parabolic curve which starts near the screen with a downward pitch, decreasing uniformly until the floor is practically flat at about the twenty-fourth row of orchestra seats.

The slope of the orchestra floor in existing theaters is not sufficient to permit seeing the bottom of the screen over the head of the person immediately ahead. If the pitch were sufficient for this purpose, it would be too great for comfortable walking, and would make it difficult to adjust the standards and leg supports of chairs to the slope of the floor. The mild pitch of the reversed floor necessary to allow full view of the bottom of the screen eliminates these difficulties.

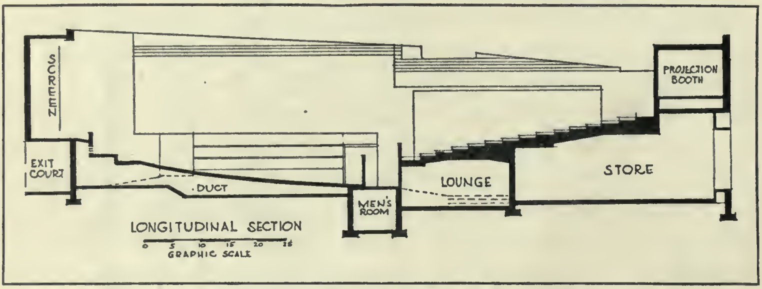

FIG. 4. Adaptation of reversed floor to a small theater.

A full, comfortable view of the entire screen can not be obtained until the ninth row of the present orchestra floor slope is reached, causing severe neck- and eye-strain in about 300 seats in the average theater. The reversed floor corrects this condition entirely, allowing a comfortable view from every seat in the orchestra and higher levels.

The slope of the reversed floor automatically establishes the proper pitch for the backs of the seats in every row. This eliminates the need for specially adjusted backs, and changes in the standards and leg supports of the chairs. All chairs can then be exactly alike in every detail of construction. Instead of designing differently constructed seats to fit a floor slope, as is now necessary, the floor is designed to suit uniform seating. It is just as though the seats were placed in an ideal position for viewing the screen, the floor being built afterward to support the seats in the proper manner.

The matter of determining the maximum tilt for chair backs has been discussed with the engineering department of a leading seating company. A tilt of twenty-seven degrees for the row of seats nearest the screen has been suggested. This tilt will equally distribute the weight of the body to the seat and back of the chair, keeping the head of the spectator in a comfortable position. The tilt diminishes to sixteen and two-thirds degrees at about the twenty-fourth row, remaining constant thereafter. The fact that the head assumes a pitch of two or three degrees less than the pitch of the body has been taken into consideration in the calculations for determining the floor slope. The feet of the occupant of a seat are properly supported, and the sensation of sliding forward out of the seat, as experienced in the present type of orchestra seating, is eliminated, because the angle and distance between the floor and the seat remain constant. Due to the fact that the same chair can be used unchanged throughout the house, a considerable economy can be effected. The "spring edge" seats, required where the present type of floor inclines steeply from the front of the chair, are costly and unsatisfactory, and can be eliminated. The reversed floor permits the use of the "box spring" seat, which is less costly and more durable. The uneven wearing of the seats and backs of chairs is also corrected by equally distributing the weight of the body by properly tilting the seats on the reversed floor.

The results of all these studies and tests have been utilized in preparing a series of new forms for motion picture theater structures. Many variations of the seating arrangement are made possible that could not have been arrived at with the present type of floor. The chart locating the valuable areas has been used as a basis for designing these forms.

DISCUSSION

MR. KELLOGG: From a novice's standpoint, I have sometimes thought of how I might try to figure out the best arrangement of theater floor and seats. Imagine yourself looking toward the audience from the center of the screen; if the solid angle which your eyes encompass were filled as compactly as possible with eyes and ears, that would be the way you could get the most people in. Thinking of it from this standpoint, there are several parts of the possible solid angle, within which people might hear and see satisfactorily, that are poorly utilized. One is the region below, which the arrangement proposed by Mr. Schlanger is primarily aimed to utilize to better advantage; and the other is the part of the solid angle occupied by the fronts of the balconies. There is only one way to cut out waste space due to the balconies, besides making them as thin as possible, and that is, not to have balconies. But that does not furnish good space utilization, either.

From the standpoint of the utilizing angle below, one is confronted with the fact that the part of the audience nearest the stage subtends a disproportionately large angle compared with the number of people. I am wondering whether, following the idea described in the paper, we might not actually, within the proper angle, pack more people into a theater of given dimensions by not trying to begin too close to the screen. If you drop a little further back you can begin a little lower, leaving more height available for balconies.

There is one question I do not believe was answered in the paper, and that is, what is considered the desirable rise per row of seats. To be more specific, if a line were drawn from the back of one row of seats to the bottom of the screen, how much would that line miss the back of the next row? As a general rule, one can probably figure on looking between the heads of the people immediately in front, but he will have to look *over* the heads of those seated two rows ahead of him. I should be interested to learn how much allowance is made for this factor.

MR. SCHLANGER: The point about having the first eye line farther away from the screen is quite possible, but it depends on how much area in front of the screen the theater exhibitor is willing to devote to it. That area is costly. It is better practice to place the first seat a little farther away from the screen than it is usually placed.

Referring to Fig. 3, it is seen that a given person sees above and not between the heads of the persons in front of him. His sight line passes over the head in front, passing to the very bottom of the screen. The orchestra floor in the present type of theater is not pitched sufficiently to allow this complete view of the screen, therefore making it necessary for people to keep shifting their positions in order to see between the heads of the people ahead.

When constructing the diagram, a line is drawn from the bottom of the screen to the top of the head of the first spectator. This gives the eye level for the next row. The distance from the eye to the top of the head is four inches. So, connect another line from the bottom of the screen to a point four inches higher, and we have the sight line of the next row, and so on.

The pitch of the floor varies from row to row. The first row requires a greater pitch than the succeeding one, and so on. On reaching the twenty-fourth row, in the reversed floor system, the floor becomes practically flat. If the theater were big enough the curve would rise again somewhere about the fiftieth row.

In the present type of house, the low placing of the screen makes it necessary for each succeeding head to be higher, in order to see over the head of the person in front. The pitch increases so rapidly that in existing theaters a compromise has been effected, and one looks *between* the heads of those in front, and not *over* their heads, as on the reversed floor.

MR. PORTER: I should like to know how much tolerance, if any, is allowed for variations in height among individuals. Is any allowance provided for such variations, or are the angles worked out for an average height?

MR. SCHLANGER: The average height measured from the floor to the eye level, the person sitting in a normally pitched chair on a flat floor, varies from three feet seven inches, to four feet; four feet is the dimension for a person six feet two inches tall. To allow for a person five feet eleven inches, or six feet, would be about right. Therefore, about three feet eleven inches should be assumed. That would take care of almost all such conditions.

MR. RICHARDSON: On what do you base your choice of what are termed desirable areas?

MR. SCHLANGER: The desirable areas are determined by the distance above or below the level of the screen at which it is comfortable to view the screen. To establish areas of desirability, a line is drawn from a test point to the important focal point on the screen; a line is then drawn, representing the back of the spectator, ninety degrees to this line. This will show how much the spectator must lean forward or backward. The areas where the spectator does not have to lean forward or raise his head are most desirable. The degree of deviation from comfortable posture determines the relative value of a given area.

MR. SPENCE: The suggestion was made that this floor plan would be adaptable to a Trans Lux theater, but I do not think so. The Trans Lux theater was designed with a ten-foot head room, in order to be able to move in and out of established office buildings. To use this type of floor it would be necessary to break through to the cellar. If rear end projection were used, it is possible that people walking in the aisle would get into the beam, and the seats would have to be placed farther back from the screen. The angle of view is so much wider with a rear projection screen, that what would be gained by putting a projection room near the box-office, so to speak, would be lost at the front.

MR. SCHLANGER: The distance from the first row to the screen is not determined by the method of projection. It is determined by the size of the picture. Because the Trans Lux theater presents a small picture frame on the wall and we can get very close to it, does not mean that we can use Trans Lux projection and have effective motion picture exhibition.

As to the ten-foot height mentioned, the head room of the first floor of the average building is nearer twelve feet. It is possible to use standard projection in such limited heights by employing a reversed floor, thereby requiring only half the projection booth area necessary for Trans Lux projection. The saving in annual rental for this space on the street level could be used to rent a foot or two below the street grade, which would allow the use of a much larger screen than is now used in Trans Lux theaters.

MR. PORTER: What would be the total drop in your floor?

MR. SCHLANGER: The slope of the reversed floor is considerably less than the slope of the present type of floor.

MR. FOX: Mr. Schlanger showed that the weight was equally distributed between the back and seat of the chair. He meant that a certain amount of weight was taken from the seat and applied to the back. About fifteen per cent of the excessive tilt is transferred to the back from the seat. We have done what the airplane man has done, so that the passenger would not fall out of his seat when the plane was tilted for landing.

MR. HICKMAN: I should like to ask if any theaters have been constructed in this manner?

MR. SCHLANGER: Mr. Kinsila, in his book on theaters, stated that a theater having a reversed floor was built in Moscow many years ago. *Better Theatres* published an account of the Pathé Theater in Paris, which also has a reversed floor. In both cases, there is no evidence of a curved reversed floor. The Pathé Theater was constructed in such a manner because of a steep street grade condition, and a limited height usable in an existing building. The posture and sight line problems in this theater were not given any thought, as the uniform floor pitch and chair tilts show.

At present, I am working on a small theater, which is now under construction, in which the parabolic reversed floor is used. To my knowledge, this will be the first theater built wherein the principles of applied optics and good sitting postures are recognized.

A METHOD OF MEASURING DIRECTLY THE DISTORTION IN AUDIO FREQUENCY AMPLIFIER SYSTEMS*

W. N. TUTTLE**

Summary.—*The question of a suitable measure of harmonic distortion is discussed. The distortion factor employed is defined as the ratio of the effective value of the combined harmonic voltages to the fundamental voltage. A simple rapid method of measuring this ratio is described which has several advantages over earlier methods. Results are given showing the performance of apparatus for the application of this method to the testing of audio frequency amplifier systems.*

It is customary to rate an amplifier used in the reproduction of speech or music on the basis of the amount of undistorted power which it is capable of delivering to the loud speakers.

The distortion produced by the amplifier is the deviation in the shape of the electrical wave of the amplifier output from that applied at the input terminals. Several types of distortion are evidently possible. Frequency distortion takes place when the system does not amplify equally all the component frequencies of the input wave. Phase distortion occurs when these several component voltage waves are shifted in time with respect to one another. Harmonic distortion or amplitude distortion is observed when the crests of the voltage wave tend to be partly cut off. The first two of these effects, frequency distortion and phase distortion, depend largely on the fundamental design of the amplifier and are not appreciably affected by variations in the magnitude of the input voltage. Harmonic distortion has the opposite characteristic. It is important when the amplifier is operated at low energy levels, but increases rapidly when the voltage applied is increased beyond a certain value. Harmonic distortion is the factor which limits the useful output of an amplifier. It is the measurement of this effect which is to be considered.

The measure taken for harmonic distortion should, if possible, be a measure of the objectionableness to the listener of the distortion present. Different types of amplifiers cause different types of distor-

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** General Radio Co., Cambridge, Mass.

tion, so that the quantity measured should be such as to supply a basis for the comparison of amplifiers of different fundamental design.

If a single pure tone is applied to the input terminals of an amplifier harmonic distortion will result in the appearance in the output voltage wave of various harmonic frequencies of the applied tone. Let us call E_1 the fundamental voltage, and E_2, E_3, E_4 ... the voltages of the several harmonic frequencies. Let us consider the ratio

$$D = \frac{E_2^2 + E_3^2 + E_4^2 + \dots}{E_1}$$

This is seen to be the ratio of the effective value of the combined harmonic voltages to the fundamental voltage. This expression gives equal weight to all harmonics having the same value, but as each

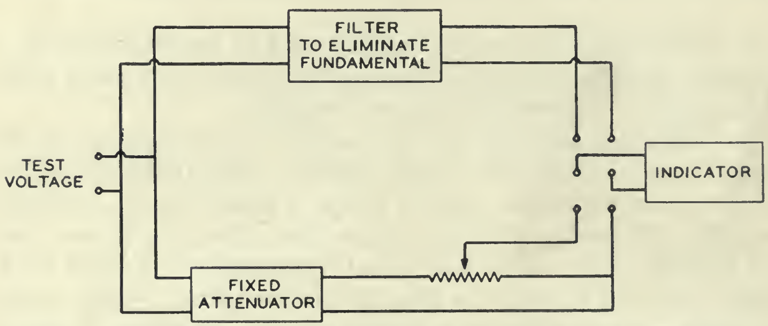

FIG. 1. Simplified functional diagram of the distortion-factor meter.

harmonic enters as its square, prominent components are considerably emphasized. A single component of two volts, for example, is given twice the importance of two harmonics, each of one volt. In view of the masking effect of one tone by another, the single two-volt component would be expected to be correspondingly more objectionable. In view of these considerations and of the fact that it lends itself readily to direct measurement, the ratio D has been generally adopted[1,2] as the best measure of harmonic distortion.

The methods of evaluating the distortion factor which have been available have been suited primarily to laboratory use. One method is that of measuring the separate harmonics in the amplifier output by means of a harmonic analyzer, and of computing from these values the distortion factor. Similarly, oscillographic records can be analyzed approximately by any one of several methods. A less laborious procedure is that of eliminating the fundamental in a suitably designed bridge circuit and measuring the combined harmonics which remain.[3] This method has one serious disadvantage in that the bridge must be

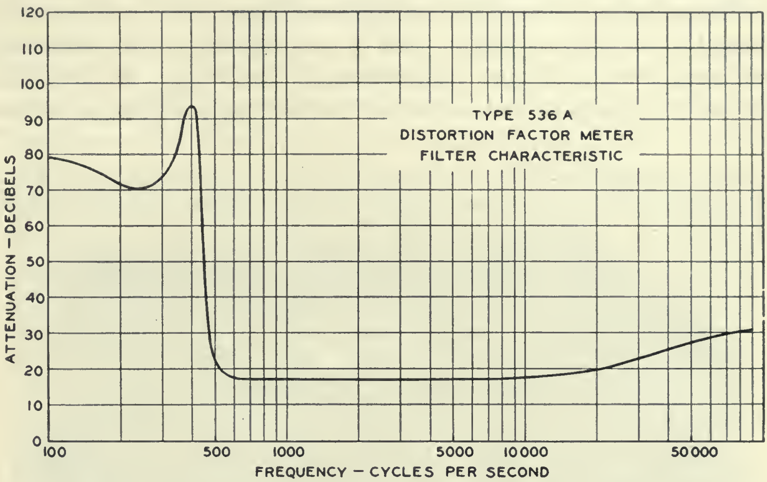

FIG. 2. Over-all attenuation characteristic of the filter and input resistances.

carefully balanced, and that slight fluctuations in the test frequency may consequently make it difficult to obtain satisfactory results. Another disadvantage is that frequencies below the test frequency, including power-supply hum, are included with the harmonics.

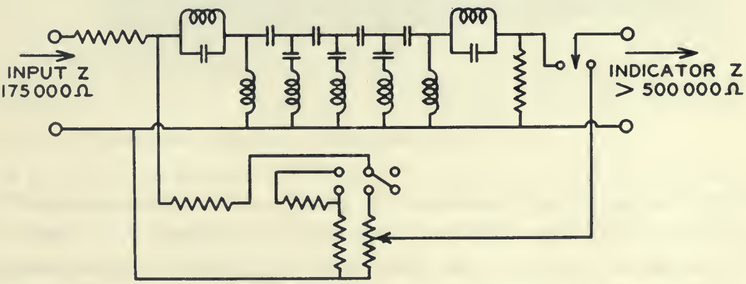

FIG. 3. Detailed circuit diagram of the distortion-factor meter.

Ballantine and Cobb[4] have developed an ingenious null method of obtaining the distortion factor which avoids these difficulties. But this method, also, is suited principally to laboratory use.

It seemed desirable to develop a rapid method of measuring the distortion factor which would require neither bulky apparatus nor the services of a skilled operator. The essentials of the method finally adopted are shown in Fig. 1.

The test voltage is applied to a high-pass filter and an attenuator in parallel. The output of the filter is proportional to the combined harmonic content of the test voltage. The output of the fixed attenuator is proportional to the test voltage itself, which is approxi-

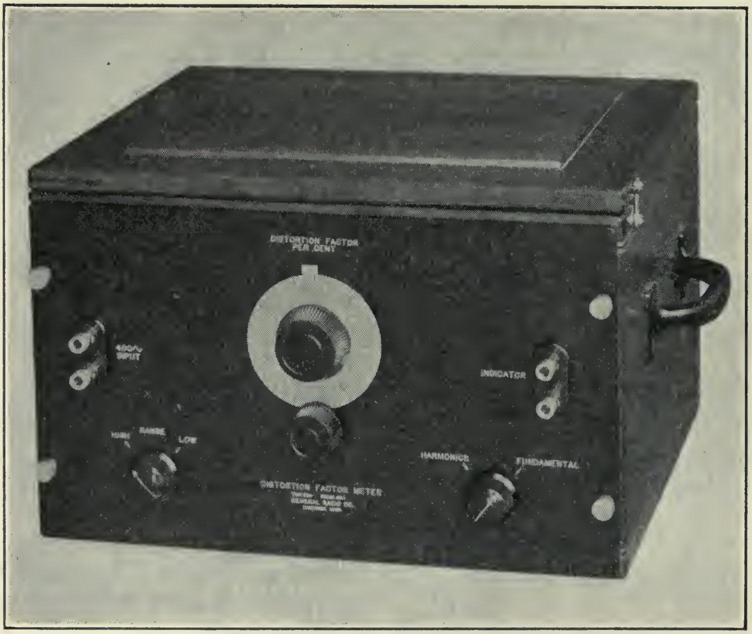

FIG. 4. Panel arrangement of the distortion-factor meter.

mately equal to the fundamental voltage in cases encountered in practice. We can therefore determine the distortion factor by comparing the output of the filter with the output of the attenuator. In the apparatus constructed, the fixed attenuator is so proportioned that when the voltage across the entire voltage divider is equal to the filter output voltage, the distortion factor is 30 per cent. A dial reading directly distortion factors from zero to 30 per cent is attached to the voltage divider control. All that is necessary to make a measurement of the total harmonic content of the test voltage is to observe the deflection of the indicator when connected to the output of the filter. The indicator is then switched to the output of the voltage divider, the setting of which is varied until the same deflection is obtained. The voltage divider scale reading then gives the distortion factor directly.

The success of this method evidently depends on the care with which the apparatus is designed rather than on the skill of the operator. The filter must reduce the amplitude of the fundamentals so that it is negligible compared with the harmonics at the lowest distortion factor to be measured. It must transmit the harmonics equally and

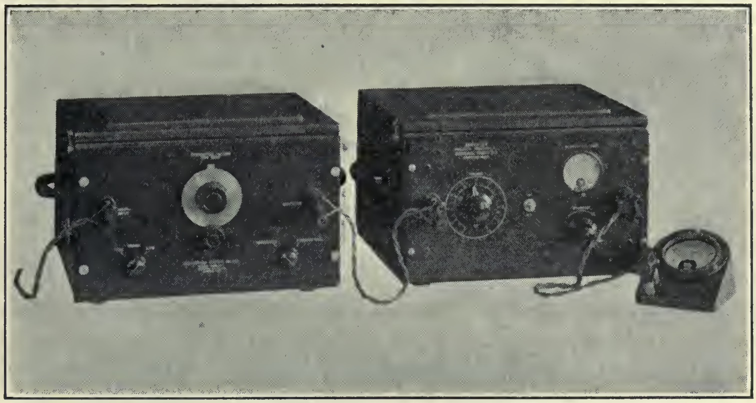

FIG. 5. Distortion-factor meter with associated amplifier and square-law galvanometer.

must not act as a generator of harmonics even when large input voltages are applied. The measured transmission curve of the filter developed for this purpose is given in Fig. 2.

It is seen that the fundamental (400) cycles are reduced relative to the harmonics more than 70 db. All harmonics up to the fifteenth are transmitted equally within 0.3 db. The attenuation of the fundamental is sufficiently great so that the test frequency can vary over a range of more than 50 cycles without affecting the result. It is seen that enough attenuation is provided at the lower frequencies to eliminate power supply hum.

The circuit details are shown in Fig. 3. It will be observed that a series resistance is placed in the input branch. This keeps the impedance out of which the filter works practically constant and makes the calibration independent of the impedance of the voltage source. It also results in the impedance at the input terminals being high enough (about 175,000 ohms) so that the instrument may be connected across practically any element in amplifier circuits without causing appreciable disturbance. Due to the input impedance characteristic of the filter alone, the series resistance reduces the harmonic content of the voltage across the voltage divider to such an extent relative to the fundamental that no correction need be applied. The "L" network R_1R_2 may be switched into the circuit to magnify the scale of the dial by ten when measuring small distortion factors.

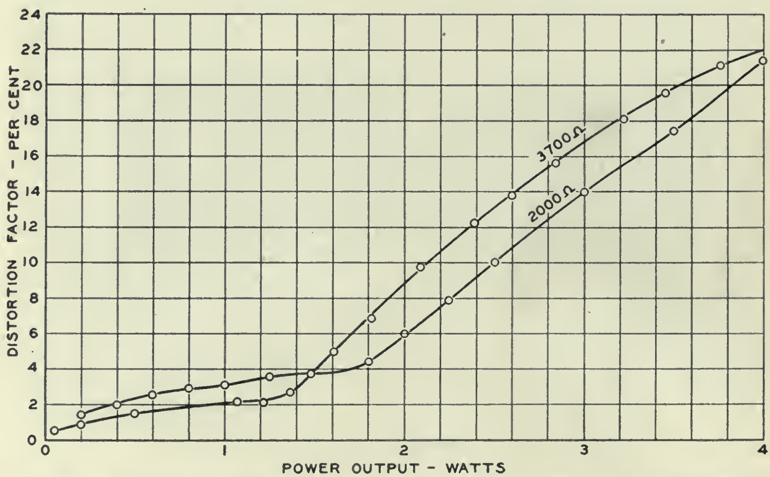

FIG. 6. Curves of distortion factor *vs.* power output for a laboratory amplifier employing a single 245-type tube, for two values of load resistance.

The apparatus is simple enough so that a compact mechanical arrangement is possible. Fig. 4 shows the panel arrangement.

The indicator must have an input impedance high compared with the filter impedance. As high sensitivity is also required in many measurements, it is convenient to employ an amplifier in conjunction with an a-c. voltmeter. To keep the impedance high, no input transformer should be used preceding the first amplifier tube. The voltmeter should be of a type that will indicate the effective value of a composite voltage. Thermocouple instruments have this property but are sluggish in action and are easily burned out. Vacuum tube voltmeters of the square-law type are satisfactory. A rectifier type 2-C galvanometer has been developed for use with the distortion factor meter which has a characteristic closely approximating a square law and which combines ruggedness with high sensitivity. The distortion-factor meter, together with the associated amplifier and the a-c. galvanometer, is shown in Fig. 5.

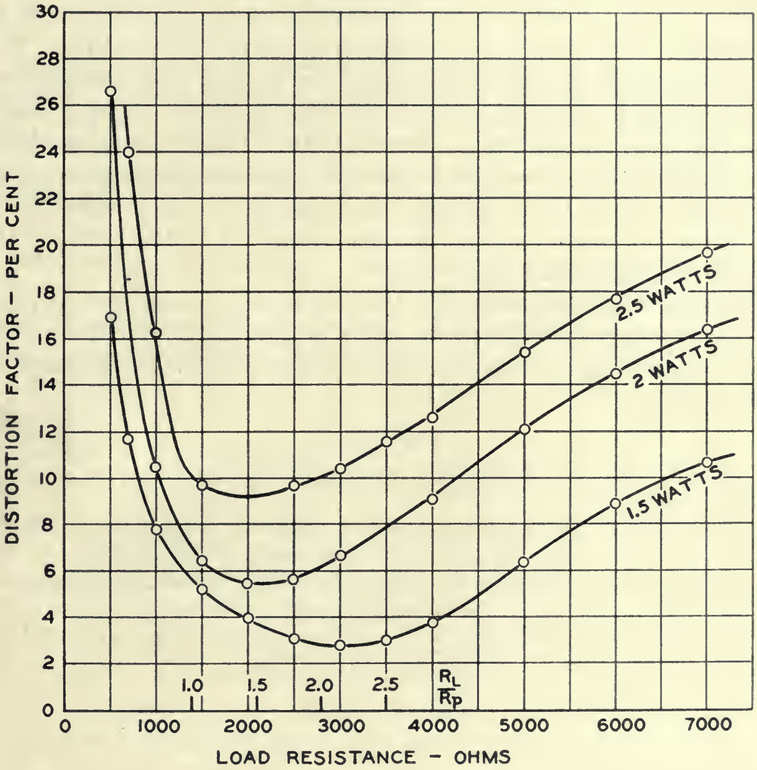

FIG. 7. Curves of distortion factor *vs.* load resistance for three values of output power for the amplifier of Fig. 6. (The ratio R_L/R_P of load resistance to plate resistance is indicated for reference.)

Curves obtained with this apparatus in testing a laboratory amplifier unit are shown in Figs. 6 and 7. In obtaining the data of Fig. 6, the load resistance was held constant as the input was varied. Observations were made of the load voltage and distortion factor as the amplifier input voltage was increased. The distortion factor is plotted against the computed power output for two values of load resistance.

Fig. 7 gives the data obtained by simultaneously varying the load resistance and the input voltage to keep the output power constant. It is interesting to note the manner in which the optimum load resistance varies with the allowable distortion factor.

These results support the conclusion that the distortion factor which has been defined is the logical index of the performance of an amplifier. The apparatus developed for directly measuring this quantity may be conveniently used in making the simultaneous measurements of power output and total harmonic content which are necessary in obtaining a definite output rating for an amplifier. The apparatus is also suited to checking the operating condition of an amplifier installation. A single measurement of the distortion factor at the rated power output indicates definitely whether or not the system is functioning properly.

In view of its adaptability to the testing of amplifier systems, it is hoped that the distortion-factor meter will prove useful to the motion picture industry in maintaining definite standards of amplifier performance.

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DIRECTIONAL EFFECTS IN CONTINUOUS FILM PROCESSING*

J. CRABTREE**

***Summary.**—Continuous motion picture film developing machines set up a unidirectional current of developer as a consequence of the motion of the film unless vigorous measures are adapted to counteract it. This current is shown to cause distortions of the H & D characteristics of the photographic material, when the usual type of sensitometer strip is used for control of the development. The effect of the geometry of the sensitometer strip on the extent of "direction effect" is discussed.*

The difficulty of obtaining equal degrees of development of photographic images over even relatively small areas of any given emulsion layer is well known to workers with these materials. The necessity for constant and vigorous agitation of the developing solution across the light-exposed area to be developed becomes evident even to the amateur.

The reason for the desirability of vigorous agitation during the development of a photographic image is the necessity for removal from the neighborhood of that image, of the products of chemical reaction, chiefly bromides and developer oxidation products, which diffuse out from the emulsion layer, and which, apart from locally reducing the developing power of the solution by exhaustion, have in themselves an actual depressing effect on density. These reaction products, being of greater specific gravity than the original developing solution, probably set up slight local eddy currents during static development which give rise to unevenness in the degree of development from point to point, even though the exposure to light is uniform. The unevenness is relatively the more pronounced, the less the degree of development, tending to disappear as gamma infinity is approached. The well-known "Eberhardt effect" or "Mackie Line" is occasioned in this manner. These designations refer to the light halo appearing around an area of high density, in a

* Presented in the Symposium on Laboratory Practices at the Spring, 1931, Meeting at Hollywood, Calif.

** Bell Telephone Laboratories, New York, N. Y.

field of lower density. The halo results from the reduced rate of development of the area of lower density adjacent to the area of higher density, consequent on the diffusion outward from this high density area of concentrated reaction products of development. A study of this effect was recently made by Walenkov[1] who gives a bibliography of the literature.

Before the introduction of machine development for motion picture film, this material was processed almost entirely by the rack and tank system, in which the film was wound on large square or rectangular racks which were immersed in deep tanks of suitable shape. The unevenness of development obtained along the length of film handled in this manner was well recognized, and has been thoroughly discussed by J. I. Crabtree and C. E. Ives.[2] The method gave locally increased development in the region of the rack-ends and cross-bars, due to

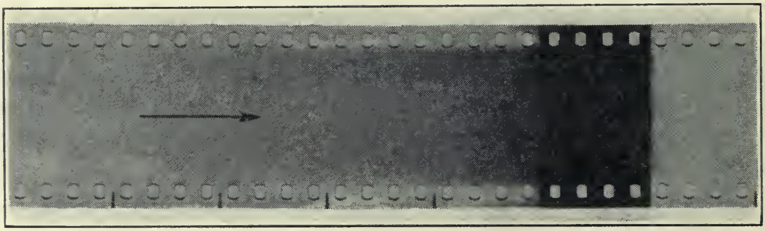

FIG. 1. Strip of dyed film showing effect of directional currents.

production of eddy currents from temperature differences as well as from differences in specific gravity of reaction products, unless agitation of the developer was obtained by motion of the rack, which was not commercially practicable. Pictures developed in this manner showed periodic light and dark bands when the resulting print was projected upon the screen, as well as Eberhardt effects when development was restricted to allow for control in contrast of the picture.

In recent years an already growing tendency to change from rack and tank development to so-called continuous development by machine was stimulated by the addition of sound to the picture, so that, as a result, almost all such film is now processed by machines in which the film is mechanically propelled at a uniform rate through horizontal trays or deep vertical tanks containing the developing solution in circulation. This method of processing has resulted in such an apparent uniformity of product that certain local effects have been lost sight of.

However, if the developing bath of a continuous film processing machine is observed during operation, it will be seen that the onward movement of the strands of film sets up a current of developer in the direction of the film movement, but which, relative to the film itself, is in a direction opposite to that of the film travel.

The result of this is shown clearly by Fig. 1, a photograph of a section of film which was first dyed red over a small area, then passed

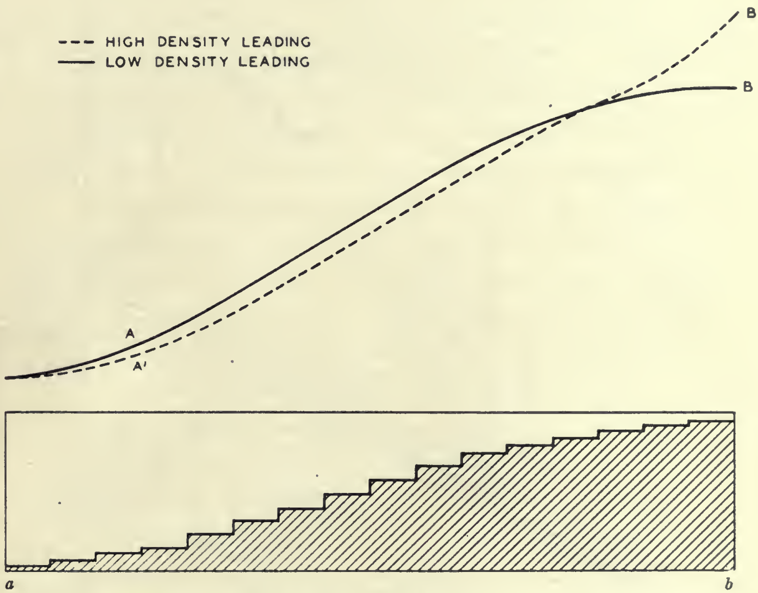

FIG. 2. Typical "direction pair" H & D curves; machine development.

through the developing and fixing trays of an Erbograph machine at sixty feet per minute in the direction shown by the arrow. It will be seen that as the color diffused out from the dyed area it was carried backward along the film surface and partly absorbed by it.

During the development of a photographic image, the products of the chemical reaction taking place diffuse out from the gelatin layer much as the solution of dye did in the manner shown in Fig. 1. Therefore, when developing motion picture film in such a continuous processing machine as the above, the products of reaction of the development of any image must flow across the images immediately following it. Since, as was previously mentioned, these products of reaction have a restraining effect on development, processing by this means will result in a variation in degree of development from point to point on the film depending upon the concentration of the reaction products at those points, which in turn depends upon the magnitude of the density of the image area just ahead.

Let us now consider what happens in the development of a sensi-

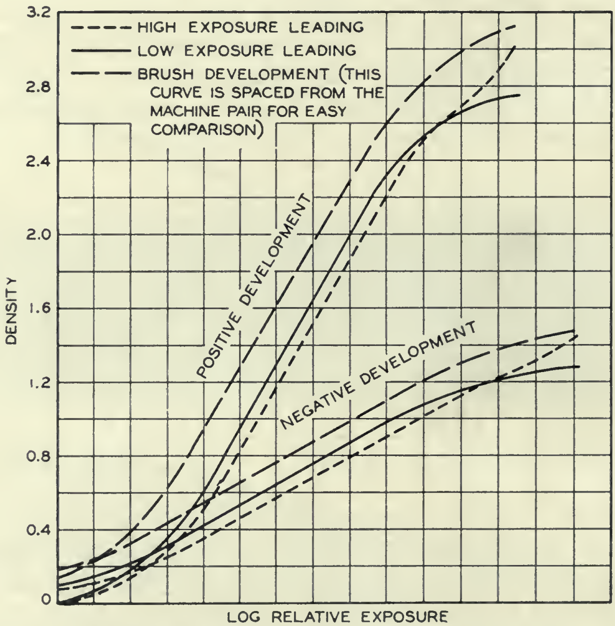

FIG. 3. "Direction pairs" H & D curves; machine development, showing comparison with brush development.

tometer exposure. This strip of exposed film bears a series of latent images increasing progressively in magnitude from step to step and which on development will result in a series of density areas. *ab*, in Fig. 2, represents diagrammatically such an exposed film, the shaded area being the image portion, and the clear area representing unchanged silver halide. If now, this strip is moved steadily through the developer in direction *AB* (that is, *B* meeting the developer first), the reaction products of development from the first step will, by virtue of the motion of the film, flow over and successively affect the other steps. The initial reaction products will be reënforced by the reaction products from succeeding steps, causing a progressive weakening of the developing effect as the end A is approached.

With the strip traveling in the opposite direction (A leading) the developer around end A will be little affected by reaction products since these will be small in amount and hence nearly full development will be obtained. As B is approached, however, the products accumulate from the gradually increasing densities so that there is a

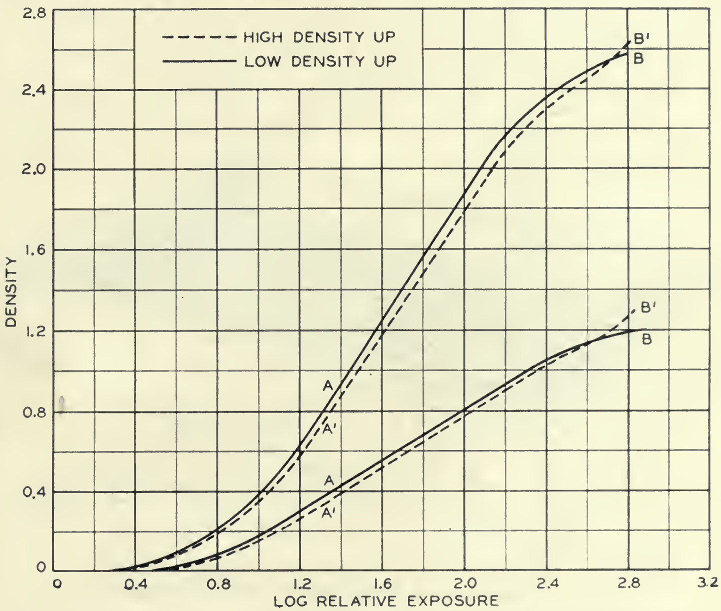

FIG. 4. "Direction pairs" H & D curves; rack tank and development.

decided loss of density in the region of B. The characteristic H & D curves plotted from the readings of density obtained in the two cases cited will be found to have the general shapes shown in Fig. 2 where $A'B'$ is that resulting from progression through the developer with the high exposure leading; while AB is obtained when development is carried on with the low exposure leading.

The general effect is to straighten out the shoulder in $A'B'$ and to depress it somewhat in AB. The effect on gamma is slight but there is an appreciable difference in the estimate of latitude (straight line portion) and inertia (intercept on log E axis) in the two cases. That neither curve is true in form is shown in Fig. 3, in which similar pairs of curves are shown at two gammas with the corresponding curve obtained by "brush" development. This "brush" method is one of those generally used in precise sensitometry and consists in securing a very thorough removal of reaction products from the film surface by passing a soft brush rapidly backward and forward across it during development.

A similar effect was found to result from rack and tank development where the manipulation of the rack was such as to result in a

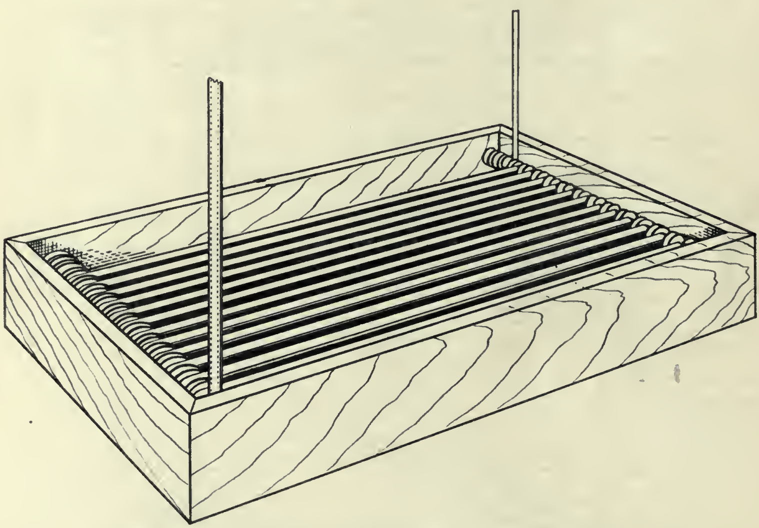

FIG. 5. Perspective of Erbograph type developing tray.

moderate amount of agitation of the developer. (See Fig. 4.) With this method, curves of type $A'B'$ resulted from those cases where the sensitometer strip was developed with the high exposure end of the test strip uppermost, while AB resulted from development with the lowest exposure uppermost. Since in this case the reaction products which are of higher specific gravity than the original developer tend to generate a downward current, the same explanation applies to the occurrence of the two types of curve as in the case of machine development.

Since the development of variable density sound records in continuous machines is usually controlled by using a sensitometer strip in some form, an inquiry was made to determine what sensitometric troubles might be encountered in practice from this "directional effect," as it will be called in this paper, and to determine the best type and manner of use of the sensitometer strip in machine development.

In the processing of variable density records the usual procedure is to develop the sound negative to an approximate gamma of 0.6 in a developer of the *D-76* borax type, and to develop the print in a *D-16*

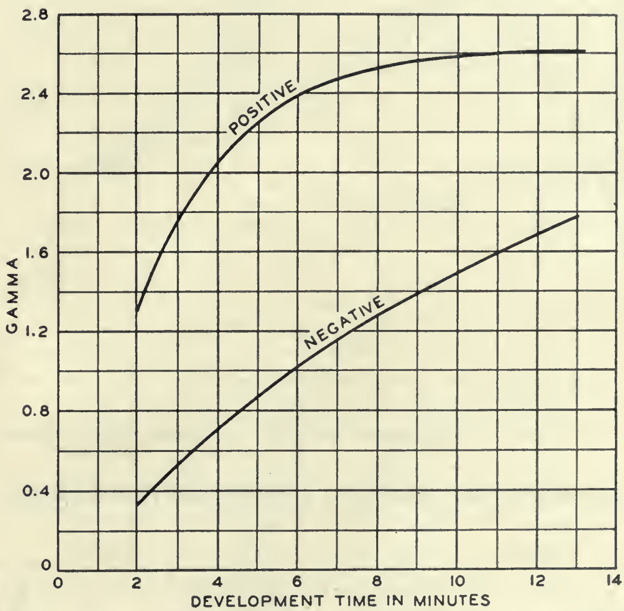

FIG. 6. Time-gamma curves for the negative and positive developer used.

type of bath to a gamma of 1.80, or higher. Attention was mainly confined to a study of these two types of developer at gammas in the region of those just mentioned. Also, the directional effect in the particular machine used has been found to be present for a variety of commercial types of film, although in this study we used only standard positive film.

The machines used in the experiments to be described were of the Erbograph type, in which the film is stranded horizontally around drive rolls in 15 loops of 13 feet each in a horizontal tray of 50 gallons capacity, as shown diagrammatically in Fig. 5. Circulation was by gravitational feed, and overflow to the return pumps was at the rate of 10 gallons per minute. The film speed may be adjusted over a range of from 10 to 100 feet per minute.

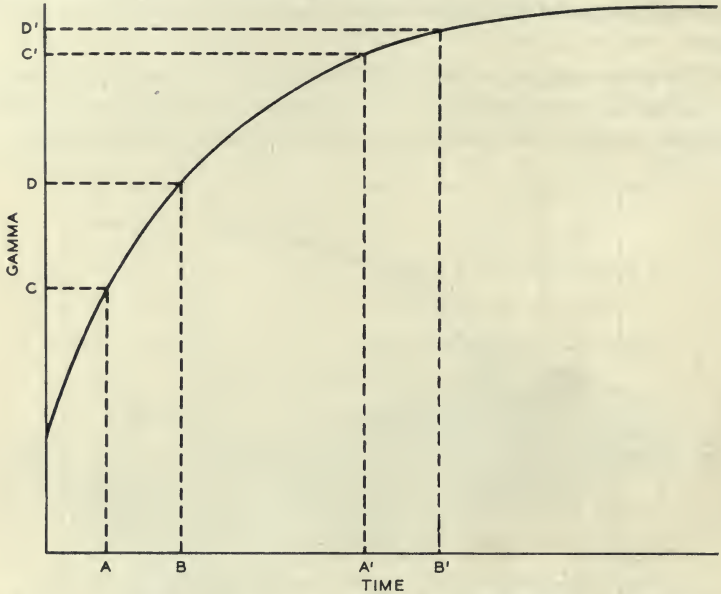

FIG. 7. Typical time-gamma curve of a photographic developer.

The formulas of the developers employed in this work are:

Negative		Positive	
Elon	2 grams	Elon	0.3 gram
Hydroquinone	5 grams	Hydroquinone	6.0 grams
Sodium sulphite (anhydrous)	100 grams	Sodium sulphite (anhydrous)	37.0 grams
Borax	8 grams	Sodium carbonate (anhydrous)	12.5 grams
Boric acid	8 grams	Potassium bromide	0.9 gram
Water to	1 liter	Water to	1 liter

Their time-gamma curves for machine development at 67°F. are given in Fig. 6.

The sensitometer exposures were made in a variable intensity sensitometer using photographic step tablets. Different dimensions of tablet were used, as will be explained later. Where not otherwise

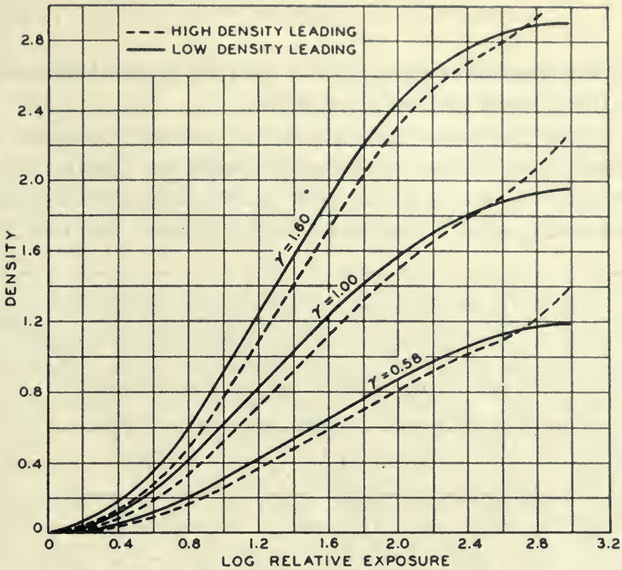

FIG. 8. Effect of gamma on "directional effect;" negative developer.

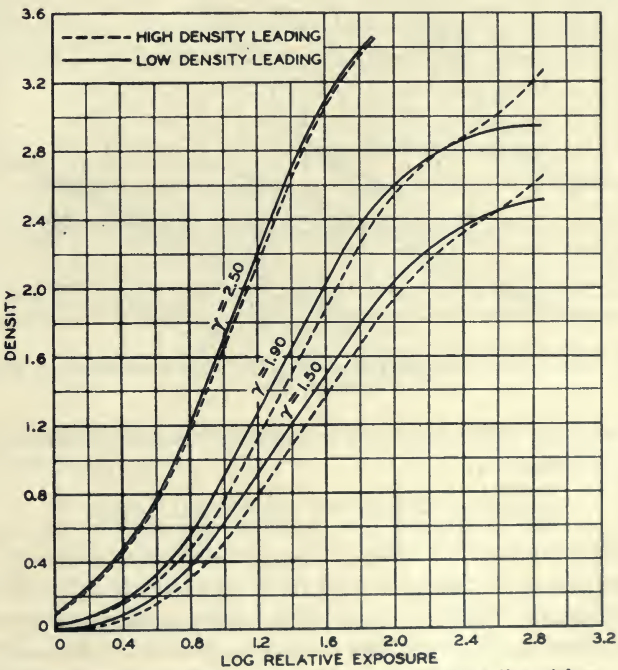

FIG. 9. Effect of gamma on "directional effect;" positive developer.

specified, the length of each step was $^5/_{16}$ inch exposed across the full width of the 35-mm. motion picture film.

Pairs of sensitometer strips exposed in exactly the same manner were passed through the machine, one with the lightest exposure, the other with the heaviest exposure leading and will be referred to as "directional pairs." The differences between the two H & D

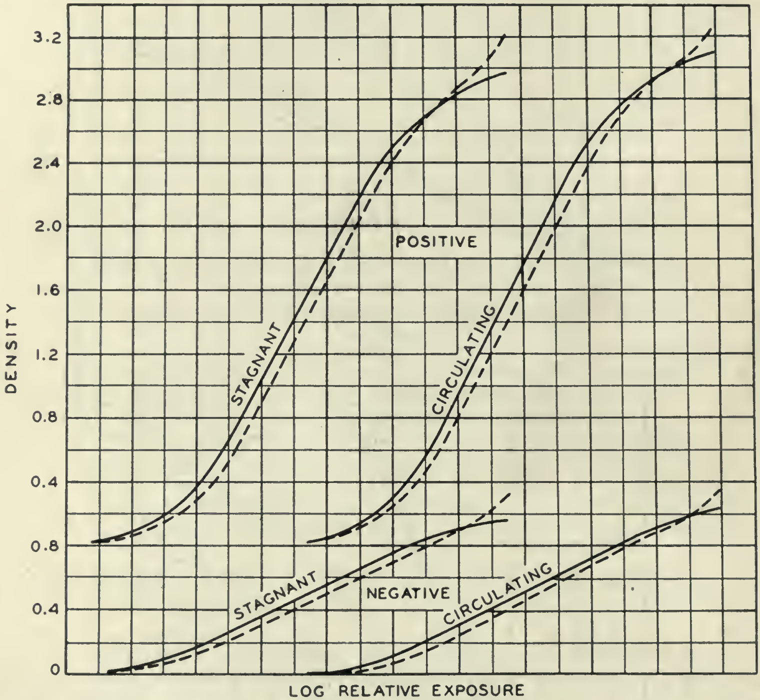

FIG. 10. H & D curves showing effect of circulation of developer in machine development.

curves resulting are considered as an approximate measure of the "directional effect."

EFFECT OF GAMMA ON DIRECTIONAL EFFECT

As is well known, the effect of an increase of circulation during development is to decrease the time required to attain a certain degree of development. This is a result of the more rapid removal of reaction products from the emulsion surface of the film. We may therefore, for our present purpose, consider the effect of the accumulation of reaction products at any point to be equivalent to a loss of effective time of development. Reference to a typical time-gamma curve in Fig. 7 indicates that this will be more important at low gammas, since a given interval of time has, in that region of the curve, more effect on gamma or density.

Since the "directional effect" is considered to be a result of local

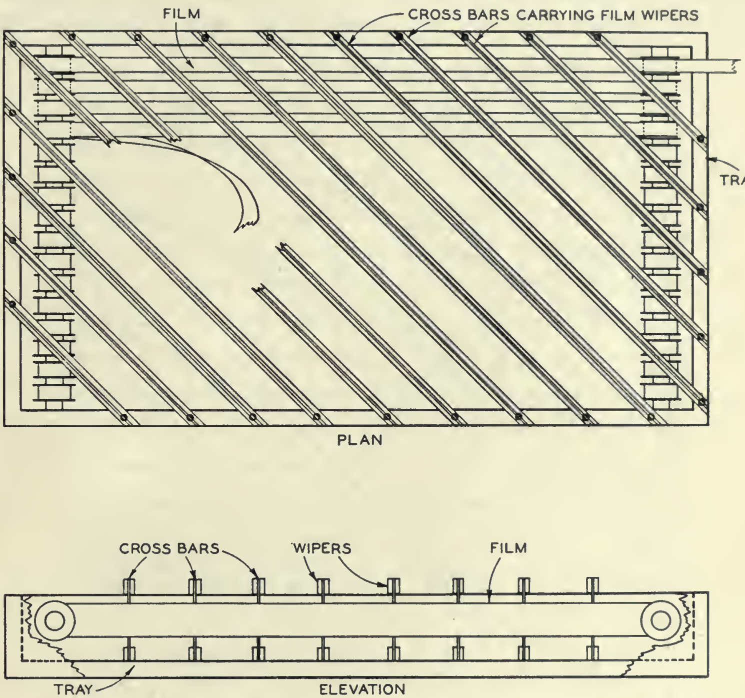

FIG. 11. Plan and elevation of device for eliminating "directional effect" in machine development.

accumulations of reaction products, its degree might well be expected to vary with gamma.

Figs. 8 and 9 show three "direction pairs" at low, intermediate, and high gammas in the negative and positive developers, respectively. From these curves it will be seen that directional effect is present at all gammas likely to be used in negative development but that it tends to disappear at higher gammas with the positive bath. This is consistent with the remarks on the slope of the respective time-gamma curves (Fig. 8) at the particular gammas used.

It should be mentioned here that, as the effect has been found to be less pronounced in the positive than in the negative developer, the inquiry was, in many cases, restricted to a consideration of negative development only.

INFLUENCE OF DEVELOPER CIRCULATION ON "DIRECTIONAL EFFECT"

The fact that high gammas (*i. e.*, low film speed) in the negative developer showed as much "directional effect" as low gammas (high

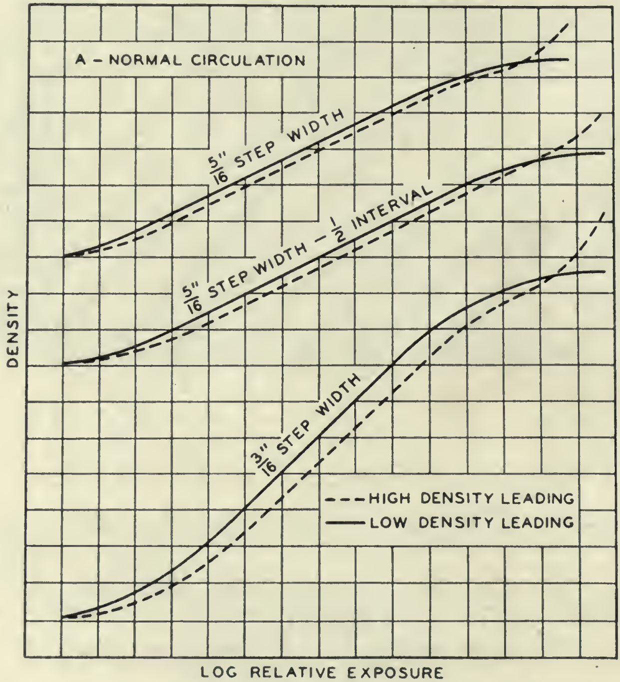

FIG. 12. Typical curves obtained without squeegee device.

film speed) in the same developer indicates that the general circulation provided by the pumps to the developer had but little effect in breaking up the "direction current." This was further confirmed by tests in which for one case no gravity, and pump-return, circulation of developer was used; while, for the other, all the circulation which the system was capable of giving (ten gallons per minute) was used.

Fig. 10 shows the curves applicable to the two cases for each developer at a film speed of 60 feet per minute. No difference is apparent that could be considered to be in favor of the circulating developer.

From these results it is evident that additional means of developer agitation must be provided if "directional effect" is to be avoided. This could be achieved by agitation by such means as paddle, propeller, jets, or by injection of air.

It was found, however, that the directional current could be broken

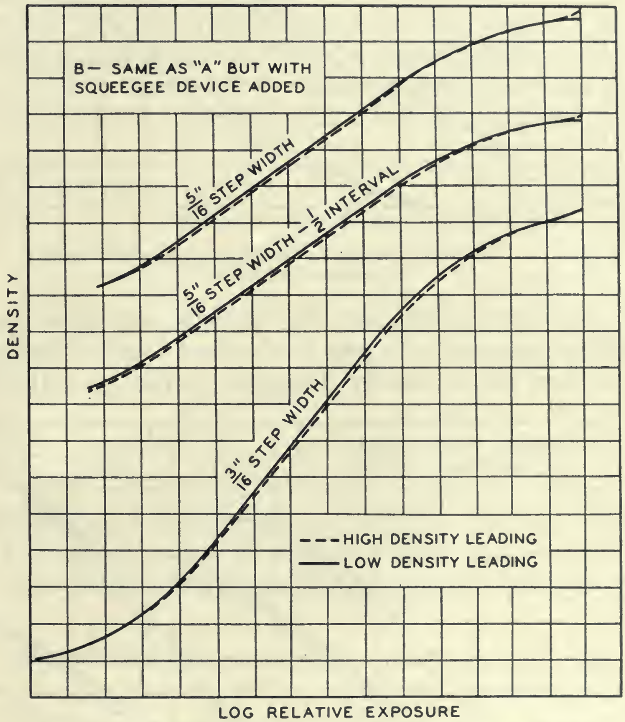

FIG. 13. Typical curves obtained with squeegee device.

up by diverting it from the surface of the film at frequent intervals by the use of a squeegee device. The contrivance used is shown in Fig. 11 and consists of a series of stationary rubber squeegees installed in the developing tray. Each squeegee is about 6 inches apart and set at an angle of 45 degrees to the longitudinal axis of the film. As the film passes each squeegee the developer in contact with it is diverted sideward into the surrounding mass of developer and is so replaced by fresh solution. This is found effectively to prevent any setting up of continuous currents in the direction of the movement of the film.

Fig. 12 shows curves for negative development at two different

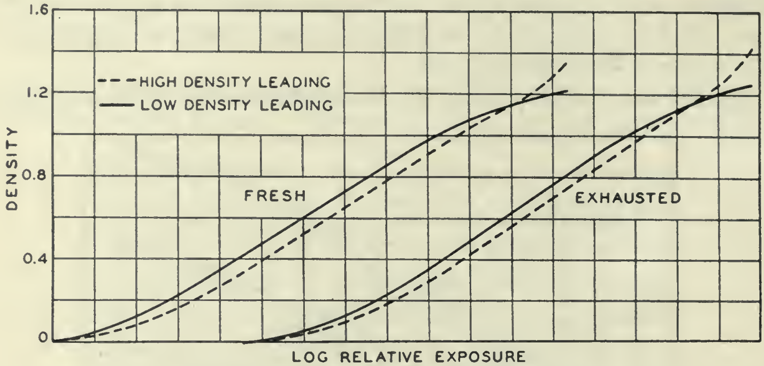

FIG. 14. Relation between condition of developer and "directional effect."

gammas, obtained without, and Fig. 13 similar exposures developed with such an appliance. It will be observed that the "directional effect" has been almost entirely eliminated by the use of this device.

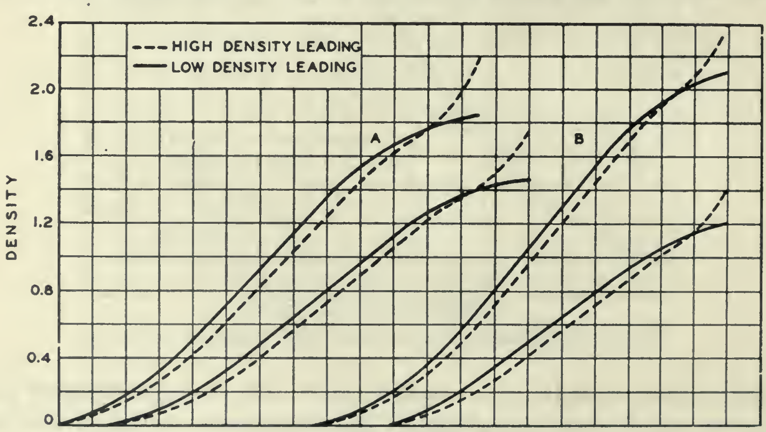

FIG. 15. Relation between bromide content of developer and "directional effect."

CONDITION OF THE DEVELOPER

Since the distortion of the H & D curves produced by directional currents is caused by the presence of reaction products, it was thought that if such reaction products were already present in the developer, as in the case of a partially exhausted bath, the effect should perhaps be relatively less than with a fresh solution. Fig. 14 shows the results of such a test and gives "direction pairs" of curves from strips developed in fresh negative developer and in the same developer after exhaustion to a degree beyond that normally used in practice. The improvement shown by the use of the exhausted developer is comparatively slight.

A similar test was conducted in which the effect of the addition bromides to the negative developer was studied. Fig. 15 shows curves of "direction pairs" developed in a fresh bath (*A*) and also in the same bath to which potassium bromide had been added (*B*).

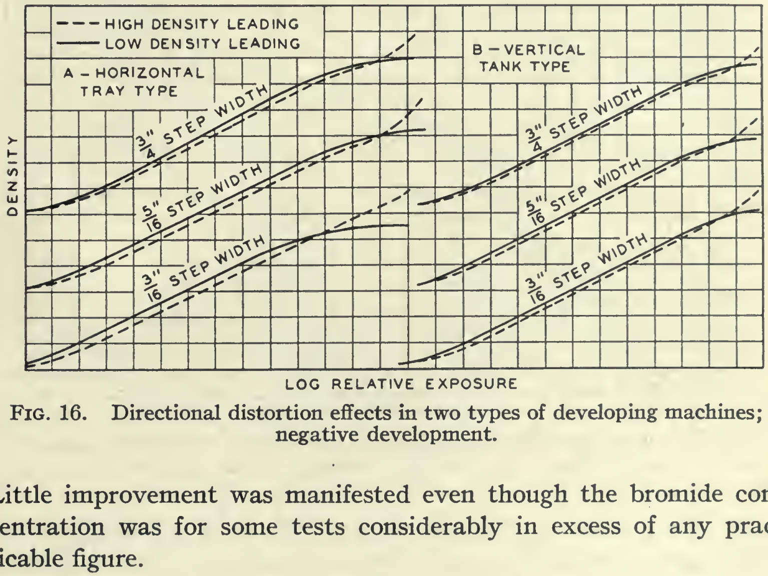

FIG. 16. Directional distortion effects in two types of developing machines; negative development.

Little improvement was manifested even though the bromide concentration was for some tests considerably in excess of any practicable figure.

MACHINE DESIGN

The cause of the "directional effect" is such that its presence and amount must depend upon the design of the particular processing machine employed. A series of "direction pairs" of strips from step tablets of different dimensions were, therefore, processed in another laboratory where a vertical-tank type of machine was available. A comparison of results obtained with the horizontal tray type used in our laboratory is shown in Figs. 16 and 17. The indications are that the directional effect is somewhat less in the vertical-tank type. No information was available as to developers used. It would seem reasonable, however, that in the vertical type gravity will assist in removal of the reaction products since they are of higher specific gravity than the fresh developer.

SENSITOMETER STRIP DESIGN

The trailing of reaction products from any given area will influence following images only for a certain linear distance for a given density magnitude. It would therefore follow that the longitudinal dimen-

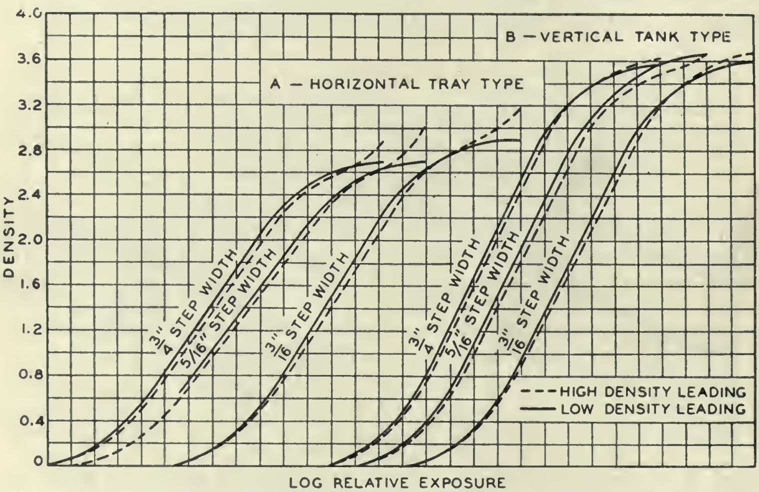

FIG. 17. Directional distortion effects in two types of developing machines; positive developer.

sions of a sensitometer exposure strip will have a bearing on the differences in the H & D characteristics shown by a "directional pair." Also, since a narrow trail would have a better chance of diffusion into the surrounding mass than a wide one, the width of the exposure should also have an influence. Other factors of importance are the density interval between steps and the length of the toe and shoulder portions of the curve, respectively. These various factors have been examined with the following results.

(*a*) *Effect of Length of Step.*—Step tablets were obtained having step widths in the longitudinal direction of film travel of $^3/_4$, $^5/_{16}$, $^3/_{16}$, $^1/_8$, and $^1/_{16}$ inch. The $^3/_4$ and $^5/_{16}$ inch tablets were of different origin and had different density intervals from the remainder but the $^1/_8$ and $^1/_{16}$ inch were identical in origin with the $^3/_{16}$ inch tablet, having been constructed from a portion of it by dissection and re-

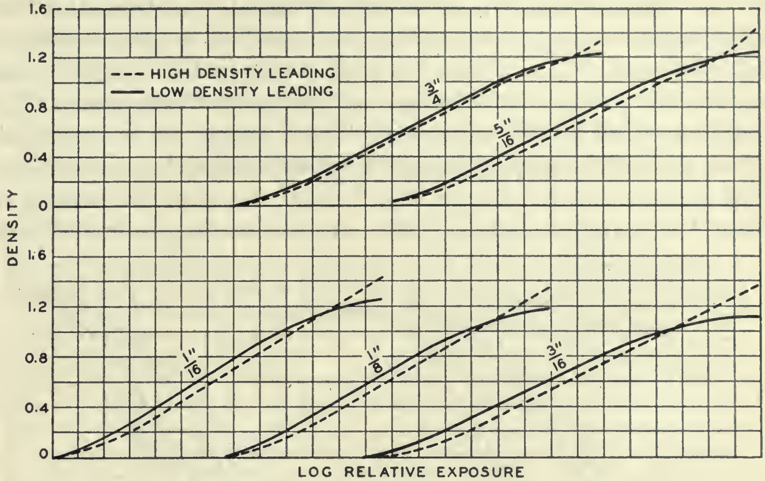

FIG. 18. Influence of step width on "directional effect;" negative development.

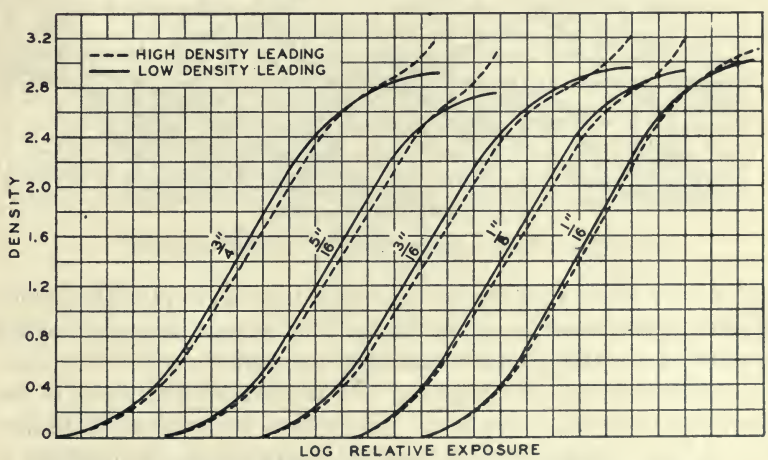

FIG. 19. Influence of step width on "directional effect;" positive development.

assembly. "Direction pairs" of curves are shown in Fig. 18 for negative and in Fig. 19 for positive development. They are spaced along the log relative E axis for convenience of comparison. Gamma relations do not hold, since development was performed on different occasions, except for the $^3/_{16}$, $^1/_8$, and $^1/_{16}$ inch curves which were developed together. It will be seen that the directional effect is more evident in negative development than in positive, and that in the negative the effect increases as the width of the step decreases; and that in the $^3/_{16}$, $^1/_8$, and $^1/_{16}$ inch curves in both negative and positive the gamma tends to rise as the step width decreases. The results obtained in the negative developer appear to be reasonable in that the farther away the center of one step is from the center of the preceding step, the less the density at the center of the former will be affected by the latter, and *vice versa.* Also, as the longitudinal dimen-

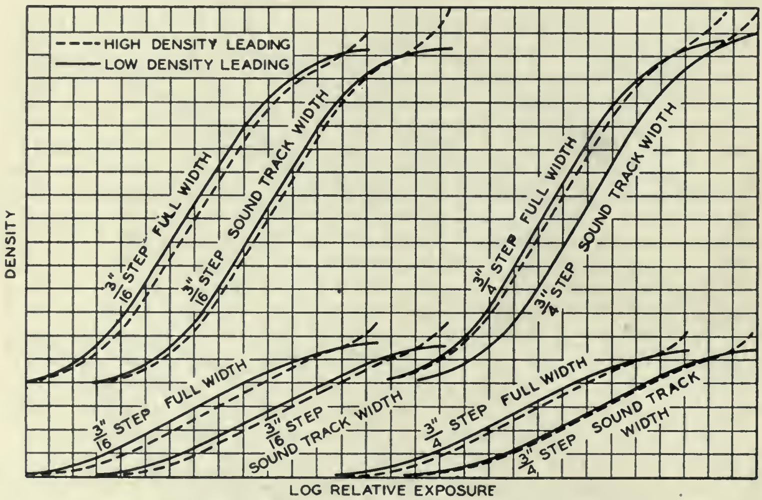

FIG. 20. Effect of track width on "directional effect."

sion of the sensitometer exposure is reduced, the less will be the general dilution of the supernatant developer by the total mass of reaction products, and so the gamma reached will be higher.

(*b*) *Width of Track.*—Limiting the transverse dimension of the sensitometer exposure was found not to show any noticeable diminution of "directional effect" so long as the exposure was confined to the center of the film. However, limiting the width of the exposure to sound track dimensions and its position to that of the sound track resulted in a diminished effect compared with the full width exposure. The directional effect was very considerably reduced with a $^3/_4$ inch step at positive gammas (Fig. 20) made under these conditions.

(*c*) *The Density Interval between the Steps of the "Sensitometer Tablet."*—The magnitude of the difference in exposure from step to step of the sensitometer tablet may be expected to have a bearing on the degree of the distortion of the characteristic curve from the exposed strips, since the depression of density, by the "directional effect," of any given step will depend on the magnitude of the density of the step preceding it. A comparison was therefore made between tablets having the same exposure range but in which one tablet had twice as many steps as the other, and hence but half the density interval.

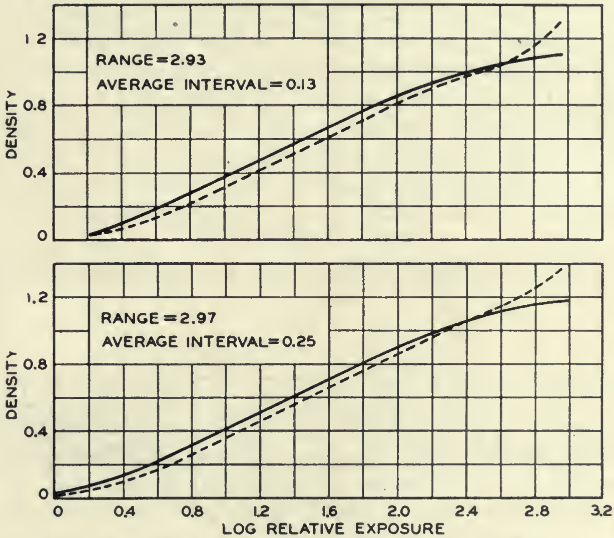

FIG. 21. Effect of sensitometer exposure interval on "directional effect."

The curves are shown in Fig. 21 and indicate that decreasing the number of steps in the tablet, while not affecting the degree of separation between curves of a "pair," shows greater distortion at the shoulder and so is less desirable.

(*d*) *Effect of the Exposure Range of the Sensitometer Tablet.*—The range of exposure in the step tablet type of sensitometer depends on the density range of the tablet, and upon this and upon the time and intensity of the exposure applied will depend how many of the resulting readings of density will fall on the toe and shoulder portions of the curve.

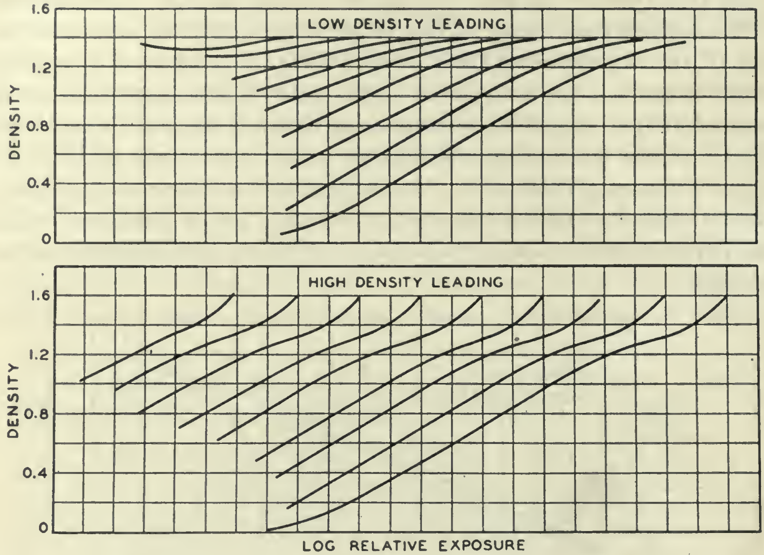

FIG. 22. Effect of restricted exposure range in sensitometer; absence of toe.

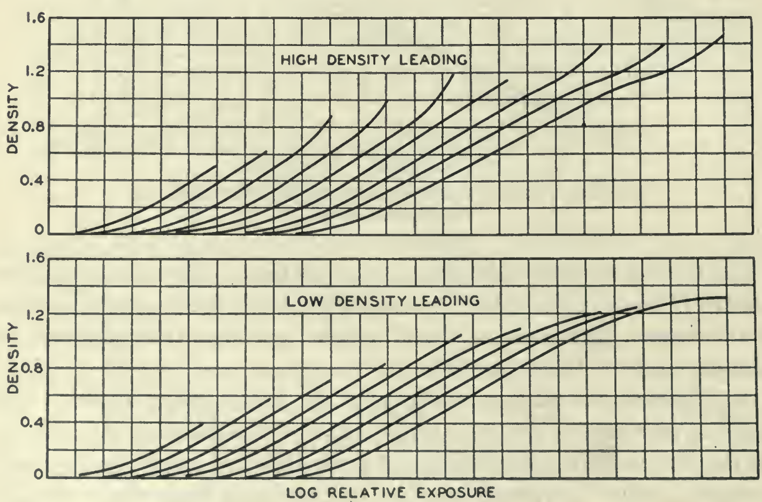

FIG. 23. Effect of restricted exposure range in sensitometer; absence of shoulder.

It was found that varying these factors resulted in extraordinary distortions of the characteristic. Fig. 22 shows curves derived from a series of exposures made through a sensitometer tablet in which the density steps were progressively masked off from the toe end of the curve while in Fig. 23 is shown a similar series in which the steps were removed from the shoulder end. The time and intensity of the exposure incident on the tablet were constant throughout to ensure that no gamma differences could accrue from differences in the reciprocity relation. In this case the "direction pairs" are separated into two groups, (*a*) being the group having the high exposure leading and (*b*) the group having the low exposure leading. The curves

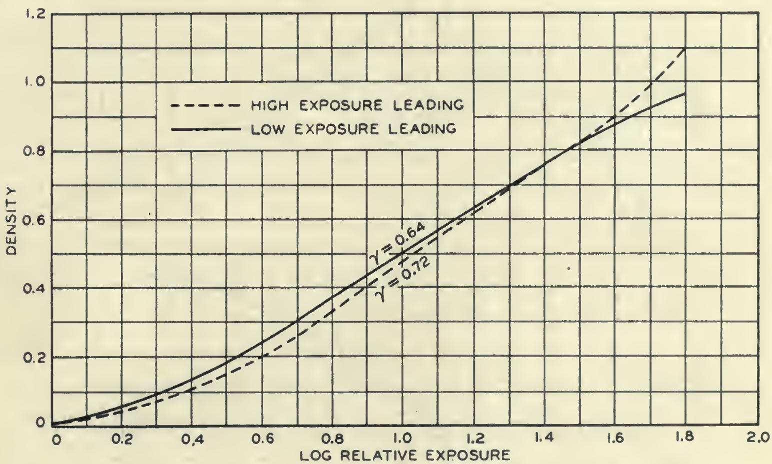

FIG. 24. Example of errors resulting from "directional effect."

are spaced along the log relative exposure axis for ease of comparison of shapes. They show that unless a full toe and several points on the shoulder are obtained in the sensitometer exposure an erroneous impression may be gained from the curve resulting from machine development, not only of the characteristic, but also of the gamma obtained. This is by reason of the fact that whenever the first exposure to meet the developer happens to be on or near the straight line portion, the abnormal increase in density of the first few steps will alter the angle of the straight line drawn through the points. Under these conditions the effect is to raise the apparent gamma when the shoulder end of the straight line meets the developer first and to depress it when the toe end leads through the bath.

The conclusion to be drawn is that the sensitometer exposure should be arranged to give a full toe and shoulder, and that where the range of the sensitometer does not permit this, a full toe should be obtained and the strip developed with the toe end leading.

A typical example of the errors into which one may be led by lack of consideration of "directional effect" is that of a particular study of an alleged change of gamma with printer point. When a sensitometer strip is exposed in the printer a full curve will usually be obtained at the highest printer point, but as the printer point is decreased, the shoulder part, then the upper portion of the straight line, disap-

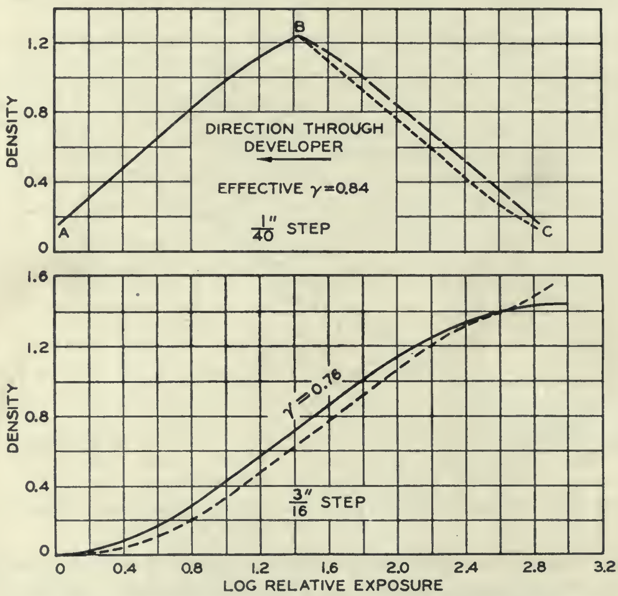

FIG. 25. "Directional effect" in a simulated sound record.

pears. The resulting strips are now analogous to the case of the shoulder cut-off shown in Fig. 23. If the strips should happen to be processed toe end leading, no change in gamma will be noticeable in the curves; but should the high exposure end lead, there will be gamma distortion at the lower printer points.

A further case in point relating to field practice is illustrated in Fig. 24 which shows a directional pair of H & D curves derived from exposures to positive film on a particular time-scale sensitometer. In this case an entirely false determination of both gamma and characteristic would be obtained by this sensitometer from a strip processed with its high exposure end leading through the developing bath.

INFLUENCE OF DIRECTIONAL EFFECT ON THE SOUND RECORD

A frequency cycle of a variable density sound record consists of a series of gradations of density arranged much like pairs of minute sensitometer strips with their high densities abutting. It is reasonable, therefore, to conclude that "directional effect" in a processing machine will distort the recorded sound wave. In a properly exposed frequency record there should, however, be no shoulder densities such as are met with in a sensitometer strip. Exposures from a

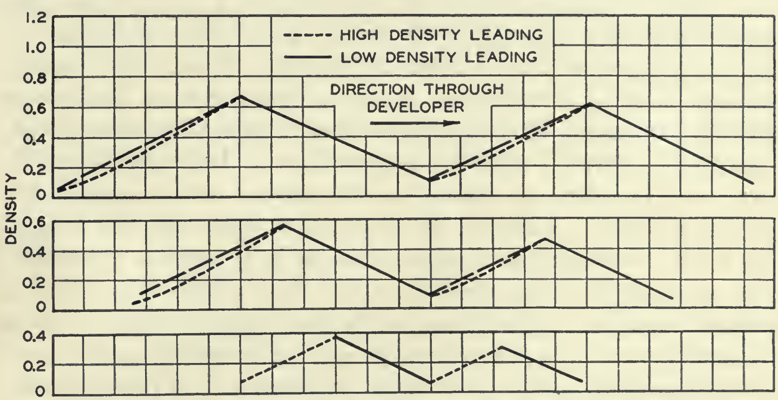

FIG. 26. Effect of peak density on "directional effect."

very small step tablet having steps each 0.025 inch long and arranged so as to give a series of densities simulating a sound wave of 45 cycles showed a definite difference of slope for the two sides of the wave as shown in Fig. 25. Other tablets arranged to give a similar condition with progressively decreasing "peak densities" show the effect to persist to density values as low as 0.5 peak density. (Fig. 26.) Microdensitometric measurements of single frequency records reveal a distortion of the wave shape in the manner which would be anticipated from a knowledge of the direction in which they were processed.

CONCLUSIONS

Evidence has been presented to show that in a continuous film processing machine of the type used in these experiments, the unidirectional motion of the film through the developer tends to set up a current within the developer solution which is parallel to the film's longitudinal axis, and which is sufficiently strong to dominate the effect of developer circulation provided by the gravity feed.

This current results in a preferential development of any graduated series of light exposures such as is presented by the conventional sensitometer strip used in the control of sound picture development.

This preferential development, referred to herein as a "directional effect," causes a distortion of the characteristic H & D curves obtained from such sensitometer exposures, unless gamma infinity is approached or unless means are used to obtain the necessary circulation of developer.

The reason for this preferential development is that the reaction products from any image area are carried across the succeeding images by the afore-mentioned dominant current. This trail of reaction products causes a retardation of the development of the images over which it flows. The "directional effect" is the more pronounced, as would be expected from a consideration of the respective time-gamma curves, when developing motion picture positive film in the customary "borax" negative developer to a relatively low gamma than when developing to a higher gamma in a positive developer. When processing in a machine in which this "directional effect" is known to exist, more than usual care in the exposure and processing of the customary type of sensitometer strip is necessary if consistent and representative results are to be obtained. It is recommended that constant exposures be given to sensitometer strips such that a full toe and several points on the shoulder are obtained, and that the strip be processed in such a way that its toe end is leading through the developer bath.

Care is particularly necessary in drawing conclusions relative to the characteristics of the H & D curves as to the shapes of the toe or shoulder or the limits of the straight line portion, especially when work of a fundamental nature is involved.

Where the "directional effect" is present in a film processing machine, it may result in the production of an asymmetric negative sound wave when the wave is recorded on a high gamma material such as positive film, and developed to a low gamma in a developer of the "borax" type customarily used. As a corollary to this last conclusion, the combination of any high gamma material and low gamma development will always be susceptible to irregularities in development, and for sound recording may for the present be perhaps regarded only as a temporary but necessary evil.

"Directional effect" may be eliminated by the use of any device that will maintain a degree of circulation which will overcome the current set up by the forward motion of the film itself.

For use in machine processing, the arrangement of density areas in the conventional type of sensitometer strip merits consideration so as to provide that no density be subject to the influence of the reaction products of an immediately preceding density. With the present arrangement, distortion of the H & D curves by "directional effect" will be less in the case of those sensitometer strips having the larger physical dimensions and where the steps are as numerous as practicable, thus ensuring a smaller density interval between steps.

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RÉSUMÉ OF THE PROCEEDINGS OF THE DRESDEN INTERNATIONAL PHOTOGRAPHIC CONGRESS*

S. E. SHEPPARD**

The 8th International Congress of Photography was held at Dresden, Germany, from August 3 to 8, 1931, inclusive. Occurring at the time of a financial crisis in Germany, there was a question at one time as to the possibility of holding the Congress at this date; but fortunately, it was found possible to carry it through, and in spite of this unfavorable circumstance there was a very large attendance.

The preliminary arrangements for the Congress, and the carrying out of these by the German committee under Professor R. Luther of the Technical High School of Dresden, were in the last degree praiseworthy and successful.

The last day's session of the Congress was held in Berlin. After a visit to the magnificently equipped and sumptuously decorated new printing house for periodicals of the world-renowned Ullstein-haus the members of the Congress were taken in motorbuses to the studios of the Universum Film A. G. (Ufa) in Neubabelsberg. A very interesting survey was made of both the silent and sound film studios and laboratories.

The work of the Congress was covered by the following sections:

I. (*a*) Theoretical bases of photography.
   (*b*) Practice of photography.
II. Cinematography (including the sitting of the Ciné-Standards Commission).
III. Applications of photography and cinematography in science and technology.
IV. History, bibliography, legal, and medical applications.

The members of the Society of Motion Picture Engineers will be chiefly interested in the proceedings taking place in Sections II and III. However, under Section I was included the discussion of sen-

* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Dr. Sheppard was the official representative of the S. M. P. E. at the Congress.

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sitometry, which contained several papers and reports of immediate interest to our Society.

I propose to review the proceedings of the Congress under the following headings:

A. Ciné-Standards Commission.
B. Sensitometry.
C. Miscellaneous papers of cinematographic interest.

A. ACTIVITIES OF THE CINÉ-STANDARDS COMMISSION

It should be mentioned that some time prior to the holding of the Congress certain changes proposed in cinematographic standards by the Committee of Standards of the Deutsche Kinotechnische Gesellschaft had been brought to the attention of the Standards Committee of the Society of Motion Picture Engineers in order that it might express opinions on these proposals prior to the meeting of the Congress. I received letters and some criticisms of the German proposals from Mr. T. E. Shea of the Bell Telephone Laboratories, and a joint criticism by Messrs L. A. Jones, J. G. Jones, and E. K. Carver, and as far as was possible these criticisms were brought to the attention of the Ciné-Standards Commission of the International Photographic Congress during their sittings and incorporated with the final proposals.

The final conclusions of the Ciné-Standards Commission, copy of which was sent to the chairman of the Standards Committee of this Society, and which are included in the report of the Standards Committee, were provisionally translated by the writer and Mr. W. Webb of the Eastman Kodak Company. This translation was based on the German text submitted to us by Dr. Erich Lehmann, chairman of the Committee. This statement is necessary in view of any possible discrepancy with the authoritative version which will be reproduced in the proceedings of the Congress when published, or with any version produced in the German technical journals. It was evident from the original proposals and the dimensional drawings, submitted as Deutsche Industrie Normen (DIN) by the Deutsche Kinotechnische Gesellschaft that the German proposals represented an attempt to bring their standard dimensions as closely as possible in conformity with the dimensional standards of the S. M. P. E. This, I think, is confirmed by the conclusions of the Committee which now follow:

CONCLUSIONS OF THE CINÉ-STANDARDS COMMITTEE

(I) *Perforation Pitch.*—It is recommended that the length of film equivalent to 100 perforations be equal to $475 \, {}^{+\,0.0}_{-\,1.0}$ mm. This is the same as the standard for normal negative film.

(II) *Width of Take-up (Also Feed) Sprocket between Centers of Sprocket Teeth.*—It is recommended that the width of the take-up (also feed) sprocket measured from tooth center to tooth center be $28.15 \, {}^{+\,0.00}_{-\,0.20}$ mm.

(III) *Over-all Width of Take-up (and Feed) Sprocket.*—It is recommended that the over-all width of the take-up (and feed) sprocket be $35.00 \, {}^{+\,0.00}_{-\,0.05}$ mm.

(IV) *Gate Opening (Frame) for Silent Film Projectors.*—Recommendation is postponed. The Society of Motion Picture Engineers is requested to express an opinion on this question since the pamphlet *Dimensional Standards ASA—Z22—1930* contains nothing on this point.

(V) *Gate Opening (Frame) for Sound Film Projectors.*—Conclusion is the same as for gate-opening for silent film projectors (See No. IV above).

(VI) *Tolerance in Standard Specifications.*—The S. M. P. E. is requested to amplify their standard specifications by the inclusion of definite tolerances in the dimensional specifications. These tolerances should be expressed in metric as well as in English units and as far as possible should conform with the tolerances published in the German Industrial Standard Specifications (DIN = Deutsche Industrie Normen).

(VII) *Shrinkage.*—It is recommended that the shrinkage for nitrocellulose film should not exceed 1 per cent after being dried by suspending loosely for 240 hours at a temperature of 40 ± 1°C. in air having a relative humidity of 50 to 55 per cent, the air to be changed once or twice per hour.

(VIII) *Discrepancies in S. M. P. E. Standards.*—The S. M. P. E. is asked to express an opinion on the disagreement in the dimensions for the distance between teeth on sprockets as given in charts No. 6 and No. 7 of the pamphlet *Dimensional Standards ASA—Z22—1930.*

(IX) *Sound Gate for Projector.*—The question of the length of the sound gate (sound slit) in projection machines must be investigated in all countries. There are differences between the German and the American standards. Special attention is called to the fact that the dimensions of the sound slit in projectors must be such that the slit does not extend over the film perforations. Recommendations are postponed until existing differences are cleared up.

(X) *Diameter of Projection Lenses.*—It is recommended that a study of the dimensions of projection lenses be undertaken from the viewpoint of establishing international standard diameters.

(XI) *Definition of Safety Film.*—The following definition of Safety Film is recommended as standardized basis for all codes and regulations in all countries of the world:

(A) Safety Film is a film which is "*slow burning*" and "*difficultly inflammable.*"

(B) A film can be considered to be "*slow burning*" if the burning time of a piece 30 cm. long is more than 45 seconds. In the case of film less than 0.08 mm. in thickness the burning time for a piece 30 cm. long must be more than 30 seconds.

(C) The burning time is to be determined in the following manner:

(1) A film strip is to be used from which the emulsion has been removed by washing in warm water, after which the emulsion-free film base is to be dried by suspension in air at a temperature of 18° to 22°C. and a relative humidity of 40 to 50 per cent for a period of 12 hours.

(2) The test-strip has a total length of 35 cm. At a distance of 5 cm. from one end a mark is placed.

(3) The test piece is suspended edge upward, if possible, in a horizontal position between two thin wires which are threaded through the perforations at intervals of not more than 32 mm. and in such a manner that the perforation holes utilized on the edge for this purpose do not lie opposite those so utilized on the other edge, *i. e.*, the threaded holes are staggered. The wire for threading must have a diameter not greater than 0.5 mm.

(4) The burning time is calculated from the time the flame reaches the mark 5 cm. from the lighted end to the time that the whole strip has been completely burned. The burning test is to be carried out immediately after the film is dry and in a room free of draughts. The mean of at least three tests is taken as the final results.

(D) A film can be considered to be "difficultly inflammable" if, when tested according to the method given below, it does not kindle (flash) at a temperature of 300°C. in less than 10 minutes.

(E) Method of making inflammability test:

(1) The test is made in a small electrically heated furnace, the interior of which has the form of a vertical cylinder, with hemispherical bottom, having a diameter of 70 mm. and an average height of 70 mm. The opening at the top of the furnace is provided with a sheet iron cover in which are two symmetrically placed openings, one having a diameter of about 7 mm. and the other about 15 mm. The distance between the openings is about 15 mm. from center to

center. The small opening is for the introduction of an iron-constantan thermocouple with a porcelain sleeve which just fits through the opening. The measurement can also be made by means of a thermometer for which stem correction has been made and of which the projecting stem is protected by means of a cork disk placed around the thermometer a short distance above the furnace cover.

(2) The piece of film to be tested is hung on a U-shaped wire hook and introduced through the larger opening in the furnace cover. The solder joint of the thermocouple, or the bulb of the thermometer, and the center of the film test piece must be at the same height in the furnace which should be about 35 mm. from the top of the furnace.

(3) The piece of film to be tested should be 35 mm. long and 9 mm. wide and should have the emulsion removed by washing in warm water and drying exactly in the same manner as that used for preparing a piece for the burning test elsewhere described.

(4) Before the introduction of the sample the furnace is brought to a temperature of 300°C. which must remain comparatively constant, *i. e.*, the variation should not be more than ±1°C. per minute. At 300°C. the sample is quickly introduced.

(5) Before repeating each test the cover of the furnace must be removed and the products of combustion completely removed by means of an air blast.

(XII) *Edge Marking of Safety Film.*—It is recommended that, upon safety film, having a width of more than 34 mm., there be placed a special characterizing mark which will be visible and recognizable when the film is spooled in the form of a roll. As a means of accomplishing this it is recommended that the edge of the film be provided with a thin protective coating which hinders alteration in the emulsion layer during the subsequent processing operations.

On those matters for which no conclusion was arrived at, such as No. (IV), the gate opening for silent film projectors, No. (V), for sound film projectors, it will be noticed that an expression of opinion is requested from the S. M. P. E. It should also be noticed in regard to No. (VI) that the Society is requested to change its previous policy by including definite tolerances in their dimensional specifications.

The chief difference on any one point from the Society's definitions is in regard to the definition of safety film. In the writer's opinion a burning test based on the horizontal burning is more reliable than one based on the test piece in the vertical position. In connection with these definitions it should be recalled that Dr. Lehmann's proposals were made in connection with a meeting of the industries interested on the one side and the governing bodies in Germany on the other side, in connection with the safety regulations for cinema shows, and in particular a draft act known as a Narrow Film Act. It may be of interest to quote its first three paragraphs:

NARROW FILM ACT

Paragraph 1

Narrow films, in the sense understood by this act, are film ribbons which are intended for taking pictures, writings and the like, and whose width is less than 34 mm.

Paragraph 2

Narrow films must not be easily inflammable nor easily combustible. Easily inflammable and easily combustible narrow films must not be manufactured at home or be introduced from abroad.

Paragraph 3

Easily inflammable and easily combustible narrow films must not be brought into the market nor introduced in the trade after the coming into force of this act. Also, their application in cinema theaters, public buildings, halls, or picture palaces is prohibited.

It will be seen that the definition given in regard to the specifications of safety film refer particularly to paragraphs 2 and 3 by way of actual definition and interpretation of the terms "not easily inflammable" and "not easily combustible," or alternatively, the terms "slow burning" and "difficultly inflammable."

The conclusions reached by the Committee are necessarily held for six months for approval by the national committees for the International Congress of Photography.

B. SENSITOMETRY

In regard to sensitometric standardization, several important developments occurred. First, the other national committees on sensitometric standardization accepted the light source and filter proposed by the American Committee at Paris, 1925, and accepted by the British in 1928. In the meantime, no definite agreement had been reached, nor indeed had very definite proposals been made on the subjects of sensitometers or exposure meters, development, density measurement, and methods of expressing sensitometric results, although much discussion and controversy on this subject had taken place. At the present Congress, a body of recommendations for sensitometric standards was put forward by the Deutschen Normenausschusses für Phototechnik, which endeavored to cover the latter questions and bring the subject of sensitometric standardization into the industrial field. It was stated by the German committee that this action had been forced on them by difficulties arising from indiscriminate and uncontrolled placing of speed numbers on photographic sensitive goods, a situation which was summarized at the Congress by the term "Scheiner-inflation."

The gist of these recommendations was as follows:

(*a*) Acceptance of the light source and daylight filter as proposed by the American commission.

(*b*) As exposure meter, a density step-wedge combined with a drop shutter accurate to $^1/_{20}$ second.

(*c*) Brush development in a tray with a prescribed solution of metol-hydroquinone according to a so-called "optimal" development.

(*d*) Expression of the sensitivity by that illumination at which a density of 0.1 in excess of fog is reached.

(*e*) Density measurement shall be carried out in diffused light according to details to be discussed later.

These proposals aroused a very lively discussion. The American and the British delegations criticized the proposals both as a whole and in detail. As a whole they considered that the time was not ripe for application of sensitometric standards to industrial usage. In matters of detail they criticized the proposed employment of a step-wedge, and the particular sensitivity number proposed. The latter approaches very roughly the idea of an exposure for minimum gradient, but even such a number is not adequate for certain photographic uses of certain materials.

The upshot of the discussion was that the German proposals in somewhat modified form are to be submitted simply as proposals of the German committee for sensitometric standardization to the various national committees for definite expression of opinion within six months of the expiration of the Congress. Further, in case of general approval of these recommendations by the other national committees, that a small International Committee on Sensitometric Standardization shall, within a further period of six months, work out a body of sensitometric practices for commercial usage.

In this connection it should be noted that it was agreed that both the lamps and filters and exposure meters should be certified as within certain tolerances by the national testing laboratories of the countries in question.

BRIEF REVIEW OF PAPERS PRESENTED

It is obviously impossible, as it would be undesirable, to review *in extenso* the papers of cinematographic interest presented at the

Congress. These papers will be published in full in the Proceedings of the 8th International Congress of Photography, and it is for the benefit of those who may wish to study them more fully there that I am giving the following references.

The following papers represent those of general interest to cinematography on its technical side, although not necessarily cinematographic:

A paper by W. Dziobek, of the Physikalisch-Technische Reichsanstalt, dealt with the use of the tungsten vacuum lamp in sensitometric measurements. It points out that for this purpose the following data should be known:

(1) The amperage at which the radiation has a color temperature of 2360°K.

(2) Light intensity in international candles at the amperage determined by 1.

It was concluded that if the color temperature can be reproduced to within 10° the resulting error in actinic intensity amounts to only 0.5 per cent. Curves were given showing alteration of color temperature of a series of tungsten vacuum lamps over a lengthy period of burning. The constancy was found sufficient after a period of running of from 80 to 100 hours. If run for at least 80 hours at a normal load only exceptionally should a falling-off of 1 per cent occur for 100 hours' further running.

Color cinematography was considered in only two communications, and these both in the nature of semi-popular, general lectures. Professor J. Eggert of Leipzig gave a special lecture on the present position of color cinematography illustrated by examples covering two- and three-color additive processes, two-color subtractive processes, direct and indirect screen processes.

Mr. Thorne-Baker gave a paper illustrated by examples of the Spicer-Dufay process of color cinematography. This consists in preparing upon a continuous band of film base a three-color matrix or "screen" having 900 or more colored rectangular areas per square millimeter. The "screen" is then coated with emulsion and exposure is made through the support and "screen." It may be developed as a negative or as a reversed positive. Methods of making copies at the standard rate of 800 pictures per minute were described.

In connection with sound film and sound pictures papers of both general and special interest were presented.

Dr. E. Goldberg, of Zeiss-Ikon, Leipzig, gave an extremely well demonstrated and illustrated popular lecture on "Fundamentals of the Talking Films."

O. Sandvik and L. A. Jones of the Eastman Kodak Company presented a review of the talking film.

A paper by H. Thirring dealt with "Sound Reproduction by the Selenophon Process" which has been developed by the Austrian Sound Film Company. The modulation of the light beam is effected by a string oscillograph in which a metallized thread stretched in the field of an electromagnet cuts the real image of a luminous slit at a small angle and in a position of rest covers half of it. The telephonic currents from the microphone of the taking studio, after suitable amplification, are conducted through the thread which is thereby set in oscillation and modulates the length of the free part of the line of light. By the registration of this line of light of variable length on a film moved perpendicularly to the length of the line there results a variable width sound record. It is stated that the process has been adapted to the reproduction of a photo-phonic gramophone, the phonograms consisting simply of paper copies of sound film records.

A paper by C. R. Keith, of the Western Electric Company of London, dealt with "Distortion Factors in Sound Reproduction by the Intensity Process." It was pointed out that the differences which exist between the actual gamma value of a sound record and the gamma of a sensitometer strip developed at the same time could be traced to (1) the effect of the different light intensity and reciprocity failure; (2) the Callier effect; and (3) the color effect resulting from incomplete correspondence of the spectral composition of the light sources used. The author described methods for overcoming these difficulties.

R. Thun dealt with "Technical Problems of the After-Synchronization of Films" (Dubbing). He analyzed the problem as follows:

(1) Determining the desired association of sound and picture.
(2) Approaching the sound sequence as closely as possible to the fixed scheme.
(3) Detection of residual defects.
(4) Removal of these by correction of the picture or the sound sequence.

It is claimed that better results are obtained by corrections applied to the picture rather than to the sound records.

R. Schmidt, of the Agfa Company, discussed "Ultra-Short-Exposure Sensitometry and Reciprocity Failure in Special Relation to the Making of Sound Films by the Method of Variable Exposure Time." For periods of illumination from $^1/_{100}$ to $^1/_{80,000}$ second it was observed on decreasing time of exposure that a flattening of the gamma value of the characteristic curve occurred. It is of special importance for the intensity process with variable time of exposure to know the actual gradation curve of the taking exposure in order to compensate for distortions. The author has applied the form of representation (formerly given by Arens and Eggert) of the relation of density to light intensity and time of exposure by means of density-intensity-time surfaces.

New results in x-ray cinematography were described by K. Jacobsohn, scientific editor of "Photographische Industrie." This dealt particularly with experiments made with Dr. V. Gottheimer of the Pankow Hospital, Berlin. They were made by the indirect method, namely, cinematographing the image on a fluorescent screen. The improvements discussed consist in:

(1) Taking camera having a special claw mechanism by which the film is kept longer at a standstill at the gate at the expense of the time of exposure.
(2) A lens of great aperture $f/1.25$ consisting of two pairs of cemented glasses.
(3) Special fluorescent screen, resembling an intensifying screen.
(4) Ultra-sensitive film.

The value of x-ray cinematography as compared with subjective observation of movements of internal organs was discussed.

Of papers of more specialized character the following may be mentioned: "A Micro-Cinematographic Outfit" described by H. Linke, constructed by the Askania-Werke of Berlin-Friedenau, and which was on view at the exhibition associated with the Congress.

F. Beck of the same firm described "Cinematographic and Photographic Methods for Investigating Rapidly Recurring Processes." The operations of high-speed cinematography were described in detail, as well as the use of rotating cameras and series cameras. The application of these methods to the study of explosions, operation of explosion motors, combustion processes, spark phenomena, explosive tests, and lightning were discussed.

Another paper on somewhat the same subject was by W. Ende, of the A. E. G., Berlin, entitled "New Results in the Application of High-speed Cinematography to Technical Research." This discussed the special requirements in regard to speed and registration in the design of high-speed ciné cameras for technical and scientific research. It was considered that the Thun "Zeitdehner" (time stretcher) was the best instrument for taking a large series of pictures on a running band of film. Various modifications and accessories of the Thun "Zeitdehner" were described, such as apparatus for regulating the speed of taking on the film, an optical indicator, and an automatic release by the camera. A method of increasing the speed of taking was described which allows the number of pictures to be increased from 6000 to 30,000 per second. The paper was illustrated by a film showing the high-speed study of mechanical movements, of arcs and spark phenomena, with exposures ranging from 1000 to 30,000 per second.

9TH INTERNATIONAL CONGRESS OF PHOTOGRAPHY

At the concluding business meeting of the Congress, the writer, in the names of the Society of Motion Picture Engineers and the Optical Society of America, offered a provisional invitation to the Congress to make its next meeting (1934) in North America. This proposal was received with much appreciation, but with definitely expressed doubts as to its feasibility. It is hardly to be denied that a meeting on this side is desirable. Eight of these Congresses have now taken place in Europe. The last three *post bellum* Congresses were held in Paris, London, and Dresden. They have exemplified in their own field the unity of science in western culture, in the face of national and linguistic differences. If the International Congress of Photography is to be truly international, and not merely European, it is essential that it should meet before long on this side of the Atlantic. Our technical societies, directly or indirectly concerned with photography, and the great American industries of cinematography and photography, will assuredly honor themselves and materially assist photographic advance by helping to bring about an American meeting of the International Congress. I call to your attention that this would be the first meeting of the Congress under its new name, since at the conclusion of the Congress it was decided to change the name of the Congress from the International Congress of Photography to International Congress of Scientific Photography and Cinematography. It is my sincere hope that this Society will do all in its power to make the invitation effective.

COMMITTEE ACTIVITIES

REPORT OF THE PROJECTION SCREENS COMMITTEE*

The first report of the Projection Screens Committee was published in the September issue of the JOURNAL. It was to have been read at the May Convention of the Society but unfortunately the copies shipped to Hollywood by air mail were lost in transit. It dealt with, in some detail, the manufacture, installation, and maintenance of screens, and their light-reflecting and sound-transmitting properties. Curves were given to illustrate the reflection characteristics for the three types: diffusing, metallic, and beaded. Sound requirements and test methods were discussed at length.

It is, of course, our hope to consider screens from every possible angle of interest to the Society. At the present time we are able to report further progress on the program we originally formulated. We have some data on deterioration of screen surfaces, enough to indicate that a serious condition exists. The troublesome problem of determining the optimum illumination for screens has been given considerable attention, and some interesting information on rear projection screens, and incidentally rear projection, has been accumulated. This material follows.

LIGHT REFLECTION

That screens lose their reflective power with use is common knowledge. However, reliable data as to the magnitude of this loss have never been accumulated. We have made a beginning in this direction. The few results we have had the time to obtain indicate the range of variation and the really serious extent of the deterioration.

Our measurements were made with equipment constructed by one of the members of this Committee. The apparatus consisted of a metal tube 4 inches in diameter, holding a lamp operating at a color temperature of 2360°K. Concentric with this first tube, there was a second narrower one with a viewing aperture at one

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

end, in which it was possible to insert the photometer unit of a Macbeth illuminometer. The light source was an automobile lamp placed so that the angle of light incident upon the screen was approximately 3 degrees with the normal, which was the viewing angle. Between the viewing aperture and the screen was placed a blue filter such as to make the color of the light entering the photometer correspond to 5000°K. The light in the Macbeth comparison lamp was corrected with a similar filter in order to eliminate color difference in making the photometric balance. A battery of five dry cells made the apparatus entirely portable and independent of external power.

Measurements were made in several convenient theaters. The device was placed against the screen which was observed through the photometer inserted in the aperture. Obviously, the data are restricted to only one angle. It is felt that the loss of reflection which occurs at one angle will indicate approximately what occurs at other angles. The results are summarized in the following table. The original values for these screens ranged from 77 to 85 per cent.

Reflection at 3 Degrees from Normal

Sample	Per Cent
A. Broadway Theater (In use 18 months)	45
B. Auditorium; New York, N. Y. (In use occasionally for 3 years)	48
C. Broadway Theater (In use 18 months; lately reprocessed)	70–80
D. Broadway Theater (In use 9 months; reprocessed 3 months)	64
E. Hoboken Theater (In use occasionally 9 months)	80
F. Review Room (In use 9 months)	76

It will be noticed that deterioration is not very consistent. However, we should expect it to vary widely, depending on the conditions surrounding the use of screens. The valuable results obtainable from surface reprocessing are demonstrated by case *C*. In addition to a possible degradation of picture quality there will be a financial loss accompanying deterioration of reflecting ability. Some idea of the possibilities may be grasped from the following table.

The figures are based on a hypothetical decrease of 20 per cent in reflection, a serious loss. It is assumed as a first approximation that this corresponds to a 20 per cent waste of electric power. Other assumptions are: operation, nine hours daily, and energy cost, five cents per kilowatt hour. These are common conditions.

Type of Lamp	Amperage	Weekly Current Cost	Weekly Loss
Low intensity arc	25	$ 8.75	$1.75
Hi-Lo intensity arc	75	26.00	5.20
High intensity arc	120	42.00	8.40

Obviously, if projection occurs only a few hours daily or weekly, the loss is not serious. However, it is not difficult to imagine a case where replacement of a screen would soon pay for itself by the saving of power required for illumination. One example is the theater given as case *A* above, which runs approximately thirteen hours every day. Another case when difficulty arises occurs when the projection outfit is operating at the limit of its capacity and is unable to supply sufficient light to overcome the loss of reflective ability of the screen.

SCREEN ILLUMINATION

Upon the appointment of the Projection Screens Committee, President Crabtree stressed the need for recommendations on the amount of screen illumination required for motion picture presentations. This complex subject has received a great deal of attention in the past, being one of the oldest of projection problems. Much scattered work has been done without the achievement of standardization or a complete realization of the factors involved. Among these factors are included the simplification of studio lighting and printing control as well as projection illumination technic. We will review hastily a few of the facts that are known, before describing a series of tests conducted at the meeting of the New York Section, Friday, September 25, 1931.

Factors that must be considered include visual acuity; flicker; other physiological factors; fidelity of brightness, contrast, and tone reproduction; and auditorium lighting. A complete unraveling of these is impossible but we may analyze them to some extent to obtain a better understanding of the problem.

A picture projected on a plane surface will be seen to consist of a grouping of areas of different brightnesses, that is, it is merely a pattern of contrasts. The relative brightness of the images must be presented much as the subjects are in actuality. For our purposes it is not necessary to discuss so much the relations involved among the areas as it is the intensity of light with which the picture as a whole is to be projected, that is, the absolute values of brightness. We seek to learn how brilliant bright objects must be, how dull the dark subjects may be and yet be discernible.

Obviously it is not possible to reproduce on the screen values of brightness as they occur in nature. To a large extent this is not necessary and often not even desirable. One purpose of a motion picture is to create artificially an impression which will be accepted as a satisfactory illusion of reality. More than that, it aims to convey a story, using its own devices. The brightness element, together with size, depth, and color, is secondary, being subordinate to the story and continuity. Hence, it is not necessary that sky scenes be shown with clouds as lustrous as clouds are, human faces as bright as they are in every-day life, deep shadows as profound as they often are. What is essential is not so much faithfulness to actuality as it is adaptation of illumination to achieve a smooth vivid portrayal of the story. This is fortunate in as much as we possess no light sources capable of producing on a screen brilliancies comparable with those under direct sunlight. Nevertheless there may be some instinctive demand for reasonable fidelity in brightness reproduction.

The pictures on the screen should be easy to see under conditions of illumination existing in theaters. The projected image should be the brightest area in the theater to facilitate concentration. However, in addition to this psychological element, there is another practical requirement. The auditorium should be provided with as much light as is consistent with preserving satisfactory detail in the picture, and the intensity should increase with the distance from the screen. This light should be sufficient to mitigate screen glare and permit easy finding of seats. There should be no sudden change at any point, as sharp contrasts are harmful to the eye. Stray light falling on the screen must be kept to a minimum in order to preserve picture contrast. Clearly, if the stray light should equal the illumination on the screen corresponding to a shadow, the shadow would disappear.

The lower limit of screen brightness should therefore be determined by the light reaching the screen from the auditorium. There is no criterion for the maximum desirable amount of illumination corresponding to the highlights. We do know, however, that with the auditorium in a darkened condition it would not do to have too bright a screen as this would be physiologically harmful.

Desirable screen brightness is dependent on all these variables. Only by analysis of judgments drawn from many observers subject to varied, controlled conditions will it be possible to determine the optimum relations.

In an endeavor to obtain more information on this subject, we conducted our tests at the meeting of the New York Section. This meeting afforded an excellent opportunity in as much as there was present a body of trained men who would readily understand our aims. We did not expect conclusive results from our tests, but regard them as a preliminary step in the investigation. Obviously, a complete study of all the factors would require the time of many men over a period of months.

In these tests we used two projectors, one a hi-lo and one a low intensity arc, setting these to produce known values of screen illumination. Two types of arc were employed to determine whether different color characteristics affect the amount of light judged desirable. There was no illumination in the auditorium other than that supplied by screen reflection. It would have been interesting to vary the lighting also, but the time at our disposal necessitated restriction of the variables. Two reels of film were used, one with a large percentage of brilliant scenes in it, such as outdoor shots, the other consisting of interiors, emphasizing human features and shadows. We wished to learn whether different amounts of light would be found desirable for different types of subject-matter.

The arc light intensity was varied by means of wire filters inserted in the projection machine behind the condenser lens. Four settings were used. The first setting was 68 per cent of the maximum, which was the second setting. The third and fourth settings were 50 and 25 per cent, respectively. The low intensity machine was first used for both reels and was followed by the hi-lo intensity arc. There were present 61 observers, most of whom commented on the projection on questionnaires which were distributed among them. Their findings are summarized in the following table. The brightness values are without film and with the shutter running.

Reel 1 Interiors — Reel 2 Exteriors

Low Intensity

Brightness	Foot Lamberts 4.7	7	3.5	1.7	Foot Lamberts 4.7	7	3.5	1.7
Glaring	0	3	0	0	10	0	0	0
Bright	2	8	0	0	20	4	0	0
Preferred	9	17	0	1	12	18	0	0
Acceptable	26	25	3	1	16	29	7	0
Dull	18	4	41	12	0	8	39	15
Dark	2	0	14	44	0	0	12	43

Hi-Lo

	Foot Lamberts 11.5	17	8.5	4.2	Foot Lamberts 11.5	17	8.5	4.2
Glaring	10	20	0	0	13	6	0	0
Bright	14	14	1	0	20	10	2	0
Preferred	9	12	11	1	7	22	7	0
Acceptable	14	10	18	7	15	16	8	3
Dull	9	1	19	24	0	4	33	20
Dark	1	1	8	24	0	0	8	35

Screen reflection factor: 80 per cent.

Screen size: 9 by 12 feet.

Distance from screen: from 27 to 55 feet.

Viewing angle: 90 ± 30 degrees with screen.

Auditorium illumination: 0.02–0.5 foot candle.

Brightness of screen surroundings: 0.1–0.9 foot lambert.

19 Observers expressed a preference for the color of the low intensity lamp; 17 preferred the hi-lo.

A foot lambert is the brightness of a perfectly diffusing surface illuminated by one foot candle.

Analysis of Results.—Under the circumstances we cannot be too positive in our conclusions from these tests. It will be sufficient to point out tendencies and possibilities. To obtain decisive results it would be necessary to perform repeated and varied experiments lasting over a period of time. Admitting the limitations, we may proceed to interpret the data.

With reel 1 and the low intensity lamp the reactions were just what might be expected. A brightness of 7 foot lamberts was found to be quite acceptable. This reel consisted of views of a string orchestra, the players being dressed in dark, formal clothes. The brightness on the screen was of the same order of magnitude as those existing at an actual performance of such an orchestra. Obviously, we do not know that this value would have been preferred to a higher one, which our facilities did not permit.

The results obtained with this reel and the high intensity lamp are in fair agreement with those for the low intensity. A brightness of 17 foot lamberts is too great for such an indoor scene projected in a darkened auditorium. A value between 8.5 and 11.5 is indicated as perhaps the most acceptable.

Reel 2 consisted of comparatively brilliant outdoor scenes. It was shown after the reel of indoor scenes and it is supposed that the first reaction of the audience was to pronounce the illumination bright. After sufficient time had elapsed for ocular accommodation, a greater brightness was found acceptable and, in the case of the high intensity lamp, preferred. The light intensities on the screen were naturally far below those at which the original scenes would have been viewed.

One conclusion is that it is necessary to vary the light intensity for different types of prints, although it is theoretically possible to select one light intensity and maintain it by recording scenes on a sliding photographic scale, each value of brightness to have a definite constant position on this scale. The optimum value of brightness according to these tests should be a compromise between the extremes of 7 and 17 foot lamberts, the mean of which is 12. This is somewhat higher brightness than is customary.

REAR PROJECTION

Historical.—Rear projection is not new; it has been used for fifteen years in Germany, France, and England. In this country we are all familiar with the small projectors used in public places for advertising, demonstration, and stock quotations. Application to the theater was delayed by two difficulties: one, the lack of a suitable translucent material, and the other, of an efficient distortionless wide angle lens. Within the past six months several small theaters have opened in New York to show newsreels and short subjects on a rear projection screen.

Mechanics.—There are several possible materials for use as rear projection screens. The more common are dental rubber, treated silk, ground glass, celluloid, and a gelatin composition. The last is one which is being used on a large scale. Glass screens have a satisfactory transmission characteristic but the large sizes are heavy and difficult to protect. Celluloid screens would be satisfactory if it were not for their fire hazard. All rear projection screens have the disadvantage that large uniform areas of material must be used. They differ from front projection screens in this respect, for the latter are sewed together from strips of standard width. The process of manufacture of the gelatin screen is as follows:

On a heated table is poured a hot gelatin solution, over which is stretched smoothly a fine silk fabric which is pressed into the gelatin. The combination is allowed to cool slowly about twenty-four hours, and is then placed on a rack to dry for seventy-two hours. Care must be taken to keep water from touching the screens as the composition is soluble in water. The screens may be cleaned with alcohol. They can be furnished in any desired color but at present a slight bluish tint is standard.

Installation.—It may be of interest to point out several facts about the installation of rear projection apparatus as it is done in the new small theaters. Standard apparatus is used, two machines being mounted about 8 feet behind the screen at an angle of 45 degrees with each other and $22^1/_2$ degrees with the screen normal. Each lens is approximately 7 inches off the screen axis.

The width of screen that is possible is determined by its distance from the projection lens. The rule is that 1 foot of width is possible for every foot of separation between the screen and the 1-inch focal length lens that is employed, 8 feet in this case.

There is a general impression that film as projected over these machines must be reversed. This is not so, as a prism is employed to reverse the image on the screen and to bend the light rays through an angle of $22^1/_2$ degrees. The prism is mounted immediately ahead of the negative projection lens.

The screen is mounted about 5 inches above the head of an observer in the first row. This makes possible the installation of a horn or baffle loud speaker beneath and on a line with the screen. It must be pointed out that this position for the speaker is not quite correct for furnishing the proper illusion, which, however, is yet acceptable in the front rows to the ordinary observer. At the rear of the theater the effect is quite good, in as much as the auditorium is small and sound mixing helps create the correct impression.

One advantage of the rear projection installation may be pointed out. It requires less vertical space and no specially dimensioned auditorium. Hence it is possible to employ as theaters enclosures similar to small stores.

Light Transmission.—The light transmission may be varied to meet different requirements. We have already seen that transmission may be made to favor any particular color. It also may be made to give several different types of distribution. By proper processing, the distribution is made more uniform, and hence satisfactory for viewing at wider angles. It must be expected that there will be an additional loss of contrast as compared with front projection because of the introduction of another translucent surface, which adds to the flare effect.

Illumination.—Since the screen is light transmitting, the light intensity in the auditorium can be considerably higher than in the ordinary theater during a performance. It has been stated that the auditorium is illuminated to about 30 per cent of average theater full lighting. Nevertheless, it is necessary to take precaution to keep light from falling on the screen, in as much as there is some slight reflection from the surfaces. High auditorium illumination means that confusion in seating is practically eliminated. For types of theaters where patrons are continually passing in and out, it is very desirable to have considerable light. However, it must be remembered that a partially lighted auditorium tends to prevent patrons from "living" through a feature presentation, since it makes one too conscious of his immediate surroundings. In a theater showing newsreels and short subjects, this is not objectionable.

For much of the above information on rear projection we are indebted to Mr. W. Mayer and the Trans-Lux Movies Corporation.

S. K. WOLF, *Chairman*

D. S. DE'AMICIS	W. F. LITTLE
F. M. FALGE	A. L. RAVEN
H. GRIFFIN	C. TUTTLE

DISCUSSION

PRESIDENT CRABTREE: The work of this Committee points the way in which a committee can do real research work. They did not have to have a research laboratory in which to make these tests. They used the available research laboratory, which was the membership of the Society. I congratulate the Committee on this pioneering effort in coöperative research.

It is very interesting to find that it seems to be necessary to have a greater screen brightness for the outdoor shots than the indoor ones. On second thought, it is reasonable. Probably the matter could be taken care of by giving a uniform flash exposure to the interior scenes, or they could be printed a little heavy.

With reference to the brightness test I should like to point out that the figures show approximately ten foot candles as the minimum desirable brightness of a picture. In previous years we have made numerous tests of screens, and find that the average lies between three and five foot candles; and with low intensity light sources, three foot candles. In the studio laboratories where prints are analyzed by the studio personnel, intensities of about thirty foot candles are used—ten times the intensities used in the theaters. This is the cause of dark prints and the troubles that go with them, such as overloading. Dirty screens also require overloading, causing additional loss of picture quality.

MR. FARNHAM: In connection with the data on reflection factors of screens, the figure of eighty per cent appears to be very high. I should like to ask if that is absolute reflection, *i. e.*, incident light to total reflected light or is it the ratio of reflected light after a period of use to that of a new screen?

MR. WOLF: The measurements of reflection factor were made as soon as the process was completed; each time a comparison was made with the standard.

MR. FALGE: It happens to be the brightness at the normal which is in question rather than the total reflection value.

MR. FARNHAM: That is an extraordinarily high value, and that is why I asked.

PRESIDENT CRABTREE: Have the experiments of the Committee, Mr. Wolf, gone far enough that we can begin to think of recommending a standard of screen brightness?

MR. WOLF: The data collected at the demonstration at Bell Laboratories proves more or less conclusively that there are certain limits to be considered. We cannot say definitely what they are, but they probably lie between seven and thirteen foot candles. We definitely believe that any picture having a brightness less than seven foot candles is certainly too dull; and any picture having a brightness greater than thirteen foot candles is glaring and disagreeable to look at.

PRESIDENT CRABTREE: Can any one explain why a value of thirty is used in the screening room?

MR. FALGE: In an article published by Mr. Huse some time ago, describing some tests of Hollywood screening rooms, he gave the value as thirty foot candles. It is expected that the intensity will always be high in the screening rooms, unless deliberate attempts are made to keep it within reason, because the picture is always small and the light intensity is greater than in the average theater.

PRESIDENT CRABTREE: Were Mr. Huse's measurements strictly comparable with yours? In other words, has the Committee first of all found a method of getting an absolute measure of this reflection value? Does your figure of ten correspond with a similar figure in Hollywood?

MR. FALGE: I think you will find considerable variation among the figures that have been collected; but I think it is sufficiently important, even with an error as great as twenty-five per cent, to show that the values in the theater differ considerably from those in the studios.

MR. FARNHAM: As a result of some work that I did a number of years ago on screen brightness, I found that there is also a relation between the picture size and the screen brightness. Smaller screens should be brighter for the same projected picture, so that whatever intensities we recommend for the studio viewing rooms, they must be corrected for the size of the picture.

PRESIDENT CRABTREE: That was also observed when we were making wide-film experiments. We did not need as great a brightness as with the smaller pictures.

MR. GAGE: May I ask if the foot candles are measured with a machine stationary with the shutter open, or with the shutter running and with no film?

MR. WOLF: We have data under all conditions. In preparing the tests we made measurements both with the shutter standing still and with it in operation. We made the measurements, also, of auditorium illumination and other quantities. The screen reflection factor was eighty per cent, and the size of screen was nine by twelve. The auditorium illumination varied from 0.2 to 0.5 foot candle. The amperage of the high intensity arc varied from 7 to 4.2; of the lower intensity, from 7 to 4.7.

PRESIDENT CRABTREE: What were the limits of variation due to screen size? Do you recall, Mr. Farnham?

MR. FARNHAM: The smallest screen used was approximately four feet and the largest twenty-two feet, a linear ratio of one to five and one-half. However, the ratio of brightnesses was more nearly two or three to one, the smaller picture requiring the higher intensity, but it was by no means an inverse ratio.

PRESIDENT CRABTREE: Suppose a value of seven were required for a twenty-foot screen, what would be the value for a four-foot screen? Would it be greater than thirteen?

MR. FARNHAM: As near as I can recall, the smaller picture would require two to three times the intensity ratio.

PRESIDENT CRABTREE: Is the Committee considering the effect of screen size?

MR. WOLF: Yes, it is; but sufficient time was not available.

PRESIDENT CRABTREE: If any of you are in New York I would recommend that you visit one of the Trans Lux theaters where pictures are projected from the rear of the screen. The most amazing thing is that the brightness level in the theater is as high as it is in this room, and yet the picture is adequately bright.

MR. GAGE: With a small screen close by or a large screen far off, both subtending the same angle to the eye, and with the same foot candles of illumination would not this give equally desirable results on both screens? If so, it is necessary to relate the distance of the observer to the screen size rather than simply say that a twenty-foot screen requires so many foot candles, and a thirty-foot screen so many foot candles, *etc.*

PRESIDENT CRABTREE: That would depend on the opacity of the atmosphere.

MR. WOLF: We did find a difference in the reactions of viewers as they moved away from the screen. But the brightness is the same whatever the distance may be.

PRESIDENT CRABTREE: Not if there is absorption, and the air is full of smoke.

MR. WOLF: That effect is not appreciable.

PRESIDENT CRABTREE: I urge the Committee to push forward the experiments as rapidly as possible, because I am anxious that our Society should be the first to propose a definite standard of screen brightness with the necessary qualifications due to the various factors involved.

ORGANIZATION OF PROGRESS COMMITTEE WORK

For three years the past-chairman of the Committee has assisted in the preparation of the semi-annual report, and it has occurred to him that a résumé of the program of organization may be of some value to future chairmen. The following notes represent a description of the plan of organization of the work of the Committee.

Membership of the Committee.—It is very important in selecting members of the Committee to choose men who are representative of various departments of the industry. Such phases of the industry should include: film manufacture, lens design, camera work, and sound recording technic, studio illumination, laboratory processing, sound reproduction, theater construction and operation, and applied cinematography. Besides representatives in the United States, men should be selected from each country or part of the world where a well-developed motion picture industry exists, as well as where research on cinematographic problems is in progress.

The widely separated geographical position of the members of the Committee makes it unfeasible to hold meetings so that all the committee work must be handled by correspondence. Each member should be instructed carefully relative to the scope of the field which he is to cover in his semi-annual report to the chairman. It is very desirable to distribute the abstracting work of the Committee members, and separate journals which are pertinent to the nature of their own work should be assigned to each member.

The reports from Committee members may be composed of any one of the following types of information:

(1) Abstracts of journals.
(2) Personal appraisals of conditions in their specific field.
(3) Answers to specific questions asked by the chairman.

A combination of classes (1) and (2) is the most valuable. The Committee members should realize that information that may sound commonplace to them because of their nearness to the source may be of outstanding interest to other branches of the industry.

Work Preliminary to the Preparation of the Report.—The past-chairman of the Committee has found a card file to be the most helpful means of coördinating the many hundreds of details which require final mention in the report. The contents of this file are assembled from three sources, namely: (1) clippings from one or more photographic abstract bulletins such as the *Monthly Abstract Bulletin* of the Kodak Research Laboratories, which contains patents as well as journal abstracts; (2) abstracts and summaries prepared by committee members; (3) miscellaneous data obtained from sources other than those mentioned under (1) and (2). One valuable source of information on trade news is the weekly report of the Motion Picture Division of the U. S. Department of Commerce, Washington, D. C.

From past experience it has been found that illustrations comprise a valuable addition to the Progress Report, particularly during its presentation. The interest of the audience may be heightened considerably by the judicious use of lantern slides. A special effort should be made to secure illustrations of new equipment developed in foreign countries. Short motion picture films of significant developments may also be used as a valuable adjunct of the report during its presentation, as was shown at the Washington Meeting of the Society in May, 1930.

Preparation of Final Report—All reports from the different members of the Committee should be in the chairman's hands not later than one month before the date of the meeting at which the report will be presented. When these are received, every item of value should be card-indexed and filed so that, as far as possible, all data to be used in the report is on cards. It is not feasible in some cases to transfer the information but the reference to it should be prepared so that the data may be located with the least possible loss of time.

When all available data have been filed according to a definite classification, the actual writing of the report should be started. All references may be made most easily at the time that the material is written up, rather than after the writing has been finished. When the first rough draft has been typed, the report should be edited for the principal items of progress or "highlights" which are to be read at the meeting. These highlights should not comprise more than 20 per cent of the total report, and sufficient copies (usually about 30) should be mimeographed for the use of the Publicity Committee.

The general introduction to the report giving a broad summary of progress should be written last, after a clear impression has been secured of all the significant developments in the report. Courteous acknowledgment should obviously be made to all sources of information and illustrations apart from those actually supplied by Committee members. Care should be taken that proper credit is given under each illustration published with the report.

If the work of the Committee is carried out conscientiously and thoroughly, this report should become an increasingly valuable compendium of technical information on the motion picture industry throughout the world.

G. E. MATTHEWS, *Past-Chairman*

ABSTRACTS

Studio Practice in Noiseless Recording. George Lewin. *Electronics*, October, 1931, p. 146. The theory of noiseless recording by the light-valve method was discussed in a preceding article (*Electronics*, September, 1931). Some modifications must be made in adapting the method to studio practice and special instruments must be designed to check the characteristics quickly and accurately. The author points out one very practical advantage of noiseless recording—namely, that the average level may be kept lower, thereby reducing the danger of over-shooting. With the introduction of noiseless recording, however, a certain amount of background noise that had previously been taken for granted has become more noticeable. This includes noises originating on the stage or in the theater itself due to the ventilating system or projection machines. A. C. H.

Glow-Lamp Noiseless Recording. E. H. Hansen. *Electronics*, November, 1931, p. 177. A description of the method of producing "noiseless" records by the glow-lamp method. A. C. H.

Ideal Camera Blimp in Daily Use. Ira Hoke. *Internat. Phot.*, **3**, November, 1931, p. 27. A new and extremely useful camera casing is reported from the Educational Studios in Hollywood. It is of cast aluminum and sound insulated. The new feature is the possibility of pumping the air out with a vacuum pump whenever conditions demand the extreme in noiseless equipment. Only 25 seconds are required in this process and the method interferes in no way with the operation of the camera or sound apparatus. A. A. C.

A Standard Aperture for Sound Films. John Arnold. *Amer. Cinemat.*, **12**, November, 1931, p. 14. Sound on film destroyed the 3 × 4 proportion of the motion picture screen, when it was first introduced. Theaters remedied the condition by using a reduced aperture of the old proportion, thus forcing the producer to plan his picture to suit, as well as possible, the various sizes that were being used in the theaters. This has been accomplished by the expedient of masking the camera aperture accordingly, and confining the action to that portion of the film. About twenty per cent of the frame area is not used at all, under these conditions.

A new standard, 0.651 × 0.868 inch, for camera aperture and 0.615 × 0.820 inch, for projector, is now proposed by the Academy of Motion Picture Arts and Sciences. A full report of the proposal is being circulated by Lester Cowan, Executive Secretary of the Academy. A. A. C.

New Photoelectric Cell. *Mot. Pict. Proj.*, **5**, November, 1931, p. 37. A description is given of the Weston Photronic Cell, which employs a light-sensitive disk to transform light directly into electrical energy without the use of auxiliary voltage. It delivers about one microampere per foot candle of light intensity and the response to light variations is said to be instantaneous. The simplicity and ease of operation of the new unit are advantages that are expected to lead to its wide use as an indicator in measurements of illumination. A. A. C.

Rectifying Contact Photoelectric Cells. R. Singer. *Technique Cinemat.*, **2**, November, 1931, p. 18. It has been known for some time that certain devices, notably those using copper oxide in contact with metal for rectifying alternating currents, also possessed the property of developing an electrical potential difference at their electrodes when radiated with light. The characteristics of two commercial cells of this type are discussed briefly. Another cell is mentioned which depends on a needle contact with galena crystal. It is stated that these cells are rugged and simple in use. They require neither vacuum nor a liquid electrolyte. C. E. I.

How to Determine the Position of the Pick-up Arm. L. LUMIÈRE. *Technique Cinemat.*, **2**, November, 1931, p. 4. The author proposes a method of determining a position for the pick-up arm which minimizes variation in the angle made with the tangent to the record grooves. The geometrical steps are shown. Reference is made to an article on this subject which appeared in the preceding issue. C. E. I.

The Panoramic Motion Picture and the Chrétien Hypergonar. H. PICARD. *Technique Cinemat.*, **2**, November, 1931, p. 7. A wide-screen picture can be obtained with film of normal width by compressing the image in width by the use of an auxiliary cylindrical lens both in making the negative and in projecting the positive. This method is open to the objection that the graininess of the negative shows up in the magnified image of the positive. It is proposed to overcome this fault by using wide negative film and compressing the image by the use of the auxiliary lens in the process of projection printing to the fine grain positive. The illustrations with the article show pictures of the French Colonial exposition buildings made in this manner. Other applications using this scheme are mentioned, such as narrow vertical pictures, and color and stereoscopic processes requiring two or more pictures in the standard frame. C. E. I.

New Sound-on-Film Method. *Mot. Pict. Herald*, **105**, October 24, 1931, p. 11. This process uses a variable density record on 16-mm. film, having the usual double rows of perforations and 40 frames to the running foot of film. The sound record is made on a bias which allows greater width of the frequency band, the over-all width of the track being 0.025 in. It is claimed to be possible to record not only at the old silent speed of 60 feet per minute but also as slowly as 32 feet per minute without volume or quality loss. Reduction prints from 35 mm. film are planned to form the nucleus of a film library for non-theatrical distribution. G. E. M.

New Photoelectric Cell. *Film Daily*, **51**, November 22, 1931, p. 6. A highly light-sensitive disk on the face of this photoelectric cell transforms the light energy directly into electrical energy without the use of auxiliary voltage. The cell has an instantaneous response to light variations and relays may be operated directly from the current generated by the cell. About 1 microampere is delivered per foot candle of light intensity. When exposed to direct sunlight, the output is about 5 milliamperes. The cell resistance varies from about 1500 ohms for 10 foot candles to 300 ohms for 240 foot candles. A moulded black bakelite case $2^1/_4$ inches in diameter and 1 inch in thickness encloses the cell. G. E. M.

The Screen: A Problem in Exhibition. BEN SCHLANGER. *Mot. Pict. Herald*, **105**, Sect. 2, October 24, 1931, p. 14. With the exception of the progress made in projection engineering, the author claims that the art and science of exhibition have advanced very little. The position of the screen, for example, is still being determined from the stage floor of the drama theater. The average life of a theater building should be at least 15 years in order to amortize the initial construction cost and to show a reasonable investment profit. Bodily comfort of the patron is considered of primary importance in theater design. A maximum screen size having the ratio of 1 to 1.67 is considered preferable to satisfy various requirements. G. E. M.

A Portable Sound Recorder. *Kinemat. Weekly*, **177**, November 19, 1931, p. 56. A very light and portable sound recording apparatus, capable of being carried in a small automobile, has been developed by a British manufacturer. The recorder may be fitted to almost any modern camera, provided, however, that the camera has been silenced for sound work. This comprises changing certain gears to fit construction, enclosing the shutter drive in a sound-proof casing, and providing more sturdy bearings for the sprockets.

The recording head and amplifier of this new equipment fit underneath the camera in a casing which consists of two compartments; the front chamber carries the sound slit and guide rollers while the rear compartment contains a two-valve amplifier. The glow lamp projects in front of the forward casing and can be slipped out to protect it from damage. The lamp is made of Pyrex glass, and special non-spluttering metals are used for the electrodes, thus minimizing the risk of the glass turning black. The motor is mounted at the rear of the camera case and has incorporated with it a tachometer of improved design. The microphone used is of the transverse current type. Ear-phones are provided for monitoring purposes. C. H. S.

ABSTRACTS OF RECENT U. S. PATENTS

The views of the readers of the JOURNAL relative to the usefulness to them of the patent abstracts regularly published in the JOURNAL will be appreciated. Favorable views are of particular interest. In the absence of a substantial body of opinion to the effect that these patent abstracts are desired by the membership, their early discontinuance may be considered.

1,825,663. **Film Reel and Spindle.** A. G. HAYDEN. Oct. 6, 1931. A reel and spindle interlock on slight relative rotative adjustment, thereby to give them a driving connection and prevent the reel from accidental escape from the spindle. The film reel comprises a pair of plates and a hub between said plates adapted to have a film wound thereon, one of said plates having a hole therein and the other of said plates having an opening with tongues therein projecting toward, but not to, the center of the plate; and a spindle, in said hole and opening, having a groove for receiving said tongues to prevent movement of the reel axially of the spindle.

1,825,781. **Television Scanning Device.** L. H. DAWSON. Oct. 6, 1931. Scanning disk for television systems in which a rotatable disk is provided with a plurality of conically shaped light conducting and concentrating members extending through the disk perpendicularly to the plane thereof. The light concentrating members are constructed from quartz having a high refractive index for increasing the luminous intensity of the image by concentration of the available light rays.

1,825,953. **Device for Permitting the Continuous Feeding of the Film in Projecting Apparatus.** P. G. H. HALLONGREN. Oct. 6, 1931. Projecting apparatus in which the reflecting members are divided into at least two groups, which successively reflect the picture rays and are positively caused to turn synchronously, during which operation the active surfaces or the surfaces struck by the picture rays turn in the same direction, and the said rays pass the reflecting surfaces at the same side of the axis or axes of rotation through which the said reflecting surface or surfaces extend or with which the surfaces or surface are substantially parallel, the said axis or axes having an oblique position with relation to the plane, on which the incoming rays travel (the plane of the wandering picture).

If two axes of rotation are provided the reflecting surfaces may be located either round the axes or tangentially to cylindrical surfaces enclosing the axes of rotation and concentric with the same. In practice the two groups of reflecting members preferably are located around an axis common to the same and the reflecting surfaces of the one group located radially, while the reflecting surfaces of the second group are located tangentially to a cylindrical surface enclosing the said axis and concentric with the same.

1,825,955. **Synchronized Cylinder Record for Talking Picture.** E. S. HAYFORD. Oct. 6, 1931. Apparatus for synchronizing a sound record with a picture record comprising a cylinder of conducting material mounted for simultaneous movement with the picture record, a sleeve of non-conducting material carried upon said cylinder and having an opening, a stylus mounted for movement along said cylinder and normally engaging said sleeve and adapted to enter the opening therein and an electrically operated actuating device connected in circuit with said stylus and said cylinder for operating said sound record. The sound producing means may be rendered operative or inoperative at any predetermined position with respect to the film being projected, thereby permitting the use of a record having a limited tone groove length in connection with a greater length of film.

1,826,305. **Scanning System for Television.** H. P. DONLE. Oct. 6, 1931. A scanning system having a speed regulating drive interposed between the scanning disk and the driving motor. The shaft is formed in two parts, and the speed of rotation of one part is manually controlled by friction means and regularized by a ball governor. The other part of the shaft carries the scanning disk and the angular relation between the two parts of the shaft is adjustable by manually controlled means independent of the speed controlling means and independent of the speed of the motor.

1,826,332. **Drive Mechanism for Scanning Disk.** C. O. VERMILLION. Assigned to Wired Radio, Inc. Oct. 6, 1931. A drive mechanism for a scanning disk having means for framing the scanning holes of the scanning disk with respect to the object to be televised or the picture to be reproduced. The scanning disk driving mechanism is so arranged that constant speed may be obtained at both the transmitter and receiver even during periods of adjustment for framing the apertures in the scanning disk with respect to the picture or object.

1,826,522. **System for Avoiding Interruptions of Television Program.** F. H. OWENS. Assigned to Owens Development Corp. Oct. 6, 1931. A plurality of photoelectric cells are arranged in light paths formed through the film. The cells operate simultaneously for controlling the input circuit of an amplifying system. The light which is directed through the film is split into diverging paths toward a plurality of photoelectric cells so that any one of the cells will continue to operate for controlling the reproduction of sound in the event of failure of the others so that there will be no interruption to the sound program.

1,826,680. **Motion Picture Projector Cabinet.** A. STUBER. Assigned to Eastman Kodak Co. Oct. 6, 1931. A projector is housed with a sound reproducing instrument in the same cabinet, the projector being mounted on a rotatable support for projecting a picture in any desired direction to the most suitable location on a portable screen. A phonograph or radio apparatus may be housed in the cabinet, but is so isolated from the projector that the noises of the projector are muffled and prevented from interfering with the equipment within the cabinet. The light rays from the projector within the cabinet are directed vertically through the cabinet and then projected horizontally in any desired angular direction. The direction of the beam may be selected by shifting the projector to the desired angular position within the cabinet structure by means of a crank which engages the rotatable mount for the projector.

1,826,695. **Light-Protected Motion Picture Film.** P. FAVOUR. Assigned to Eastman Kodak Co. Oct. 6, 1931. A light protecting covering is interwound with the film strip and is normally unperforated, but capable of being perforated as a film moving mechanism advances the film through contact with the film perforations. Pasters are provided for attaching the supplementary light-protective covering to the perforated film band, the pasters attaching one end only of each supplementary light-protective covering to the film band.

1,826,754. **Method of Making Photophonographic Records.** F. EHRENHAFT. Oct. 13, 1931. A recording lamp is employed having a luminescent gas discharge controlled by sound waves, which transform said luminescent gas discharge into a transitional form of discharge intermediate between a glow and arc discharge.

1,826,786. **Sound Controlled Still Picture Protector.** P. S. HOPKINS. Assigned by mesne assignments to Agfa Ansco Corp. Oct. 13, 1931. Projecting apparatus for still pictures accompanied by a sound program. The still pictures are shifted automatically to coördinate the picture with the sound program so that a picture is projected appropriate to the accompanying sound. The apparatus is capable of use as a projector accompanied by an illustrated lecture without the attendance of the lecturer.

1,826,812. **Electroöptical Transmission Employing Mirrors instead of Light Valve.** H. NYQUIST. Assigned to American Tel. and Tel. Co. Oct. 13, 1931. A system for transmitting electrical impulses into light impulses of varying intensities, comprising two plane mirrors having their planes intersecting at right angles and controlled by incoming picture current at the receiving station, which mirrors take the place of the usual light valve. The term "90-degree mirror" is used to designate such an arrangement of plane mirrors. This "90-degree mirror" rotates about an axis at the line of intersection. The surfaces consist of alternately reflecting and non-reflecting strips which gradually increase in width from the line of intersection. The rotation of the 90-degree mirror is controlled jointly by picture currents received from a transmission line, which currents pass through a movable coil attached to the 90-degree mirror, and by current from a local source which passes through a stationary coil, the position of the 90-degree mirror varying in accordance with the amount of current received from the line. A constant light source is arranged to project a beam of substantially parallel rays of light toward the surfaces, the axis of the beam being directed toward the axis, or intersection line, of the surfaces and at an angle thereto. The reflected beam from these surfaces is directed to a focal point on a light-sensitive surface, such as a photographic film. The amount of light reflected by the surfaces and, therefore, the intensity of the light at the focal point will vary directly with the angular change in position of the surfaces as controlled by the picture currents received from the sending station. The reflecting strips on the surfaces may be so designed as to give a non-linear relation between the light intensity and the received current strength.

1,826,836. **Television Scanning Device.** M. STACHO. Oct. 13, 1931. A television scanning system consisting of a pair of rotatably mounted disks having co-acting intersecting slots therein for the passage of light rays. One of the disks has an armature member mounted thereon and associated with an electromagnetic control for retarding the disk at the completion of each revolution in a manner to cause the same to rotate periodically at a reduced speed as compared with the other disk.

1,826,858. **Photographic printing apparatus.** V. K. ZWORYKIN. Assigned to Westinghouse Electric and Manufacturing Co. Oct. 13, 1931. A concentric arrangement of drums for aligning a positive film with a negative film for the printing of positives from the negative. The light source is directed through the drums and through the negative film adjacent to the outside drum to the positive film adjacent to the inner drum. The light source, when a reduction in film size is to be made, is positioned exteriorly of the large wheels over which the negative film is fed, and the light therefrom, passing through the negative film, falls upon the surface of the unexposed film carried over the smaller wheels. If the device is to be used for enlarging, the negative film is fed across the small wheels and the positive film across the large wheels, the light source being so re-positioned that the negative film passes between it and the positive film.

1,826,970. **Television and Telephoto Device.** J. L. WALKER. Oct. 13, 1931. Picture reproducing system in which two separate scanning systems are directed upon opposite sides of a reproducing screen. A photographic plate or viewing screen uses light from two separate light sources and projects light from one light source upon one side and from the other light source upon the other side of said photographic plate or viewing screen and the illumination from the two separate light sources combined at one point. The recording lamps of the two scanning systems are connected in parallel in the output circuit of the receiving apparatus, and each so positioned on opposite sides of the screen as normally to give equal illumination upon the screen.

1,827,010. **Film Flame Stop.** L. D. KOHLMEYER. Oct. 13, 1931. The film is protected by a fire-proof frame structure forming compartments surrounding the film reels. The entrances to each of the compartments are provided with passageways formed between a pair of rollers carried on fixed axes in the passageway. A second pair of rollers is mounted adjacent to each passageway for guiding the film through the passageway and at the same time forming a fire stop in the event of ignition of the film.

1,827,018. **Photoelectric Cell.** A. JOFFE. Assigned to Industrial Research Co. Oct. 13, 1931. A photoelectric cell comprising a sheet-like insulating layer having a thickness not greater than 0.01 mm. having a photoelectrically active substance distributed through the insulating layer and a pair of electrodes supporting the layer, at least one of the electrodes being transparent to light. The invention is based on the discovery that when an ion is initiated or excited within certain substances of requisite thickness, notably dielectrics or other materials of low specific conductivity, and further, when the substance is subjected to considerable electrical stress, the medium through which the ion travels at high velocity gives rise to an augmentation of the number of charged particles. The accumulative action effects a general movement of ions toward one of the electrodes and results in a greatly magnified space current with abrupt reduction of impedance to produce amplification of the impulse originally exciting the single ion. The original impulse may be energy derived from any physical phenomenon such as light, heat, electron bombardment, or other electrical effects.

1,827,206. **Film Support for Photographic Apparatus.** F. H. OWENS. Assigned to Owens Development Corp. Oct. 13, 1931. A support for traveling films, comprising a pair of axially aligned movable members, one of said members being adapted to engage a film and cause the same to travel over the other member. A stationary member is disposed between said movable members and spaced therefrom to permit the passage of light to said film between said stationary and movable members and on each side of said stationary member.

1,827,282. **System of Composite Photography for Motion Pictures.** O.

CHOUINARD. Assigned to Motion Picture Improvements, Inc. Oct. 13, 1931. A machine to produce moving pictures of animated objects and scenic or other effects wherein the scenic or other effects are recorded in positive, direct, and accurate relation to the moving objects, without the heavy cost of "locating." The method comprises making duplicate exposures on two films of moving objects having actinic properties substantially different from those of the background therefor, developing one of said films, projecting images from the respective frames of said developed film successively toward an actinic background, successively altering the actinic effect of said background complementary to and in registration with the respective projected images, and doubly exposing said undeveloped film by subjecting its respective frames to said background as successively altered in actinic effect and without substantial effect thereon of the respective projected images.

1,827,588. **Film Drive.** E. W. KELLOGG. Assigned to General Electric Co. Oct. 13, 1931. An improved film driving apparatus in which the film is driven jointly by a sprocket and a roller or drum and in which the speed of one of said members is varied in accordance with the amount of film moved by the respective members as determined by the number of film sprocket holes. A free running sprocket hole counter is provided engaging that portion of the film moved by the drum and a variable speed driving mechanism for the drum controlled by the relative movement of a drive sprocket and the sprocket hole counter. There are means responsive to a difference in speed of those portions of the film moved by the respective sprocket and drum members, as determined by the sprocket tooth openings and independently of the length of film between said members, for varying the speed of one of said members.

1,827,598. **Motion Picture Cabinet.** A. G. MERRIMAN. Oct. 13, 1931. The projecting apparatus is mounted within a cabinet structure having a portion at one side thereof which may be moved away from the cabinet structure for supporting a projecting screen upon which the picture from the projecting apparatus within the cabinet structure may be displayed. When the apparatus is not in use the screen is foldable into a position within the cabinet structure, making a compact article of furniture for the home or a compact advertising apparatus.

1,827,735. **Volume Control in Sound Record Reproduction.** J. R. BALSLEY. Assigned to Fox Film Corp. Oct. 13, 1931. The film bearing the sound record also carries a volume control record driven in synchronism with the sound record, and adapted to control the volume level of the sound reproduced from the sound record. This volume control record may be simply a varying density photographic record, which may be prepared by reference to the volume level of the sound record as recorded, as may be determined by ordinary reproduction thereof. The volume control record, which may be printed on the same film that carries the pictures and sound record, for instance, outside the sprocket perforations thereof, or on a separate film if more convenient, is operated in conjunction with a light beam and photoelectric cell to produce a varying electrical current which is utilized to control the level of reproduction, and to do this irrespective of the level at which the sound record was recorded. The photoelectric cell which is acted upon by the volume control record is connected across the grid and plate of a vacuum tube, whereby a varying plate current corresponding thereto appears in the plate circuit of the tube with means for modifying the volume level of the reproduced sound in accordance with the variations in said plate current.

1,827,924. **Picture Copying Process.** F. D. WILLIAMS. Oct. 20, 1931. A method of copying pictures which comprises projecting primary component silhouette pictures of ultimate composite pictures upon an opaque picture perceptive screen and light-impressing a sensitized medium with a supplementary component, by aid of the light from said screen with the silhouette projected thereon so as to produce a latent stencil area. The stencil area is then light-impressed with a regular picture corresponding to the silhouette.

1,827,947. **Synchronizing Mechanism for Disk Reproduction.** W. R. MOORE, JR. Assigned to Deca Disk Phonograph Co. Oct. 20, 1931. Mechanical linkage for connecting phonograph and a picture projecting machine for taking up all lost motion between the mechanism for playing the record and that for projecting the pictures so that the music and the pictures shall perfectly synchronize. A worm gear connection is provided with an adjusting device which permits the taking up of lost motion.

1,828,032. **Projection Machine with Optical Intermittent.** R. DECAUX. Assigned to Société des Établissements Gaumont. Oct. 20, 1931. Projector wherein the film moves in a continuous manner along an arcuate guide, past a window lighted by a luminous source which is combined with a condenser. The film occupies the focal plane of an optical system which sends a beam of parallel rays on a mirror which is caused to oscillate about an axis located in its plane. From that mirror, the luminous rays are directed on a stationary mirror disposed at 45 degrees, caused to pass through an objective, from which they are projected on the screen. The oscillating movement of the mirror, which is controlled by a cam, is synchronized with the forward movement of the band in such a way that, between successive extinctions produced by a rotary blade acting as a shutter, the image of a determined point on the film is maintained stationary on the screen. The chief object of the invention is to provide a mechanical arrangement of the parts owing to which the oscillating mirror, the support of said mirror, and the control cam for controlling it are caused to coöperate under the best conditions, account being taken of the inertia of the different pieces and of the play which is liable to take place as a consequence of wear and tear. The mirror is fixed on a platform pivoted to a rocking lever of adjustable position and carrying an arm which receives the oscillations of the cam. The mirror bears at three points on the platform and is maintained in place by springs, in such a way as to eliminate all deformation of the reflecting surface.

1,828,199. **Toy Talking Movie Device.** F. H. OWENS. Oct. 20, 1931. An inexpensive form of toy talking picture apparatus wherein an intermittent picture strip may be moved past a viewing window in timed relation to the movement of a rotatable talking machine record support. The record carries the sound appropriate to the picture and is maintained at proper operating speed by a governor device.

1,828,236. **Method of Producing Visual Effects.** A. C. WATSON. Oct. 20, 1931. A neon lamp illuminating device in which substantially instantaneous intermittent illuminations are formed in different positions along a periodic path in rapid succession through repetitive cycles satisfying the critical frequency for continuous visual sensation. Visual effects of appreciable duration are produced and modified by interposing a mask between the illuminations and the observer. An instance of usefulness of this method consists in the fact that by combining the red color of neon with the yellow color obtained from it as in the "Bezold-Brucke" phenomenon and also with other types of light such as the neon mercury tube and by placing before the rotating light a rotating mask which may itself be colored, so as to reflect daylight, it is possible to secure vari-colored visual patterns. If the mask referred to be rotated at a slightly different speed from that of the light, then the colored patterns undergo a series of changes of form, as well as of color and the total effect may be upon such a large scale as to produce exceedingly attractive and beautiful patterns of various colors.

1,828,364. **Film Contact System Employing Air Pressure.** F. E. GARBUTT. Assigned to Paramount Publix Corp. Oct. 20, 1931. The positive and negative films are pressed into firm contact by an air pressure system in connection with the printer and a current of air directed against the films in such a manner that the films are held in perfect contact against the registering means upon which they are supported.

1,828,399. **Photoelectric Cell Light Ray Condenser.** C. W. EBELING. Assigned to General Talking Pictures Corp. Oct. 20, 1931. A photoelectric cell light ray condenser is provided for condensing the rays of light after the same have passed through the sound track of the film and before the same impinges upon the photoelectric cell, thus insuring higher efficiency in the action from the cell due to the concentration of the beam of light thereon. A condensing lens is carried in the light slit block in the path of the light rays before they reach the photoelectric cell.

1,828,444. **Method of Dubbing and Printing.** W. ROM. Oct. 20, 1931. A printer for applying a sound record to a previously prepared picture film, which consists in utilizing two positive films of the same picture and projecting one positive film on a screen for guidance in applying sound to a negative film made from the other positive film of the same picture, driving said other positive of said film in synchronism with the projected film, masking a portion of said other positive thereby to provide an area for the sound record, driving a negative film in synchronism and printing relation with said other positive and with the sound area of said other positive masked as to said negative, and simultaneously recording sound on the sound area of said new negative, the sound record being applied to the sound area of said negative in accordance with the projected positive of the same picture.

1,828,569. **Film Stopping Apparatus.** E. W. KELLOGG. Assigned to General Electric Co. Oct. 20, 1931. The projector is arranged to stop the film driving machine before the record film is completely unwound and disengaged from the reel on which it has been wound. This is the situation, for example, when in normal operation the film is rewound on the original reel without removal from the machine, the purpose of rewinding being to leave the film ready for immediate use, namely, with the beginning part of the record on the outside.

1,828,571. **Picture Transmission System.** I. LANGMUIR. Assigned to General Electric Co. Oct. 20, 1931. A light source of the flaming arc type is used at the picture receiver. The current supplied to the arc lamp is modulated in accordance with the received signal. The picture at the receiver is projected on a screen. Spots of light from the arc lamp are projected on the screen but light from the electrodes excluded. This is accomplished by a scanning apparatus comprising a disk having a series of lenses arranged in a spiral therein and arranged successively to pass between the lamp and the screen when the disk is rotated with a motor for rotating the disk in synchronism with a sending apparatus. An objective lens is provided and a second disk rotatable with the first-mentioned disk arranged with a series of holes therein corresponding with said lenses for excluding from the objective all light emanating from the electrodes of the lamp.

(Abstracts compiled by John B. Brady, Patent Attorney, Washington, D. C.)

BOOK REVIEWS

Handbook of the Film Industry, Vol. II, European Films (Handbuch der Filmwirtschaft, Band II, Film-Europa). *Wirtschaft und Politik,* Berlin, 1931, 272 pp.

Three volumes of this handbook of film statistics have thus far appeared. The first volume covered the period 1923 to 1925, giving a cross-indexed register of information of film productions, authors, directors, cameramen, architects, and producers. The history and development of the German motion picture producing and exhibiting industry were also traced from 1895 to 1923, together with an outline of the general film situation in Europe.

The second volume gives correspondingly indexed statistics for films produced and passed by the censors during 1926 to 1929 with indexes of authors, *etc.* Statistics also give information as to the size and distribution of theaters in the various countries of Europe, regulations pertaining to the importation of motion picture productions into these countries, the general film market in Europe, division of sales, *etc.* The book will be of greatest use to executives, film sales and distributing organizations doing business with Europe.

A third volume of *Handbuch der Filmwirtschaft,* dealing with the rise of the sound film industry and covering the period 1929 and 1930, is scheduled to appear during 1931.

L. E. Muehler

Sound Film Reproduction. G. F. Jones. *Blackie & Son, Ltd.,* London & Glasgow, 1931.

A brief text in simple, non-technical style explaining, primarily for the small theater manager and projectionist, the principles and details of construction of reproduction equipment for both disk and sound-on-film. The principal outfits available on the British market are described. Sections are devoted to the various parts of the equipment as turntables, pickups, sound heads, light-sensitive cells, amplifiers, *etc.* A section on home-designed installations mentions the chief problems to be met but points out that very little saving can be effected by such assemblies.

H. Parker

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Schlanger, B.: See August, 1931, issue of JOURNAL.

Sheppard, S. E.: Born 1882 at Hither Green, Kent, England. D.Sc., University of London, 1906; colloid chemist, Eastman Kodak Company, 1913–26; chief of department of physical and inorganic chemistry, 1920; acting director of research, 1922–23; assistant director of research, 1924 to date.

Tuttle, C.: Born March 7, 1898, at Evansville, Wis. B.A., University of Wisconsin, 1922; graduate assistant at University of Wisconsin, 1922–23; instructor in physics, University of Georgia, 1923–24; physicist, Kodak Research Laboratories, Eastman Kodak Company, 1924 to date.

Tuttle, W. N.: A.B., Harvard University, 1924; S.M. in electric communication engineering, Harvard University, 1926; Ph.D., Harvard University, 1929; instructor in physics, Harvard University, 1929–30; engineer, General Radio Company, 1930 to date.

SOCIETY ANNOUNCEMENTS

SPRING, 1932, MEETING

By action of the Board of Governors at a meeting held on December 10th at New York, N. Y., and subsequent verification of this action by the post-card ballot mailed to the membership for determining the location of the Spring, 1932, Meeting, the location of the latter was determined as Washington, D. C.

The meeting is to be held from May 9th to 12th, inclusive, with headquarters at the Wardman Park Hotel, in Washington. The technical meetings will be held in the Little Theater of the Hotel and the semi-annual banquet in the Gold Room. The Convention Arrangements Committee, under the chairmanship of Mr. W. C. Kunzmann, is working on an attractive and interesting program for the Convention, and the Papers Committee, headed by Mr. O. M. Glunt, is bending every effort toward making the technical sessions of outstanding interest.

Mr. N. D. Golden, of Washington, has been appointed Chairman of the Local Arrangements Committee, and in this capacity is assisted by Messrs. C. Francis Jenkins, Raymond Evans, C. N. Nichols, N. Glasser, C. J. North, and N. C. Haefele. As the Convention is to be held at the time of the Washington Bi-Centennial, there will be much in Washington to attract the members of the Society to the Convention, in addition to the technical activities of the Society.

An exhibit will be held of newly developed motion picture apparatus, similar to the exhibits held at the Hollywood and Swampscott Conventions. This exhibit is to be under the direction of Mr. H. Griffin. As in the past, it will not be of the nature of a trade exhibit nor will there be booths, but adequate space will be allotted each exhibitor free of charge. The exhibition rules specify that equipment be new or have been improved within the past twelve months. No pamphlets or advertising literature will be permitted. Each exhibitor will be allowed to display a small card giving the name of the manufacturing concern, and each piece of equipment will be labelled with a plain label free of the name of the manufacturer. It is required that a technical expert be present during the exhibition to explain the technical features of the apparatus.

Requests for space should be made to Mr. Sylvan Harris, editor-manager of the Society, room 701, 33 W. 42nd Street, New York, N. Y., stating the number and nature of the items to be exhibited.

STANDARDS COMMITTEE

At a meeting of the Standards and Nomenclature Committee, held at the General Office of the Society on January 9th, Mr. A. C. Hardy was appointed chairman of the sub-committee on the glossary. Questions on the standardization of camera motors, apertures, camera mountings, and adapters were discussed, and general ideas concerning the disposition of these matters were outlined. The proposal made by the Projection Practice Committee, calling for the dimensions 0.590×0.825 inch for the projector aperture, was approved by the Committee.

The question of standardization of screen brightness was given considerable study, and it was finally agreed that the Projection Practice Committee, in collaboration with the Projection Screens Committee, should study the problem and recommend to the Standards Committee, the values of brightness which will indicate the limits between which a picture may be considered reasonably satisfactory under existing practical conditions. These values would not be susceptible of standardization, but would merely represent recommended good practice.

Mr. L. A. Jones was appointed chairman of a new sub-committee on sensitometry, and Mr. J. L. Spence was appointed chairman of the sub-committee to deal with matters relating to the standardization of 16-mm. sound-on-film equipment. Considerable thought was given to the dimensions of the 16-mm. sound film and the location of the sound track, *etc.*, and plans were made for enlisting the assistance of the manufacturers in making the study, which requires a practical knowledge of possible tolerances and practical circumstances of manufacture.

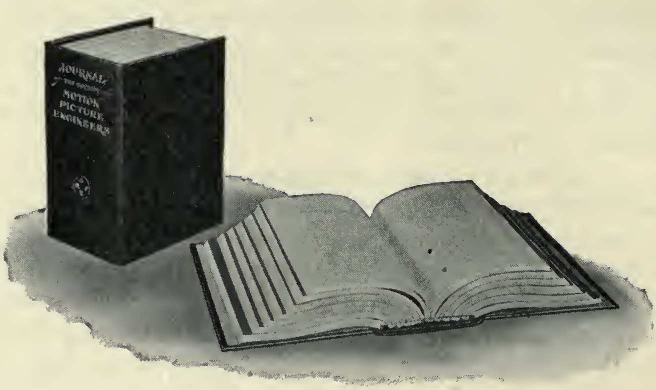
In connection with the questions raised by the Ciné-Standards Committee of the International Congress of Photography, recently held in Dresden, Germany, it was decided that the matter of specifications of safety film is to be reopened at a later meeting of the Committee.

WAYS AND MEANS COMMITTEE

At a meeting of the Ways and Means Committee, held at New York on January 9th, under the chairmanship of Mr. D. McNicol, many of the factors involved in readjusting the rates of subscription for the JOURNAL, the entrance fees of new members, and dues were discussed, and recommendations concerning the reduction of the entrance fees and subscription rates were agreed upon for presentation to the Board of Governors.

JOURNAL BINDERS

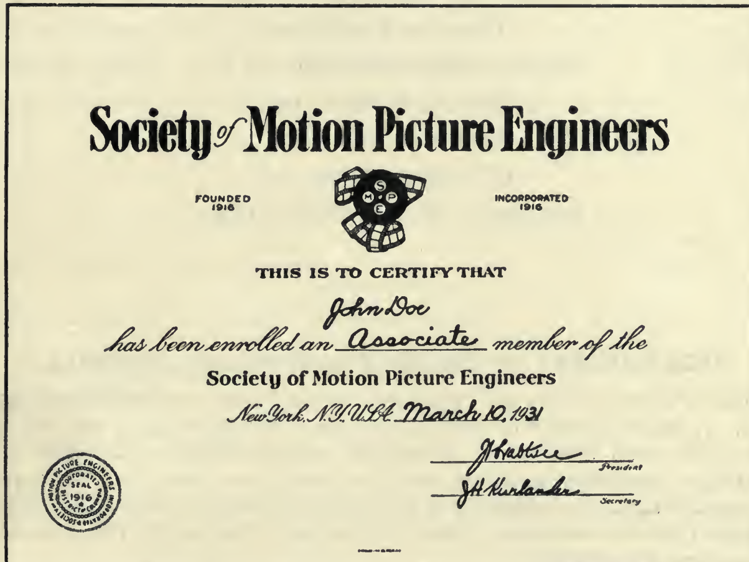
The binder shown in the accompanying illustration serves as a temporary transfer binder or as a permanent cover for a complete year's supply of JOURNALS. It is made of black crush fabrikoid, with lettering in gold. The binder is so constructed that each individual copy of the JOURNAL will lie flat as its pages are turned. The separate copies are held rigidly in place but may be removed or replaced at will in a few seconds.



These binders may be obtained by sending your order to the General Office of the Society, 33 West 42nd Street, New York, N. Y., accompanied by a remittance of two dollars. Your name and the volume number of the JOURNAL may be lettered in gold on embossed bars provided for the purpose at a charge of fifty cents each.

MEMBERSHIP CERTIFICATE

Associate members of the Society may obtain the membership certificate illustrated below by forwarding a request for the same to the General Office of the Society at 33 W. 42nd St., New York, N. Y., accompanied by a remittance of one dollar.


Society of Motion Picture Engineers

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John Doe

has been enrolled an Associate member of the

Society of Motion Picture Engineers

New York, N.Y. U.S.A. March 10, 1931

J Crabtree, President

J H Kurlander, Secretary

LAPEL BUTTONS

There is mailed to each newly elected member, upon his first payment of dues, a gold membership button which only members of the Society are entitled to wear. This button is shown twice actual diameter in the illustration. The letters are of gold on a white background. Replacements of this button may be obtained from the General Office of the Society at a charge of one dollar.

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National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted. The cost of all the available *Transactions* totals $46.25.

Year	No.	Price	Year	No.	Price	Year	No.	Price
1917	3	$0.25	1924	18	$2.00	1927	29	$1.25
	4	0.25		19	1.25		30	1.25
1918	7	0.25		20	1.25		31	1.25
1920	10	1.00	1925	21	1.25		32	1.25
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1922	14	1.00	1926	25	1.25		36	2.50
	15	1.00		26	1.25	1929	37	3.00
1923	16	2.00		27	1.25		38	3.00
	17	2.00		28	1.25			

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JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII **MARCH, 1932** **Number 3**

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JOURNAL
OF THE SOCIETY OF
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Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

TWO SPECIAL SENSITOMETERS*

D. R. WHITE**

Summary.—*Design features of two sensitometers are presented. One of the sensitometers is used to make sensitometric tests on positive film under printing conditions. The other is designed to produce exposures under sound recording conditions. The results of tests with both of these sensitometers emphasize the importance of making sensitometric tests parallel conditions of film use, and show some of the errors that occur in judging speed and contrast from sensitometric data obtained under conditions not corresponding to the actual conditions of use.*

Sensitometric workers have found it desirable to test film under the conditions of its use. The time scale sensitometers frequently used are not representative of printing conditions where the positive is always exposed through a negative, nor are they ordinarily arranged to correspond to the conditions of sound recording where the light comes to the film through an optical system and has higher intensity and shorter exposure time than is readily obtained with the usual form of sector wheel. The two sensitometers herein described were designed, therefore, to obtain accurate sensitometric information under actual conditions of printing and sound recording.

H & D PRINTER

This machine makes use of a negative, for instance, an exposed and developed H & D sensitometric strip, to produce a series of graded exposures for testing a positive material. In this test, then, the exposure is a photographic printing operation such that the results may be plotted as a characteristic curve for the material tested. Provision is also made in this machine for comparison with pictures exposed and developed under similar conditions.

A schematic view of the mechanism of the machine is shown in Fig. 1. The exposure timing shutter is driven by a synchronous motor through a pinion on the motor shaft which meshes with a large ring gear mounted directly on the rim of the shutter disk. Two

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* Presented in the Symposium on Laboratory Practices at the Spring, 1931, Meeting at Hollywood, Calif.

** Du Pont Film Manufacturing Co., Parlin, N. J.

sectors are cut from this disk, one having radial sides, 30 degrees apart, and the other having one straight side and one side stepped as shown, such that each step has ten per cent greater angular opening than the preceding, these angles being so adjusted that the center step of the series has a 30-degree opening. Geared to this exposing shutter through a countershaft, with a total reduction of 4 to 1, is an auxiliary shutter which has only one sector cut from it. Two light houses and lights, two exposing gates, and two hand shutters are provided, forming two independent exposing systems in which the exposure time is controlled by the one motor and shutter disk mechanism. The hand shutters in each system are not intended to control

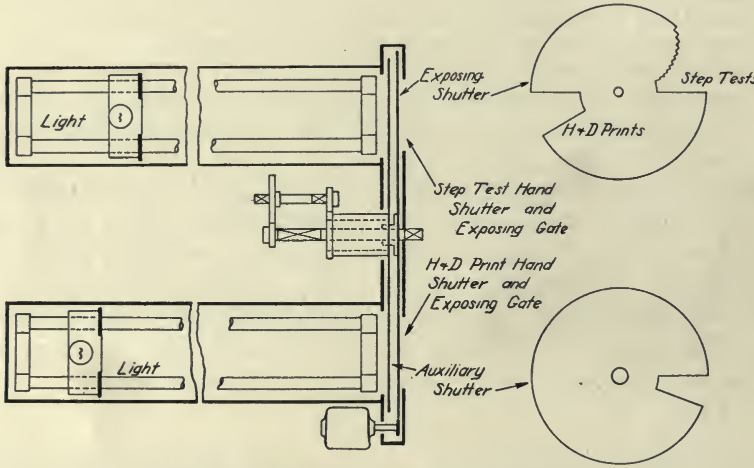

FIG. 1. Schematic view of H & D printer.

the exposure time at all but are used to prevent undesired double exposures. The positions of the lights are adjustable by moving the entire lamp support along rails provided in the light house. This motion allows a satisfactory inverse square law intensity variation of 8 to 1 in the machine as constructed. The lamp supports can be removed from the housings intact, and placed on a bar photometer for color temperature and intensity measurements.

This entire mechanism operates in such a manner that only exposures from the 30-degree exposing shutter opening for sensitometric tests are produced at one gate, and only exposures from the stepped sector for picture printing are produced at the other. With the motor speed and gear ratio used, the 30-degree shutter openings give exposures of one-eighteenth of a second, which is representative of printing exposures.

A photograph of the machine is shown in Fig. 2. The two exposing gates are visible in the foreground. The light houses are about five feet long and extend to the rear from the compartment which houses the shutter disks. The countershaft and gears are also back of this shutter compartment and between the two light houses. One of the hand shutters and the signal light used as a guide in its operation appear on the side of the machine.

FIG. 2. Photograph of H & D printer showing the two exposing gates.

The lamp support, removed from its housing and viewed from the rear, is shown in Fig. 3. With the adjustments provided, the lamp chosen for use may be centered, rotated on its own axis, or about an axis perpendicular thereto. These motions enable the selection of the lamp position which gives the best uniformity of intensity over the printing area of each exposing system.

These design features were adopted to permit making sensitometric tests and picture tests under similar carefully controlled conditions. The sensitometric tests are made by exposures through a negative, and are so arranged that curves showing both negative and positive characteristics, as they are effective in the printing operation, are obtained as a result. It is not necessary to know either the positive or negative characteristic from other tests, for both are obtained from these exposures and may be compared with the photographic characteristics of the materials as shown by other methods of testing.

The negative used in this H & D print operation may conveniently be in the form of an exposed and developed sensitometric strip. Those used in the tests here discussed were the result of time scale

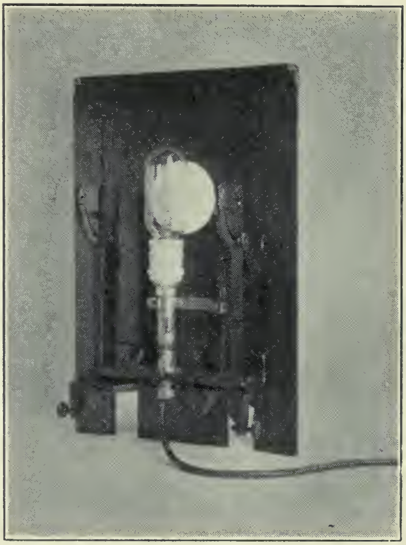

FIG. 3. Lamp support used in H & D printer.

sector wheel exposures, with exposure times increasing by factor two from area to area of the negative.

Consider, now, two exposures made through such a negative on this machine, in which the intensity of light incident on the negative is twice as great for the second exposure as for the first. The strips thus exposed are developed together and the resulting densities, read photometrically, are plotted against the log E values for the original negative exposure. Curves drawn through these points are shown in Fig. 4, where the curves labeled L and H represent the first and second exposures, respectively. Such curves, called reproduction curves, represent the relation between the density of the positive and the log E value for the negative. Theoretically perfect tone reproduction would require these to be straight lines with slope minus one. Practically, this condition is neither attained nor desired, since more pleasing and satisfactory pictures are produced otherwise. However, this point of tone reproduction, theory and practice, is outside the scope of the present paper and is only mentioned, since these

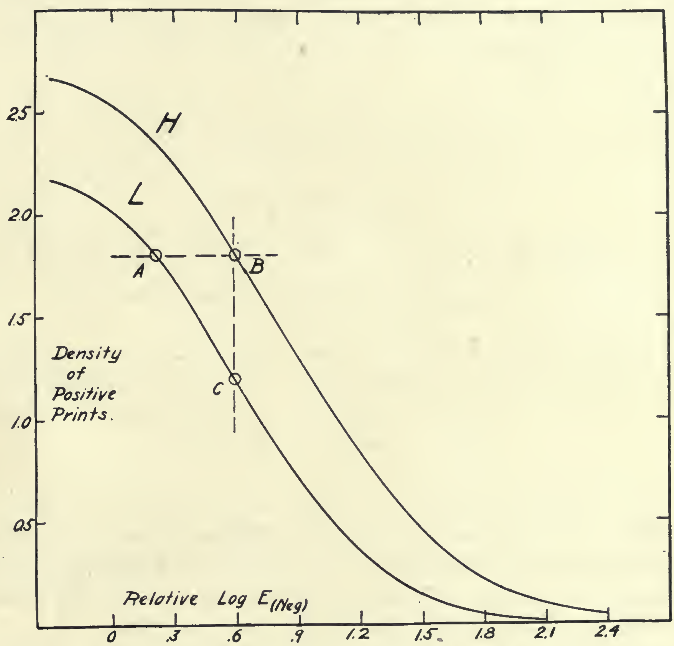

FIG. 4. Two reproduction curves. Points A and B have received equal exposure. Point C has received one-half the exposure of B.

reproduction curves are the first and most direct result of the operation of this H & D printer.

The two exposures represented by L and H had equal exposure times, hence it follows that any two points of equal density on the two curves, such as points A and B of the figure, received effectively equal intensities during the printing exposure. However, these equal printing intensities were produced under different conditions. For point A the effective printing intensity I_A is given by

$$I_A = I_L \times T_A$$

where I_L is the intensity incident on the negative during the exposure represented by curve L, and T_A is the transmission of the negative at a point corresponding to A. Similarly, for the point B, the effective printing intensity I_B is given by

$$I_B = I_H \times T_B$$

where I_H is the intensity incident on the negative during the second exposure, and T_B is the transmission of the negative at the point corresponding to B. Since, as has already been pointed out for these points A and B,

$$I_A = I_B$$

Therefore

$$I_L \times T_A = I_H \times T_B$$

or

$$\frac{I_H}{I_L} = \frac{T_A}{T_B} = 2$$

as

$$\frac{I_H}{I_L} \text{ was originally made } 2$$

But the difference in the effective printing densities of the negative between B and A, ΔD_{BA} is given by

$$\Delta D_{BA} = \log \frac{T_A}{T_B} = \log 2 = 0.3$$

It is also apparent from the method of exposure and plotting used for these two curves that any two points such as B and C of the figure, occurring at the same value on the $\log E$ scale, have densities produced by exposure intensities differing by factor two. This may be shown by the fact that, using notation similar to that above,

$$I_B = I_H \times T_B$$

$$I_C = I_L \times T_B$$

or

$$\frac{I_B}{I_C} = \frac{I_H}{I_L} = 2$$

T_B occurs in both of the first two equations since it is the same point in the negative that is effective for both points B and C.

Using these facts in the manner shown in Fig. 5, a series of points having the coördinates (D_0, $\log E_0$), (D_1, $\log E_1$), (D_2, $\log E_2$), . . . (D_n, $\log E_n$) may be found, in which the series of D's, D_0 to D_n, are the densities produced on the positive by printing exposures decreasing by factor two in intensity from density to density. These density values may be plotted, then, at uniform spaces, log ($E_{\text{pos.}}$)

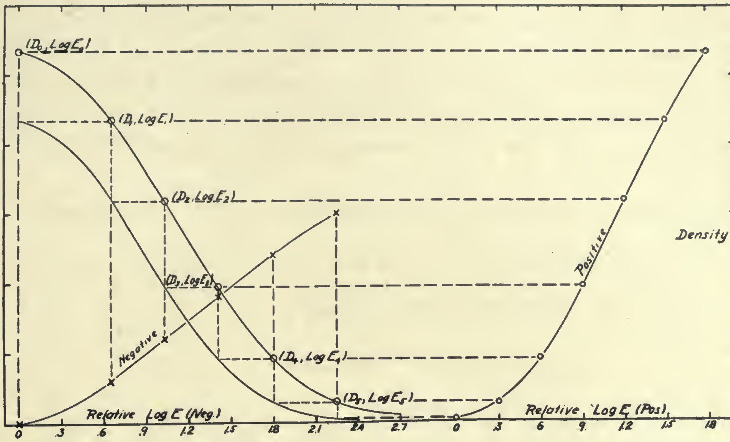

FIG. 5. Reproduction curves, and positive and negative characteristic curves resulting therefrom.

differences of 0.3, to produce a positive characteristic curve representing actual printing conditions. This is shown as the curve marked

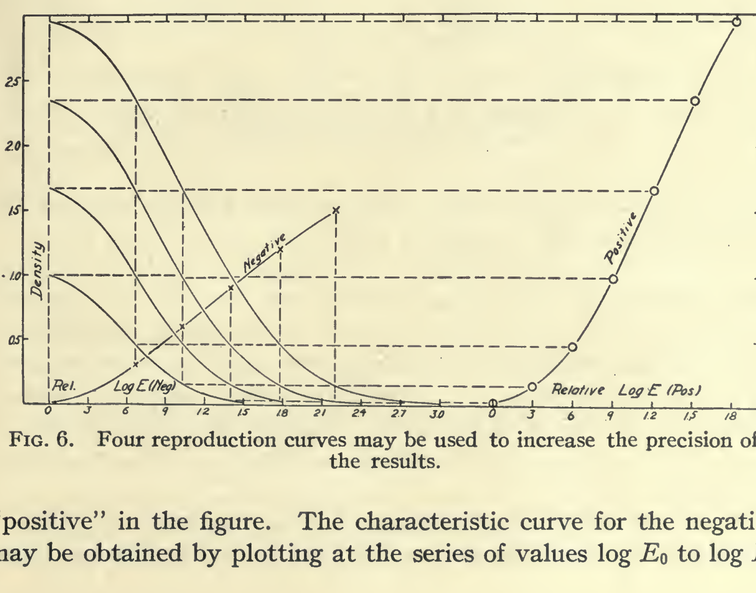

FIG. 6. Four reproduction curves may be used to increase the precision of the results.

"positive" in the figure. The characteristic curve for the negative may be obtained by plotting at the series of values log E_0 to log E_n

on the log ($E_{neg.}$) scale, density values increasing by uniform steps of 0.3 from one log E value to the next, as shown in the curve marked "negative" in the figure. The effective printing density for any other log E value can be determined by interpolation from this curve.

To improve the precision of these data, it has been more satisfactory to use four reproduction curves, as shown in Fig. 6, in determining these characteristics. The results so obtained are less liable to error, since with the greater amount of data no single point is as important.

The negative and positive characteristic curves corresponding to

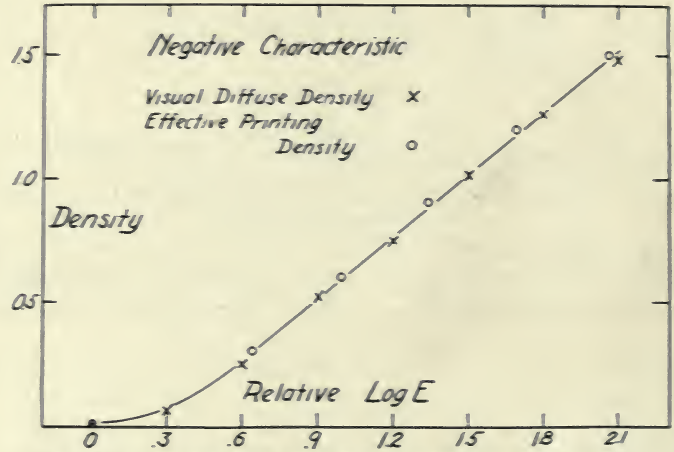

FIG. 7. Comparison of negative characteristics as obtained visually and by H & D printer.

printing conditions have thus been determined without recourse to photometric readings of negative densities as intermediate data.

The effective printing densities of the negatives tested to date have always been very close to their diffuse light densities as read on a photometer. Fig. 7 shows the characteristic curve of a negative as determined by diffuse density photometric readings and as obtained by this printing method. In both cases the fog reading is effectively subtracted by the methods used. No large density difference is shown here for this negative, which was developed in a metol-borax developer.

The sensitometric characteristics of certain positive emulsions as determined by the procedure just outlined have been found to be different from those shown by tests with the more common form of sensitometer, the time scale sector wheel. No general conversion

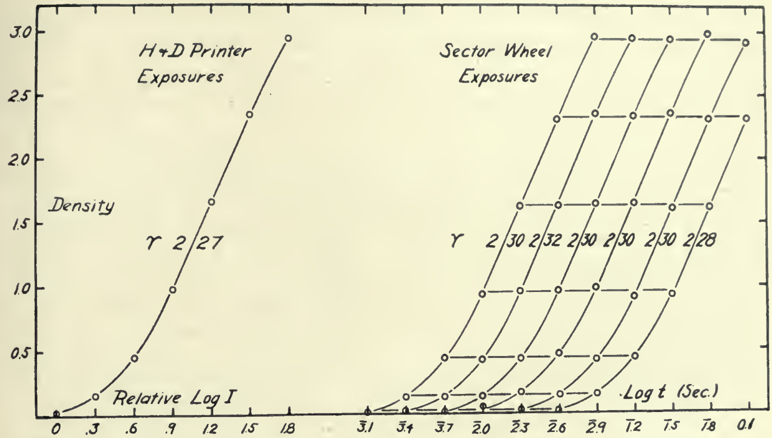

FIG. 8. Curves showing sensitometric characteristics of a positive emulsion as determined under different conditions of exposure. This emulsion obeys the reciprocity law within the range of the test.

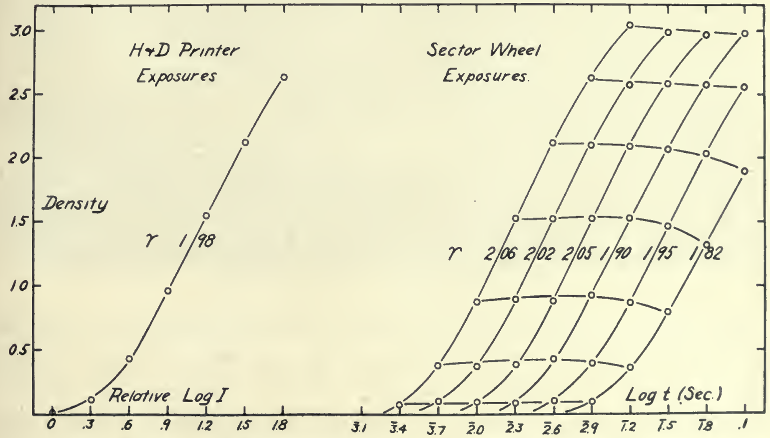

FIG. 9. Curves showing sensitometric characteristics of a positive emulsion as determined under different conditions of exposure. This emulsion shows reciprocity law failure.

factor from one type of exposure to another is possible, since not all emulsions show the same variation in characteristic.

Fig. 8 shows the characteristics of one positive emulsion as shown by a group of tests. The six curves under the heading "sector wheel exposures" show time scale characteristic curves determined at six exposure intensity levels, increasing right to left by factor two from curve to curve in the group. The printing characteristic is shown by itself, as determined by the H & D printer. No failure of the reciprocity law is observed in the range covered by these data. The contrast of the material appears independent of the exposure, and therefore only dependent on the development which the film received.

However, this condition of constancy of contrast does not hold for the positive emulsion represented by Fig. 9. This emulsion was prepared under different conditions from the first. Here, there is a noticeable reciprocity law failure even within the range of time intensity variations shown in the sector wheel tests. Gamma depends on both the time and intensity used in its determination. The contrast values shown by the sector wheel curves made with the higher

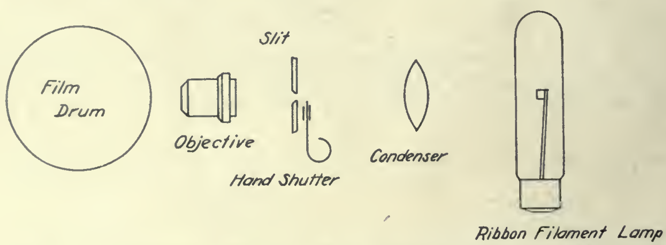

FIG. 10. Schematic diagram of the optical system of the high intensity sensitometer.

exposure levels become closely equal to that shown by the H & D printer, but differ appreciably from the values obtained at lower intensities.

HIGH INTENSITY SENSITOMETER

The second of the two special machines here discussed was designed to test film under conditions corresponding to those of sound recording.

The optical system of this machine is shown schematically in Fig. 10. A filament image from a ribbon filament light is formed at the slit by a condenser lens. The slit in turn is imaged on the photographic film carried on the film drum by a microscope objective. A series of fixed slits of various widths is provided to obtain the exposure range desired. This construction was used in preference to any form of calibrated light valve as its constancy from time to time is assured without difficulty. This group of slits is mounted on a circular plate driven from the film drum shaft through an intermittent motion and gearing. The final accurate positioning of the slits in the correct position in the optical system is assured during operation of the machine by a wedge fitting a V-groove in the rim of the slit carrying plate. The wedge is disengaged by a cam when the intermittent motion is about to operate and is re-engaged before exposure. The

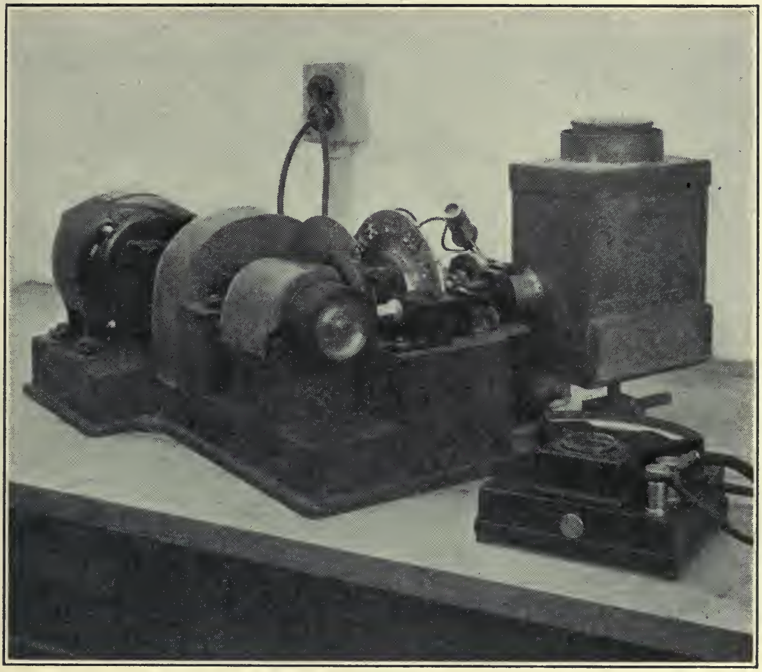

FIG. 11. Photograph of the high intensity sensitometer showing the film drum, slit carrying plate, and optical system.

mechanism is adjusted to make a complete series of eleven exposures on a single turn of film fastened to the film drum. The hand shutter placed in the optical system is used to prevent double exposure and to permit the machine to come up to speed, 90 feet per minute of the film, before any exposures are made.

Fig. 11 presents a view of the machine showing particularly the film drum, slit plate, and the optical system. The disk with the small sector cut from it is an auxiliary shutter which limits the exposures to the desired portions of the film being exposed and which cuts off the exposure during the motion of the slit carrying plate.

Fig. 12 is taken from a different viewpoint and shows more clearly the intermittent motion and slit positioning mechanism.

In making the machine, difficulty was anticipated and experienced in making the slits to exact spacings. Rather than spend too great an amount of time on an unnecessary detail, the slits were set at approximately the values desired and then finally calibrated in place

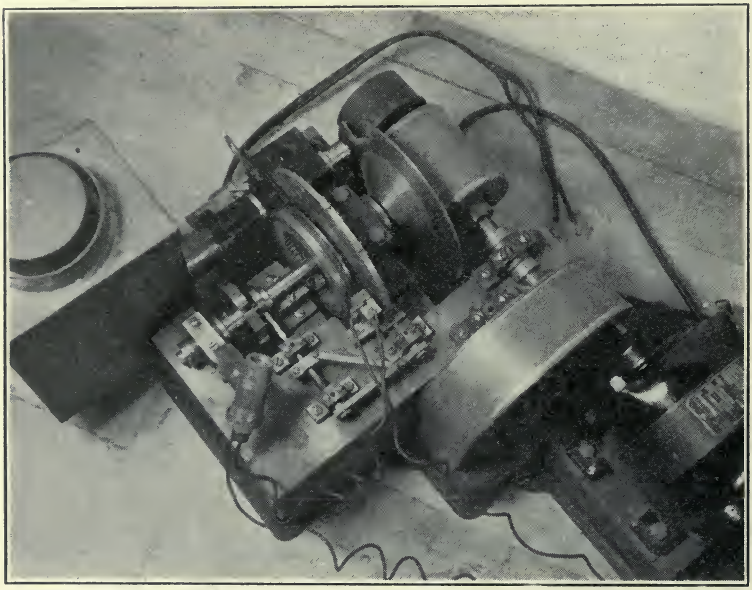

FIG. 12. A view of the high intensity sensitometer showing some of the mechanism.

by measuring their light transmission with a photoelectric cell. These slits vary from approximately 0.00025 to 0.008 inch. With eleven slits the average step is about factor $\sqrt{2}$, but the steps are not entirely uniform.

A comparison of the results of tests with this machine and with a time scale sector wheel with much lower intensity and longer exposures is shown in Table I. In this comparison the development was carried to a point representing variable density recording conditions. Compared emulsion by emulsion, the gammas produced by the two methods of exposure are not widely different, though with two emulsions the sector wheel gamma is higher. In the relative emulsion speeds, as determined by each experimental method, larger differences are found. In the table, emulsion A is arbitrarily taken as having a speed of unity in both tests, and the others are evaluated in comparison with it.

TABLE I

Relative Speed and Contrast Values as Obtained by Exposures with a Sector Wheel and with the High Intensity Sensitometer

Emulsion	Type	Developed	Gamma H.I.	Gamma S.W.	Relative Speed H.I.	Relative Speed S.W.
A	Positive	$2^1/_2$ min.	0.50	0.49	1.0	1.0
B	Positive	$2^1/_2$ min.	0.55	0.64	1.7	1.3
C	Positive	$2^1/_2$ min.	0.53	0.51	1.1	1.0
D	Fast pos.	$2^1/_2$ min.	0.58	0.66	2.6	2.2
E	Sp. recording	3 min.	0.49	0.50	3.0	2.2
F	Sp. recording	3 min.	0.52	0.54	3.5	2.7

In obtaining these data, individual development characteristics were ignored, but a difference was introduced to compensate for the lower gamma infinity of two of the special sound recording emulsions. The residual variations in gamma prevent an accurate statement of the relative emulsion speeds, but the possible errors due to this cause are much less than the differences found. Thus, it is evident that tests made under the one set of conditions furnish no sure guide to emulsion characteristics effective under the other set of conditions. The results of all these tests on both types of sensitometers emphasize again the necessity for care in selecting test conditions in photographic work. The two machines described have worked out quite satisfactorily, each meeting the special needs in its own field.

ERRATUM

The following corrections should be made in the paper, *A Method of Measuring Directly the Distortion in Audio Frequency Amplifier Systems*, by W. N. Tuttle, beginning on page 199 of the February, 1932, issue of the JOURNAL:

A square root sign should be placed over the entire numerator of the right-hand member of the equation on page 200. On page 205, line 2, the symbols "2-*C*" should read "a-c."

THE DECIBEL IN THE MOTION PICTURE INDUSTRY*

V. C. HALL**

Summary.—*The development of the term "decibel" is outlined, and its convenience in measuring the characteristics of electrical circuits discussed. The relation of the decibel to photographic density is pointed out and illustrated by calculations of the effect of ground noise reduction devices. Finally, the values of acoustic power of common sources of sound are given as the levels in decibels based on various reference points in use in the motion picture industry.*

The use of the term "decibel" has increased rapidly since its introduction into the motion picture industry because it is a convenient method of handling quantities which might otherwise lead to cumbersome expressions. Many publications have been written concerning the decibel and its historical development and its application to the problems under consideration. These papers have been freely drawn from for examples and data for this summary. No new material is presented but it is hoped that a review of some of the ways in which the decibel enters into sound motion pictures may prove of value to those who are not familiar with this unit.

Development of the Term.—The decibel (db.) is the name which was chosen for the transmission unit (TU), in terms of which a great deal of telephone and talking motion picture apparatus is calibrated. Their values are identical, and the name itself was suggested several years before its final adoption. Units of similar type had been universal in telegraphy and telephony for many years, and came into being from the fact that an electric current representing a certain amount of power loses a certain fraction of that power for every mile, let us say, of transmission line over which it travels. The unit of electric power, representing the rate of doing electric work, is the familiar *watt*, in terms of which most electrical equipment is specified. If, then, a power of ten watts is started out over a telegraph line, it would drop to 0.9 of this in perhaps two miles. This nine watts would drop to 0.9 of 9, or 0.81,

* Presented at the Spring, 1931, Meeting at Hollywood, Calif.

** Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

in the next two miles, and so on, the power decreasing the same fraction every two miles, independently of the actual amount of power starting over this particular section of line. The multiplying together of these factors was laborious, so the practice grew up of expressing a loss of power in terms of the number of miles of telephone line which would decrease the power by the same amount. Thus, if the power dropped to 0.81 in one section of a circuit, and to 0.73 in another, the total loss could be found by multiplying 0.81 by 0.73, which equals 0.591. It is much simpler, however, to say that the first section has a loss of two miles and the second a loss of three miles, and that the two together have a loss of two plus three or five miles. The substitution of addition of numbers for the multiplication of corresponding numbers is a property of logarithms, and a system which allows this to be done is called a logarithmic system. Thus the use of the "mile of standard cable" constituted a logarithmic system, standards for which were set up by those doing telephone work. It was natural that the properties of cables should change as improvements were made so that eventually the old standard became inconvenient. Also, amplifiers were developed in which the output power was more than the input power so that the circuit had a "gain" instead of a "loss." These developments led to the adoption of a simpler unit, based only on the relation between the power output of the circuit and the power input. The expression used was

$$\text{Number of telephone transmission units} = \text{logarithm}\left(\frac{\text{watts output}}{\text{watts input}}\right)$$

The values obtained from the above are positive when the output is greater than the input, and negative when the output is less than the input, indicating a loss. This unit as defined above happened to be a rather large one considering the ratios of power encountered so that the unit actually adopted was arbitrarily chosen to be 0.1 of this. Accordingly, in practice the equation becomes

$$\text{Number of transmission units or TU's} = 10 \times \text{logarithm}\left(\frac{\text{watts output}}{\text{watts input}}\right)$$

The fundamental unit was named the "bel," after Alexander Graham Bell, with the spelling simplified to avoid confusion. Since the name is for the larger unit, the prefix "deci" was affixed to the name to indicate its derivation, and now we have:

Number of transmission units or TU's = number of decibels or number of db. $= 10 \times \text{logarithm} \left(\frac{\text{watts output}}{\text{watts input}}\right)$

Method of Calculation.—In order to get some idea of the magnitude of the decibel, the following short table is presented, giving a list of power ratios from 1 to 10, with the corresponding number of decibels. These are found simply by looking up the logarithm of the ratio in a table of common logarithms, or on a slide rule, and multiplying by 10.

TABLE I

Power Ratio	Decibels	Power Ratio	Decibels
1	0.0	1.0	−0.0
2	3.0	0.5	−3.0
3	4.8	0.33	−4.8
4	6.0	0.25	−6.0
5	7.0	0.20	−7.0
6	7.8	0.17	−7.8
7	8.4	0.14	−8.4
8	9.0	0.125	−9.0
9	9.6	0.111	−9.6
10	10.0	0.100	−10.0

In the first two columns of Table I the output power is assumed to be greater than that at the input or, in other words, an amplification instead of a loss is assumed. When this is true, the output is said to be so many decibels *above* the input. When a loss occurs, as in the last two columns, the input is of course above the output, and the output is said to be *down* so many decibels. It will be noted that the power ratios in the second case are the reciprocals of the corresponding ratios in the first case, while the number of decibels is the same, with a minus sign. This means, for example, that

$$10 \times \log \frac{5}{1} = -10 \times \log \frac{1}{5}$$

which in turn follows from the general principle in logarithms that the logarithm of a number is equal to minus the logarithm of its reciprocal, which is another way of saying, minus the logarithm of one divided by the number.

If the amplifications of a group of separate amplifying units are, respectively, 3, 7, 10, and 4, the total amplification, if they are connected in series, can be found by multiplying these numbers together. This gives $3 \times 7 \times 10 \times 4 = 840$ times. If the amplifications are expressed in decibels, however, this becomes simply

$4.8 + 8.4 + 10 + 6.0 = 28.2$ decibels. In this case the result is about as simple to calculate in one way as the other. If instead of referring to amplifications, however, the numbers referred to losses, and the power were reduced to 0.33, 0.14, 0.1, and 0.25 of the original value, respectively, the multiplication of factors would be more difficult. Looking up the corresponding decibels in the second part of Table I gives -4.8, -8.4, -10, and -6.0, respectively, and the sum of these equals -28.2 decibels, which is the total power loss of the group. In practice it is rare to find the even power ratios, while the decibel equivalents are usually expressed to sufficient accuracy by two or, at the most, three figures, the addition of which is obviously more quickly done than the corresponding multiplication, while the chance of error is also greatly reduced.

From Table I other values of either decibels or power ratios can easily be found. For instance, 26 decibels is made up of $10 + 10 + 6$, corresponding to power ratios of 10, 10, and 4, respectively, and the product of these, 400, is the power ratio corresponding to 26 decibels. Similarly, a power ratio of 75 can be divided into its factors $3 \times 5 \times 5$, and we have $4.8 + 7.0 + 7.0 = 18.8$ decibels, which corresponds to a power ratio of 75.

The decibel is a convenient unit as the ear can just recognize a change in the volume of sound corresponding to an attenuation or gain of one decibel, equivalent to about 12 per cent. For this reason, volume controls and faders calibrated in decibels give a very uniform increase in the volume as the ear recognizes the changes as equal steps. Although the ear can detect a change of one decibel, most volume controls are set to change the volume by about 3 db., as this step is not so great that a change of one step will raise the volume from too low to too high, and the reduction of the number of steps simplifies the apparatus. For the control of volume in sound recording where a smooth stepless change is wanted, a potentiometer or volume control similar to that on a radio receiver is used, and the scale is graduated in decibels for certain intervals on the dial.

Methods of Measurement.—So far there has been no mention of the method by which the measurements are made. In the electric circuits used in talking motion pictures it is usually too difficult to measure the power, in watts, directly, since the frequency of the alternating currents which must be measured varies all the way from 30 to 10,000 cycles per second, and the power levels are of the order of thousandths of watts. Both of these factors tend to make the use of wattmeters impracticable, so most results are obtained by measuring either the *current* through a known resistance, or the *voltage* across a known resistance. If it is necessary to know the power it may be found from the following relations which exist between the various electric quantities.

Power (watts) = current × voltage (amperes × volts)
Voltage (volts) = current (amperes) × impedance (ohms)

From these two are derived:

$$\text{Power (watts)} = (\text{current})^2 \times \text{impedance}$$
$$= (\text{voltage})^2/\text{impedance}$$

In order further to simplify the circuits electrically, most sound motion picture apparatus, and a great deal of telephone equipment, is designed so that the impedances in both the input and output are equal, the actual value usually being approximately 500 ohms. This is true of amplifiers, filters, equalizers, volume controls, *etc.*, and further simplifies the calculation of losses or gains in the various units as follows: If we substitute for the power input and output in the formula for the decibel the expression for the power in terms of the current and resistance, it becomes:

$$\text{Number of db.} = 10 \times \log \frac{(\text{current output})^2 \times \text{impedance}}{(\text{current input})^2 \times \text{impedance}}$$

and the resistance cancels out, leaving the formula

$$\text{Number of db.} = 10 \times \log \frac{(\text{current output})^2}{(\text{current input})^2} = 10 \times \log \frac{(I_1)^2}{(I_2)^2}$$

letting I_2 stand for the current input, and I_1 for the current output. From the principle that the logarithm of the square of a number is equal to twice the log of the number it is possible to write, instead of the relationship above,

$$\text{Number of decibels} = 10 \times 2 \times \log \frac{(I_1)}{(I_2)} = 20 \log \frac{(I_1)}{(I_2)}$$

It is important to note that while the power is independent of the impedance, the above formula is true only when the impedances through which the currents I_1 and I_2 are flowing are equal. If it is more convenient to measure the voltage across a known impedance than the current through it, as is often the case, we can write, again assuming that the impedances are equal in the two places the measurements are made,

$$\text{Number of db.} = 10 \log \frac{(\text{voltage output})^2/\text{impedance}}{(\text{voltage input})^2/\text{impedance}}$$

The impedance cancels out as before, and the expression becomes

$$\text{Number of db.} = 10 \log \frac{(V_1)^2}{(V_2)^2} = 20 \log \frac{(V_1)}{(V_2)}$$

which is exactly the same as if the current output and input were measured. The most usual methods of measuring electric currents of audio frequency as found in sound motion picture work are by the hot wire ammeter and the vacuum thermojunction. The thermojunction is the more accurate, and in it the current heats a length of resistance wire in a vacuum, while near the center of the wire is fastened a junction of two wires of different composition. When this junction is heated a voltage is developed which depends on the nature of the two metals and the temperature to which it is heated. A meter connected across the other ends of the two wires will deflect in accordance with the current variations, and if calibrated in terms of a standard meter can be used to measure the current accurately. The volume indicator, which is essentially of the vacuum tube voltmeter type, although it may draw a small current, due to its ruggedness is the most popular of audio frequency measuring instruments. In this the voltage across a resistance changes the grid voltage on a vacuum tube which is so connected that the change causes a variation in the steady plate current of the tube. A milliammeter in the plate circuit then reads in accordance with the changes in voltage across the resistance. Most volume indicators are built on this principle although, since the entire scale of the meter corresponds to a relatively small number

TABLE II

Power Ratio	Voltage or Current Ratio	Decibels
1	1.0	0.0
2	1.4	3.0
3	1.7	4.8
4	2.0	6.0
5	2.2	7.0
6	2.45	7.8
7	2.64	8.4
8	2.83	9.0
9	3.00	9.6
10	3.16	10.0
20	4.47	13.0
40	6.33	16.0
100	10.0	20.0

of db., most of them have a resistance device connected so that the readings may be cut down by fixed amounts, say, 2 db. per step. By using this device the needle of the meter can be kept at one position on the scale as the voltage varies, and the db. change noted by the change in the setting of the control mechanism.

In Table II are shown the power ratios, voltage or current ratios, and the decibel changes which correspond to them. Thus, if the measured current ratios between output and input of three amplifiers are 2.45, 4.5, and 6.3, the total gain is

$$\begin{array}{r} 7.8 \\ 13.0 \\ 16.0 \\ \hline 36.8 \text{ db.} \end{array}$$

If the composite voltage or current gain is desired it is found by

$$36.8 = 20 \log \text{(voltage ratio)}$$

from which log (voltage ratio) = 36.8/20 = 1.84, and voltage ratio = 69.1

Reference Levels for Calibration of Apparatus.—While from its definition the difference in decibels between any two amounts of power is calculated without reference to any standard power, it is convenient to have some value of power which may be considered as a reference level. Power is always expressed in watts, so that at first thought it might seem obvious that one watt of power would be the correct unit to choose. The amount of power encountered in either electrical or acoustic measurements in sound motion pictures, however, is nearly always much smaller than one watt, and the expression of levels when the ratio of power is less than unity is negative. This unit would involve the use of negative numbers for the expression of nearly all powers measured, and would prove inconvenient.

In acoustic measurements, the power of a sound wave in air is usually very small and is spread throughout a considerable volume of space. To simplify calculations it is generally assumed that the sound waves radiate uniformly in a hemisphere from the source. Results indicate that the assumption is justified, provided that a reasonable distance from the source is allowed and that no difficulty is encountered from reflections from walls, ceilings, *etc.*

The energy in the sound wave may be measured either in its entirety, or as the amount passing through a unit area (usually a square centimeter) at certain distances from the source. Since the smallest amount of energy which can excite the sensation of hearing is the smallest amount of *useful* energy a sound wave can have, this value is taken as the "audibility threshold" or "acoustic level," and is usually considered to be about 4×10^{-16} watts per square centimeter.

Another value sometimes used is the "phonic level," which is simply one microwatt per square centimeter of cross-section of the air through which the wave is traveling.

In the electric circuits associated with sound motion pictures, the powers vary in value from as low as the audibility threshold up to several watts, as the power necessary to operate loud speakers in theaters satisfactorily may in extreme cases be as great as 15 watts or more. The general levels at which measurements can be made easily correspond to a few milliwatts, and volume indicators are usually calibrated to read "0" level at about 6 milliwatts.

Relation between the Decibel and Photographic Density.—The amount by which the silver deposit on a photographic film reduces the amount of light transmitted by the film is expressed by a logarithmic unit called density. The first measurements of the decrease of light intensity were made by observing the percentage of the incident light which the film transmitted. Various considerations led to the adoption of a logarithmic unit which is defined as the logarithm of the reciprocal of the fractional transmission, thus density $= \log 1/T$, where T is the fraction of the light transmitted by the silver deposit. Since the value of the light transmitted is always less than that which is incident, this fraction is always greater than unity, all photographic densities being positive, and varying in practice from 0.04, the ratio in which clear film base reduces the light transmitted to about 6.0, representing opacity for all practical purposes.

When a variable density sound record passes through a projector the changes of density cause the light of the exciting lamp which is incident on the photoelectric cell to vary in intensity. This causes the photoelectric current to vary, but as it is proportional to the light striking it, the change of current is proportional to the *transmission* of the film, and not to the density. Thus, if a transmission T_1 corresponds to a current I_1, and if the transmission should change to T_2, the photoelectric current would change proportionally to I_2, so that it can be written:

$$\frac{T_1}{T_2} = \frac{I_1}{I_2}$$

This can be changed to $\log \frac{T_1}{T_2} = \log \frac{I_1}{I_2}$ by taking logarithms of both sides of the equation, and can be multiplied by 20 also without changing the validity of the statement. This leaves

$$20 \log \frac{I_1}{I_2} = 20 \log \frac{T_1}{T_2}$$

The left-hand side of this equation is identical in form with the expression for the power reckoned in decibels when two currents act through equal resistances; and since the photoelectric currents in this case both pass through the same resistance (the amplifier input resistance) we can substitute the decibel for this part of the expression. We have

$$\text{Number of db.} = 20 \log \frac{T_1}{T_2}$$

The right-hand side contains the logarithm of the ratio of two photographic transmissions. These can be written as the product of $1/T_2 \times T_1$, and since the logarithm of a product is equal to the sum of the logarithms, it becomes

$$\text{Number of db.} = 20 \left(\log \frac{1}{T_2} + \log T_1 \right)$$

or

$$\text{Number of db.} = 20 \left(\log \frac{1}{T_2} - \log \frac{1}{T_1} \right)$$

The logarithm of $1/T_1$ is no more than the density corresponding to this transmission (D_1), and log $1/T_2$ equals the corresponding density (D_2). We may therefore substitute these values and reach the expression

$$\text{Number of db.} \doteq 20\,(D_2 - D_1)$$

showing that any change in photographic density, multiplied by 20, gives the corresponding change in electrical power in decibels. From these statements it is possible to calculate the efficiency of the noise reduction units now in use in light valve recording studios. The "ground noise" arising in sound motion pictures is due partly to slight irregularities in the current which are inherent in the photoelectric cell, but chiefly to the changes in current caused by dirt and scratches in the photographic film. The effect of a scratch or particle of dirt is to cut the light down by a certain fraction, so that its effect on the photoelectric current will be less in proportion to the amount of light which is left to be affected. Therefore, whatever can be added to the average density of the positive sound track will help to reduce both types of ground noise in an amount equal in decibels to 20 times the difference between the two densities. It must be noted that an increase in the average density of an ordinary sound print does not cut down this noise, as the volume it is possible to get also is cut down, so that the amplification must be raised, restoring not only the signal, but also the noise, to its former level. It is only by cutting down the light while the sound volume is low, or during silent passages, that any effect is found, and if the density of the film can be decreased to its normal value when the sound volume increases, the amplification does not have to be increased to keep the proper level in the theater. The amount by which the noise may be decreased depends fundamentally on the amount by which the valve may be closed in recording. This narrowing of the light valve slit is accomplished by sending a direct current through the valve in addition to the amplified signal coming from the microphone. This decreases the density of the negative during sound passages of low volume, increasing the density of the positive during the same sequences. In following through the theory of sound recording and reproducing by the light valve method, proper sound reproduction depends on the proportionality of the movement of the light valve strings to the sound pressure at the microphone in recording, and the photographic processing must be such that the transmission of the positive is also proportional to the sound pressure. Therefore the transmission of the positive must be proportional to the valve opening. If the normal slit width is 1.0 mil (0.001 inch), and it is biased in noiseless recording to 0.3 mil, the positive will have a transmission T_1 for the 1.0 mil slit and a transmission T_2 for the 0.3 mil slit. The proportionality equation is

$$1.0/0.3 = T_1/T_2$$

taking logarithms of both sides

$$\log 3.3 = \log T_1/T_2.$$

It has been shown that $\log T_1/T_2 = (D_2 - D_1)$, so the above becomes $D_2 - D_1 = 0.52$, and since the reduction in noise is 20 times the change in density, in this case it becomes 10.4 decibels. As has been stated this would be about three steps on an ordinary fader and would be very appreciable.

In the variable width method of recording, during silent passages one-half the sound track has a high density and one-half is clear. In order to reduce the noise due to transmission of light through the clear area, a mask is arranged in making the negative to cut off the light incident to this area. During printing this area is printed to a high density, leaving only a very narrow unexposed line in the center of the record. As the sound intensity increases, the mask is moved farther and farther over, leaving more and more of the sound track available for the making of the record. In such a case, the intensity of noise is again dependent on the amount of light transmitted, but since the film is either clear, letting through all the light, or so dense as to allow practically none, the amount of light transmitted is proportional to the width of the clear portion of the track. The decrease in the noise intensity, following the same line of reasoning as before, will depend on the width of track it is necessary to leave in the center during silent passages. This is at least 5 mils, and since in the variable width recording system the width of the whole sound track is 70 mils, the clear portion is normally 35 mils. The reduction in the intensity of the noise can be calculated from the change in the photoelectric current, which depends on the width of the clear track. Thus from equation

$$\text{Number of db.} = 20 \log 35/5 = 20 \log 7 = 20 \times 0.845$$
$$\text{Number of db.} = 16.9 \text{ or approximately } 17 \text{ db.}$$

Conclusion.—It is hoped that the foregoing explanation of the various ways in which the decibel enters into the sound motion picture may prove of value to those who find that the literature of the art includes many statements which depend, for a complete understanding, on an accurate conception of exactly what the function of the unit is, and the reasons why its use is convenient. For reference a tabulation of the various levels occurring in parts of sound motion picture systems is added. These levels are in some cases only approximate, owing to their nature, but they indicate the order of magnitude to be expected.

Distances as given refer to columns *A*, *B*, and *C*. Radiation is assumed to be in the form of a hemisphere with the power given in the first column generated at the center. (*A*), decibels above audibility threshold (acoustic level, assuming 4×10^{-10} microwatts per sq. cm.); (*B*), decibels above one microwatt per sq. cm. (phonic level); (*C*), decibels above 0.006 watts (electrical level) of output of condenser microphone into 25 megohms input.

TABLE III

Total Power	Microwatts	Source of Sound *A*	*B*	*C*	Distance
Soft whisper	0.001	17	−77	−144	3 feet
Average speech	10	57	−37	−104	3 feet
Very loud speech	1000	77	−17	− 84	3 feet
Peak of speech	5000	84	−10	− 77	3 feet
Peak of singing	30000	91.8	− 2.2	− 69.2	3 feet
Soft violin in orchestra	4	43	−51	−118	10 feet
Piano—average	4000	73	−21	− 88	10 feet
Piano—highest peak	2×10^6	100	+ 6	− 61	10 feet
Bass drum peak	25×10^6	107	+13	− 54	15 feet
75 piece orchestra peak	66×10^6	113	+19	− 48	15 feet
Pipe organ—peak	13×10^6	105	+11	− 66	15 feet

No attempt has been made to quote sources of data given in the course of the paper. The data for Table III were derived from the first two references given and further references will be found in the following list.

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OPTICAL INSTRUMENTS AND THEIR APPLICATION IN THE MOTION PICTURE INDUSTRY*

I. L. NIXON**

Summary.—*This paper deals not with the optics of the photographic lens, motion picture projector, or studio illuminator, but rather with those instruments such as microscopes, photometers, etc., the use of which has contributed greatly to the advance of the motion picture art of today. A simple explanation is given of the different types of instruments and the general optical principles involved, and some of their specific applications, which indicate the debt which industry owes to optical science.*

When speaking of optics in the motion picture industry, it is but natural for those of us who are most intimately connected with the industry, to think of optics as applied to the photographic lens as used on the motion picture camera, or to the optics of the projector, or for illumination in the studio, but I purpose to outline briefly some of the different types of optical instruments that have been used or might be used in the development of new materials, control of processes, and control of accuracy of parts. Because of the fact that many of these devices have been used largely in a research way and not in sufficient numbers to attract attention, they might be classed as the modest group of silent workers that have made the high perfection of the present art possible and that will play an important part in the achievements of the future.

The microscope of one form or another is probably the most widely used optical instrument in the motion picture industry. It hardly seems necessary to define a microscope, but it might be described generally as a device having a system of lenses, suitably supported by mechanical arrangements, which will produce a magnified image of a small object so that the eye may distinguish between details of structure not otherwise discernible.

A simple magnifying glass might be considered as qualifying as a microscope under this definition, but this paper will deal with what may be termed a compound microscope, a typical one being repre-

* Presented at the Spring, 1931, Meeting at Hollywood, Calif.

** Bausch and Lomb Optical Co., Rochester, N. Y.

sented by Fig. 1, where a system of lenses, mounted together and known as an objective, is attached to the lower end of what is known as a body tube and another system known as the eyepiece is mounted in the upper end of the tube. The objective acts as a photographic lens would act, and forms a magnified image of the object in the focal plane of the eye lens which, in turn, magnifies that image. Hence we have compound magnification and in turn a compound microscope. By varying the power of one or both of these units the magnification is accordingly changed, the range of magnification being from $10X$ to approximately $2000X$.

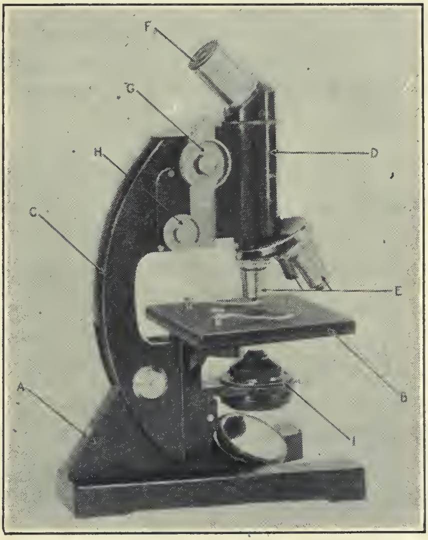

FIG. 1. A typical compound microscope.

The design and accuracy of the mechanical parts of such an instrument are quite as essential to its functioning as are the optical parts. It must be substantially constructed, and yet a certain symmetry of design is demanded and its movable parts must be accurately fitted and free from any lost motion, yet immediately responsive to adjustment.

The mechanical part of the compound microscope is referred to as the stand and consists of the following general parts:

(A) Base, of a design that will have sufficient spread and weight to assure the stability of the instrument in either an upright or inclined position.

(*B*) Stage, on which is placed the object to be observed. This may be either plain, rectangular, or circular revolving, and both styles may be fitted with mechanical devices for moving the object in two directions at 90 degrees to each other for easy searching of the specimen. These adjustments may also be provided with scales for relocation of the specimen if desired.
(*C*) Arm, attached to the base and supporting the body tube with its adjustments.
(*D*) Body tube.
(*E*) Objective.
(*F*) Eyepiece.
(*G*) Coarse adjustment, by rack and pinion, which must move easily and yet be free from lost motion.
(*H*) Fine adjustment.
(*I*) The substage with condenser or illuminating lens system, which functions either in conjunction with daylight or a suitable artificial light source to illuminate the specimen efficiently, if it be one with which transmitted light may be used.

In Fig. 2 we have shown diagrammatically the path of light of such a microscope, which seems to need no further explanation except to point out that when looking into the microscope the image appears as though it was being viewed at a point 10 inches below the equipment. If a screen is held 10 inches above the eyepiece an image will be formed at that plane equal in magnification to the image observed in the eyepiece and the magnification would increase proportionately as the distance was increased beyond 10 inches.

This represents the typical biological or medical type of microscope, large numbers of which are manufactured annually for use in the schools and colleges, but which are being used more extensively each year in industrial laboratories where transmitted light may be used.

A number of deviations from this typical instrument in the way of special illuminating devices and accessories of one sort or another make the equipment particularly suited for some specialized work. Before passing on to these, however, it will be interesting to note the similarity of the optical system of the microscope to that of the motion picture projector. A light source with the substage condenser corresponds to the light source and the condensing lens system; the stage on which the specimen is placed may be compared to that of the film gate supporting the film, and the objective lens and eyepiece may be considered as one unit corresponding to the projecting lens.

In addition to using a microscope as a device for studying the structure of materials it may also be used for measuring the size of particles or parts, or their separation, by the use of a ruled disk to be placed in the eyepiece at what is known as the diaphragm plane or in the same plane as that of the image formed by the objective so that both the scale and the image of the object will be in the focus of the eye lens. (Fig. 3.)

Such a scale may be ruled with divisions to represent a definite value on the specimen (0.001 of an inch, for instance) for use with definite combination of eyepiece and objective producing a fixed magnification, or the eyepiece disk may be ruled in definite values,

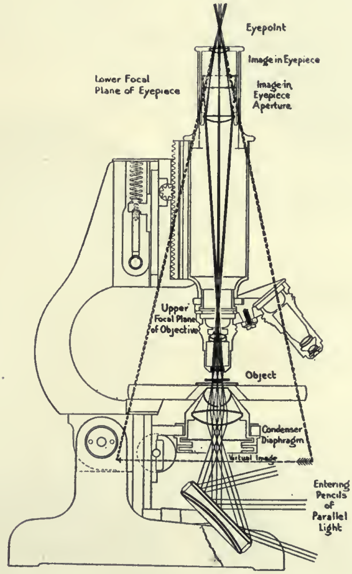

FIG. 2. Diagram showing path of light of a typical microscope.

and a stage micrometer used to evaluate the rulings on the eyepiece disk, according to the combination of objective and eyepiece being used. The use of such a device was probably first used by the doctor in counting the number of blood corpuscles per given quantity of solution, but has been adopted by the industry as a means of measuring and determining the distribution of silver grains in emulsion.

As evidence that the microscope is being recognized as one of the most important tools in modern industry is the fact that a number of the leading universities are introducing as a division in the chemical engineering courses one known as "Chemical Microscopy" in which the principles of the microscope, its applications, and the interpretation of the results are taught.

There is no industry that I know of in which a microscope could

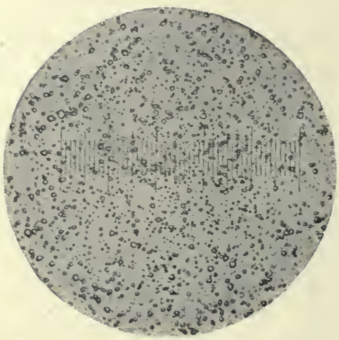

FIG. 3. Photomicrograph of silver grains with micrometer scale.

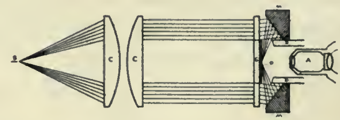

FIG. 4. Path of light of special microscope for examination of paper surfaces.

not be used to advantage in the control of its raw materials and finished product.

The number of ways in which a microscope is used in the laboratory

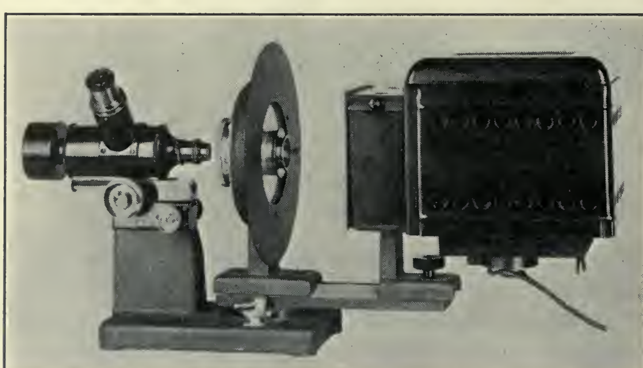

FIG. 5. Special paper microscope.

of a manufacturer of film is amazing. An almost constant study is made in the size, shape, and distribution of silver grains in the emulsion both before and after development. Photomicrographs are frequently made for record and control purposes from which frequency curves may be plotted if desired.

We do not ordinarily think of the finished film being built up of a series of layers, but it is; and each one of the processes contributing to this building up must be carefully controlled. When something goes wrong, they send for the trouble shooter, the man with the microscope. A cross-section of the film will probably be made with a microtome, a device for making sections only a few microns in thickness; and when this is observed one clearly sees these layers of different materials, and the trouble can usually be traced to a certain operation or to impurities that are causing the trouble.

Standards of surface finish of both film and paper may be set up

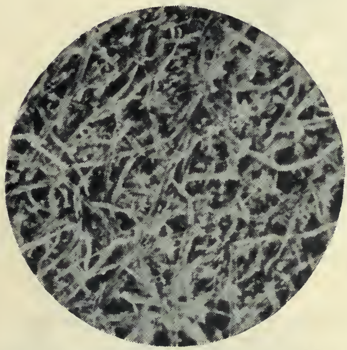

FIG. 6. Photomicrograph of a paper surface at 40 magnifications.

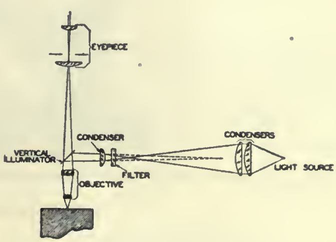

FIG. 7. Path of light when illuminating opaque objects.

according to microscopical specifications and in the event of trouble it is fairly easy to trace back against the standard and locate the source.

Dr. L. A. Jones, of the Eastman Kodak Co., in his study of paper surfaces decided that there was needed a special type of illumination with provision that the exact illumination could be duplicated at any time, because surface appearance of paper depends so much on the amount and angle of illumination. There was developed a microscope with an illuminating system as indicated in Fig. 4.

A light source and condensing system produces a beam of light passing through a ground glass at G, which strikes the 45-degree annular reflector M, and the light is reflected upon the specimen at O. It is obvious that this is annular illumination which illuminates equally from all directions, and with no direct top illumination. By means of the movable tube D the amount of illumination and the angle of incidence may be regulated. A very smooth surface will be best illuminated by light from a small angle while a rough surface requires

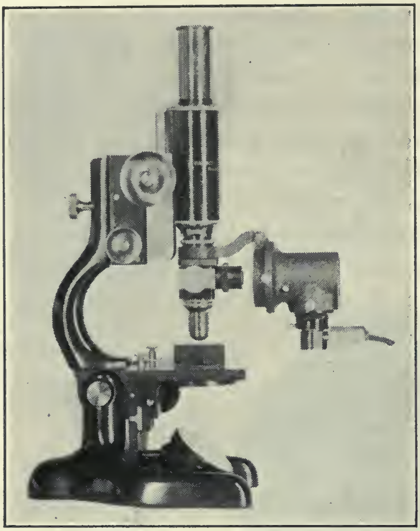

FIG. 8. Metallurgical microscope.

higher angular illumination. The length of fibers, how they are arranged, and how the filler and the coating has been applied may all be easily studied under this kind of illumination.

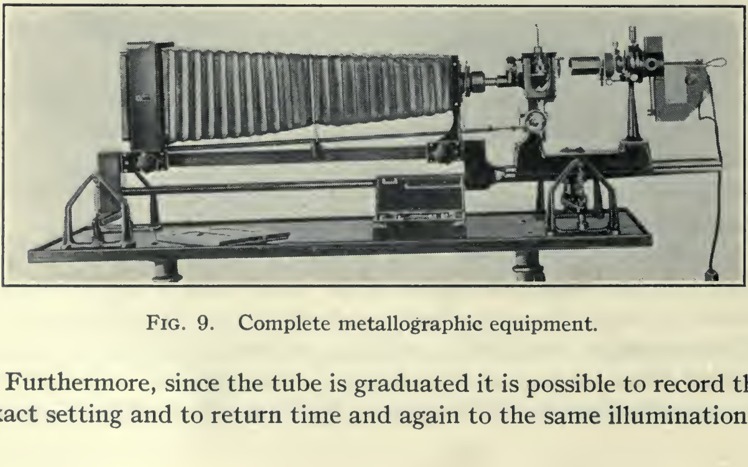

FIG. 9. Complete metallographic equipment.

Furthermore, since the tube is graduated it is possible to record the exact setting and to return time and again to the same illumination.

Fig. 5 shows this microscope as it is now commercially made, with an observation tube which may be withdrawn so the light passes on through the other tube to the camera for making photomicrographs. Fig. 6 shows such a photomicrograph. Provision is made for the making of stereophotographs if desired.

A number of other modifications of the standard microscope or

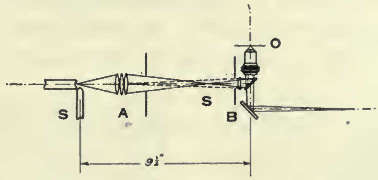

FIG. 10. Path of light for large metallographic equipment.

special accessories are made use of in the film laboratories in more or less highly specialized investigations, among which is a device known as a dark ground illuminator for the illumination of colloidal particles, a microscope with accessories for producing polarized light by means of which strains may be detected in crystals and film base, and a

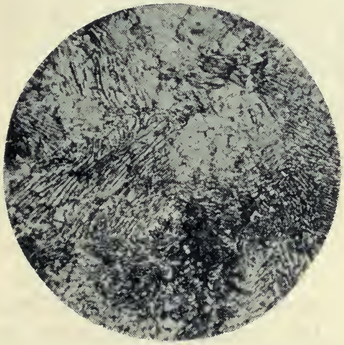

FIG. 11. Photomicrograph of steel.

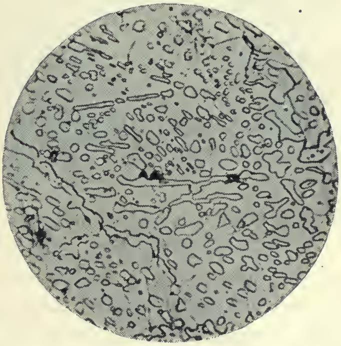

FIG. 12. Photomicrograph of steel.

micromanipulator, by means of which individual crystals or particles of impurities may be isolated and submitted to all kinds of treatment.

While many materials may be satisfactorily illuminated with transmitted light there are many that are opaque and, consequently, must be illuminated from the top. In the case of low-power equipment this may be by means of light directed downward, striking the object at an angle, in other words, flood lighted; while in the case of high-power equipment the objective works so close to the object that it is no longer possible to illuminate in such a manner and then one must resort to what is generally known as a vertical illuminator.

Fig. 7 is a diagram showing the path of light of such a device. This vertical illuminator is inserted between the end of the body tube and the objective. In one side of the mounting is an opening usually fitted with a small condensing lens. A small concentrated beam of light from a suitable light source enters through this aperture and is

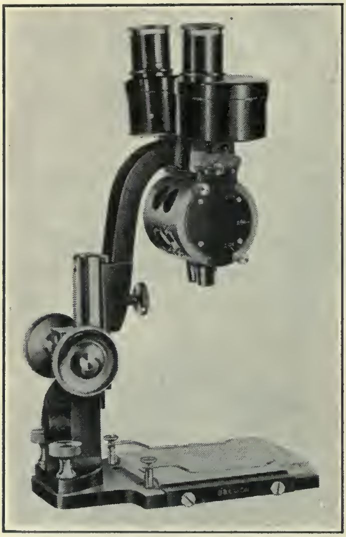

FIG. 13. Wide field binocular microscope.

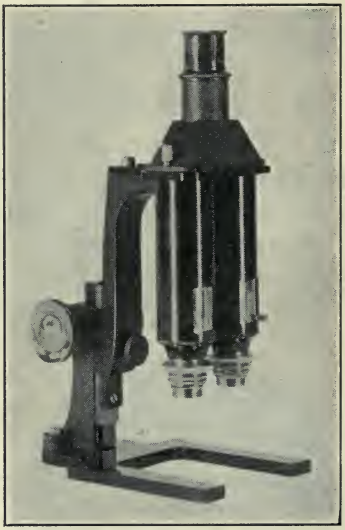

FIG. 14. Comparison microscope.

reflected 90 degrees downward, either by a clear glass reflector or by a prism, through the objective lens onto the specimen; and since the rays of light are striking normally to the surface of the specimen they will be reflected directly back along their original path. This is assuming that the specimen is fairly well polished. If a clear glass reflector is used, a portion of the returning light passes through the glass to the eyepiece. If using a prism as the reflecting medium, it must be mounted off the center of the optical axis; the light then passes down through one side of the objective and back through the other, past the prism and on through to the eyepiece.

This kind of illuminator is a part of all metallurgical microscopes of which there are two general types. The first one, Fig. 8, is essentially the same as the regular microscope except that it is fitted with the vertical illuminator and usually is without substage condenser, but it has the stage movable vertically by rack and pinion. This is necessary to bring the object into focus without changing the position of the vertical illuminator with relation to the light source after it has once been aligned and centered. Such a microscope as this has wide use as a routine instrument in the industrial laboratory. The other type of metallurgical microscope is that shown in Fig. 9.

This is known as an inverted microscope, the stage being at the top, the specimen placed with its polished side down and the illumina-

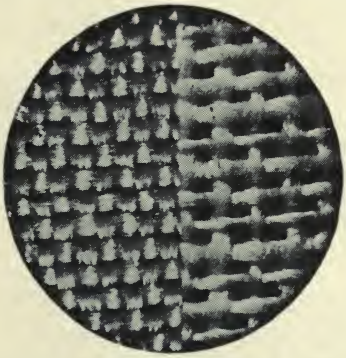

FIG. 15. Photomicrograph of two pieces of textile as seen through the comparison microscope.

tion coming up from underneath by means of a vertical illuminator, as will be seen from the diagram of the path of light in Fig. 10.

The illuminating system of this instrument is mounted on a base with the microscope, so that both units may be very carefully and permanently aligned and centered, a point which is very essential when working at high magnifications. This microscope is almost always sold in conjunction with the camera as shown, the combination then being known as a metallographic equipment. It is common practice with such equipment to make photographs at 2000 or 3000 diameters, and they have been made as high as 15,000 diameters.

The value of such equipment to the manufacturer and user of steel, brass, copper, and all metal alloys is beyond estimation. Suffice it to say that if it were not for the microscope we probably would not have the high-speed motor cars, aeroplanes, *etc.*, that we have today. The chemical analysis will determine whether the correct percentage of the different constituents has been maintained or not, But that does not tell whether a piece of steel will be suitable for the purpose for which it has been intended or not; such can be told only by determining the crystalline formation after the various heat treatments, rolling, drawing, *etc.*

A piece of steel, for instance, of a given mixture will have a very definite crystalline structure following certain treatments which the

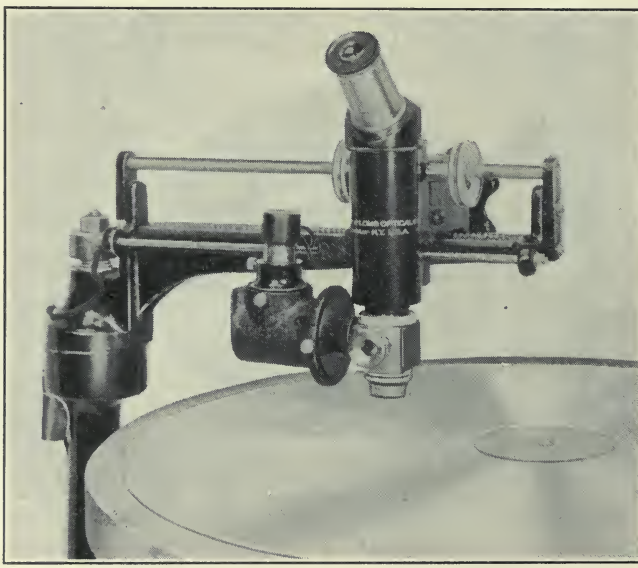

FIG. 16. Special microscope for wax records. Photograph by courtesy of Bell Telephone Laboratories.

trained metallurgist can at once recognize. So he takes a small sample, grinds, polishes, and etches one surface, checks it on the microscope and many times will photograph it for record purposes. Such photographs might look like Figs. 11 and 12.

The first shows a steel heated to a certain point of the treatment and the other a steel carried beyond this point in the hardening process.

Probably one of the most useful instruments for general use around the laboratory or the factory is a wide field binocular microscope. (Fig. 13.)

This, as its name implies, is arranged for binocular vision with a large field, and the image produced is an erect one, so that in working with materials, dissecting, *etc.*, all movements may be naturally made. Furthermore, one sees naturally, that is, stereoscopically. Its most useful range is at from magnifications of approximately $7X$ to $30X$. Because of the large field and third dimension it is most useful in examining small parts, machine surfaces, and raw materials.

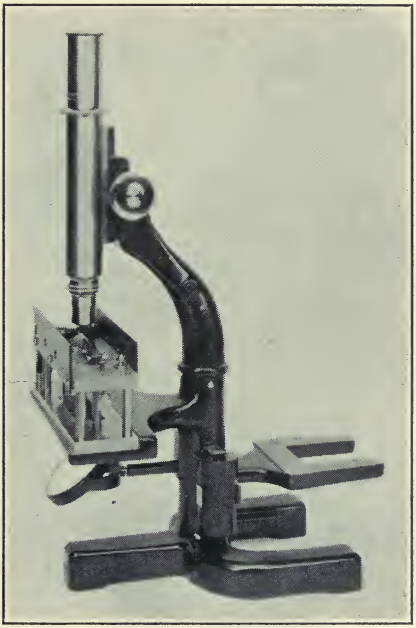

FIG. 17. Special microscope for setting width of light valve. Photograph by courtesy of Bell Telephone Laboratories.

In a paper presented by O. E. Conklin[1] at the 1930 Fall Meeting of the Society, the applications of the comparison microscope in the film industry are set forth in detail. Such a microscope has two objectives which focus on two objects to be compared, and a prism which brings their images together so that they can be seen in a single eyepiece side by side. (Fig. 14.)

In a film laboratory, either manufacturing or processing, a comparison microscope is invaluable because one is always wanting to compare two things, one of which may be a standard. Two films may be compared for general graininess, or tint, papers for surface finish, *etc.* (Fig. 15.)

For the details of its application I refer you to Mr. Conklin's paper in which he also describes how this instrument had been used as the basic unit in the construction of a picture comparator, a sound track photometer, a graininess comparator, and a perforation comparator.

This paper of Mr. Conklin's shows most conclusively how with a

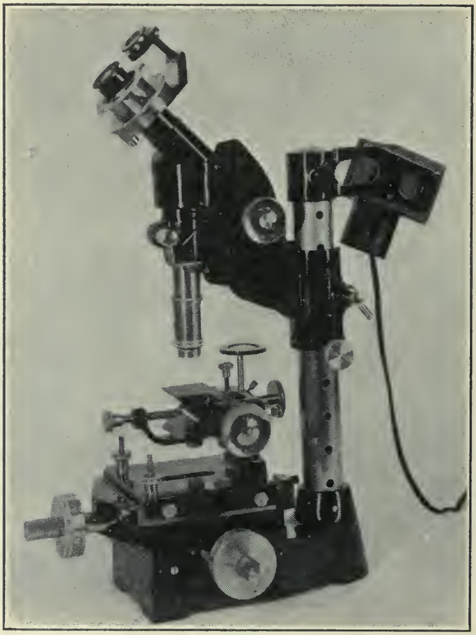

FIG. 18. Toolmaker's microscope.

little ingenuity a single basic microscope may be made to serve in a number of important control steps—leading to the uniformity and general efficiency of the film.

In making sound records on wax a microscope becomes indispensable to check the performance of the cutting needle and for that purpose there has been employed a body tube with objective and eyepiece mounted on an arm to be swung over the record. A special vertical illuminator has been employed for proper illumination and an inclined eyepiece for greater convenience in viewing. (Fig. 16.)

The setting of the width of the slit on the light valve of the Western Electric sound recording unit necessitates the use of a microscope to which a special holder is attached for holding the valve unit. (Fig. 17.) This equipment is provided with an optical system having a magnification of 100 and a scale in the eyepiece with ten spaces, each space representing 0.001″ on the specimen.

In modern shop practice it becomes essential to work to much closer limits in making screw threads, gears, cams, cutting and forming tools, and the mechanic is often confronted with checking curved forms whose contour is almost impossible to control without recourse to one

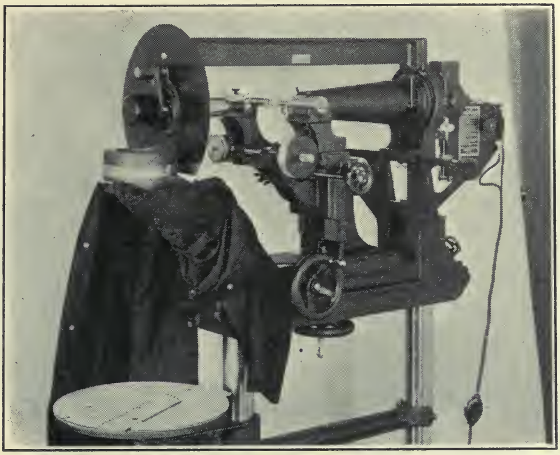

FIG. 19. Contour measuring projector.

or the other of two optical devices, one known as a toolmaker's microscope and the other as a contour projector. (Fig. 18.)

The toolmaker's microscope is provided with an illuminating system producing a parallel beam of light passing the specimen and an objective specially corrected for use with parallel pencils of light. The stage has a micrometer movement of one inch in two directions at 90 degrees to each other with graduated drums reading at a tenth of a thousandth of an inch.

The eyepiece may be with a simple cross-hair against which settings of the image may be made, or it may be what is known as a protractor eyepiece with cross-hairs adjustable for angles of from 40 to 70 degrees.

With such an instrument the angle, lead, and pitch diameter of screw threads may be easily and accurately measured, and in addition it has been used particularly in the motion picture industry for checking the spacing and size of perforations, checking the tools with which the perforations are made and the slit on the Western Electric light valve.

The contour projector, as its name implies, is a projector of contour forms, screw threads, gears, cutting tools, *etc.* (Fig. 19.)

There are a light source, a special object holder, and a projection lens producing the image either on a distant screen or upon the chart attached to the stand depending on the size of object being in-

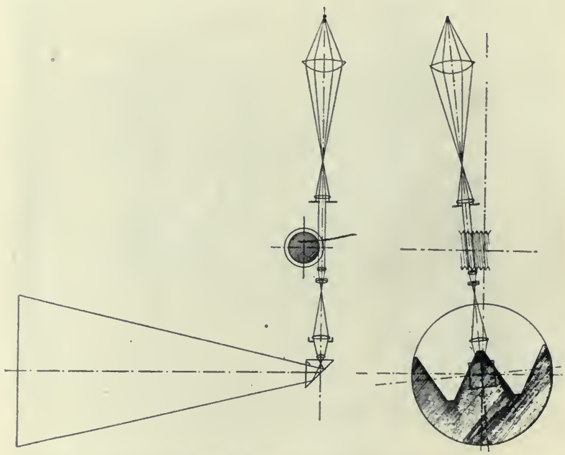

FIG. 20. Path of light for contour measuring projector.

spected. (Fig. 20.) Here again we have an optical system resembling the typical motion picture projector, except that the beam illuminating the object is made up of parallel pencils.

A five-ampere arc lamp is usually used as the light source with an aspheric condenser in an adjustable mount which may be set to illuminate approximately a 2-inch area for large objects, and a supplementary condenser with diaphragm for use with small objects and high magnification objectives.

The object may be held either between centers, in *V* blocks or, in the case of gears, on studs and special holders for special forms. The object holder has a forward and backward movement for focusing, and a vertical and transverse movement for moving the object into the field of view. These two movements may be fitted with micrometer screw and drum for measuring distance, lead of screw threads, *etc.*

In checking screw threads it is customary to use a special chart against which the thread outline is readily checked for angle, size, and general correctness of form. (Fig. 21.)

A plate holder or special paper holder may be substituted for the chart and photographs made for record purposes.

The contour of gear tooth form may be checked against a master

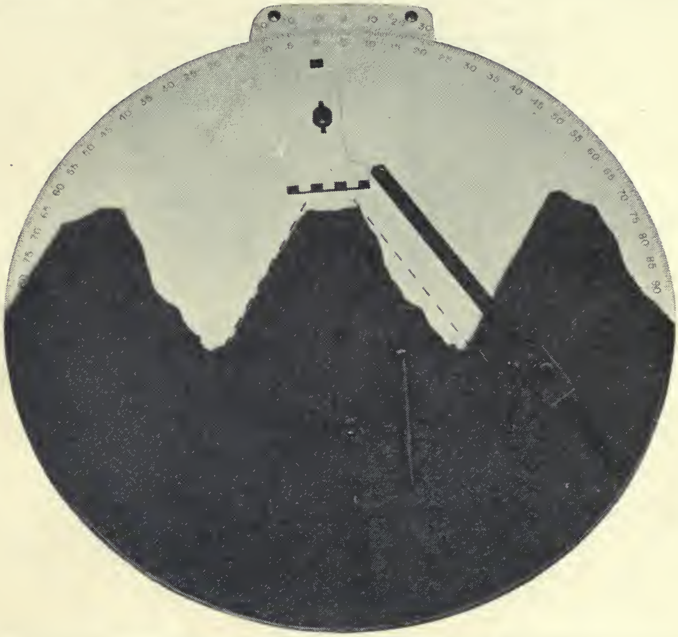

FIG. 21. Photograph of commercial thread and thread chart.

drawing for size and exact form or two gears may be mounted enmeshed and slowly rotated, and their exact rolling action carefully studied. The silent transmission gear systems on the present-day automobile are a result of the study of gear action with such a device. Many tool departments are using such a device for checking the contour of cutting tools against a master template before turning them over to the operating departments.

Several manufacturers in the motion picture industry are using such equipment for controlling the accuracy of their mechanical parts, and no doubt the silent mechanisms of today are largely the result of a study of the parts involved on such a projector. Spacing and shape of film perforations are also being controlled by such a device. In measuring the spacing, one edge of a perforation is carefully lined up with a target on the chart, then the carrier is moved over until the edge of the next perforation is in line with the target. Then, with the micrometer screw and drum, the amount of movement or the spacing can be easily checked to a tenth of a thousandth of an inch. The radii of the corners can be easily checked against a master outline so

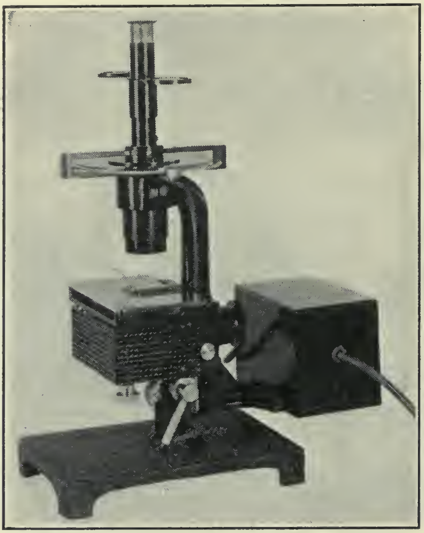

FIG. 22. Densitometer.

that the accuracy of the die and the amount of wear may be quickly determined.

Up to this point we have been considering the type of equipment by means of which material things might be examined, measured, *etc.*, but there is another group of optical instruments that are quite as important to the industry and their use marks in many instances the high state of achievement. Such instruments are photometers, and spectrometers in a broad sense.

A photometer is an instrument which has for its purpose the measurement of light intensity. There are many kinds ranging from the portable kind, known as a luminometer for approximate measuring of lumens or foot candles for screen illumination, to the highly specialized type for close measurement of film density.

In designing optical systems for projector or lighting units the amount of illumination and its distribution are checked by a photometer, and the highly efficient systems are largely due to the ability to record accurately their performance with some type of photometer. The same thing applies to the study and development of light sources.

We are indebted to Martens, a German physicist, for the conception and development of the polarization type of photometer, which has been embodied in a number of special instruments, an example of

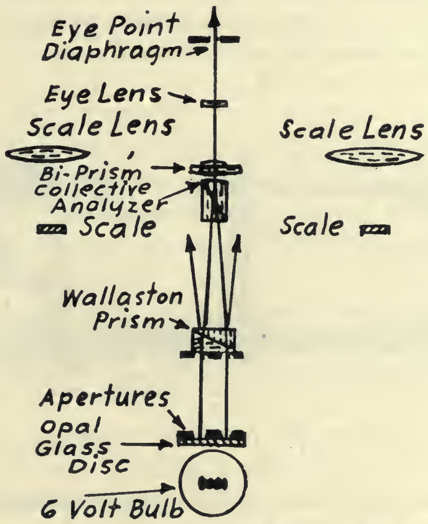

FIG. 23. Path of light of densitometer.

which is one known as a densitometer. Its purpose is, as its name implies, to measure the density of the exposed portions of film.

Fig. 22 illustrates a densitometer developed along lines suggested by the Bell Telephone Laboratories, with which extensive study of sound track density has been made. While this incorporates the general principle of the Martens photometer there are a number of modifications and the general design of the instrument has been around the requirements necessary for easy and accurate study of sound track densities.

Fig. 23 shows the path of light of this densitometer. In this design the two entrance pupils have been removed from the body of the instrument and placed on the stage over which the film travels and are diffusely illuminated.

The upper portion of the photometer consists of a Wollaston prism, a bi-prism, and an analyzing prism, with suitable lenses to produce a photometric field, one-half of which is illuminated by light from the aperture over which the film travels and the other by light from the clear aperture. The rotatable analyzing prism is provided with a six-inch divided circle, on which are engraved both density and transmission scales. These scales occupy two oppositely located 45-degree sectors, and are designed so that either transmission or density may be read from the same setting, the former on the left and the latter on the right. The scales are read by means of two magnifiers mounted on the eyepiece tube of the photometer. The accuracy of

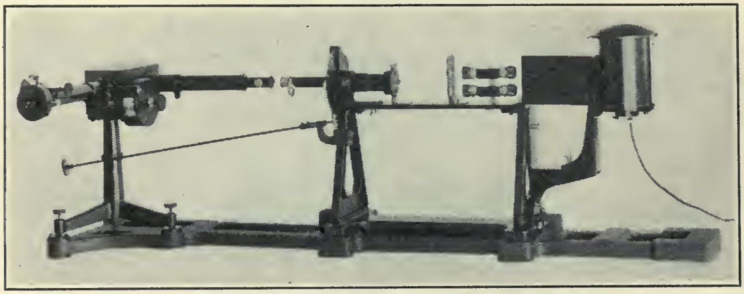

FIG. 24. Spectrophotometer.

reading is within 3 per cent at any point in the scale and the maximum density which can be read is approximately 3.5.

Other still more highly specialized instruments, known as microdensitometers, have been made in very limited number by European manufacturers for examination of very small areas; usually used in the study of spectral lines, but have been used in the sound research laboratories for the study of individual vibrations on the sound track.

Another specialized piece of photometric apparatus which has been of decidedly important usefulness to the industrialist has been the spectrophotometer. The spectrophotometer is an instrument by virtue of which any controllable beam of light may be split up into its spectral components; that is, into the component colors of light tending to compose it, and to measure the comparative proportion of each wavelength or color present in this light. It is possible by this instrument to identify or to make a record of the color characteristics of a substance whether it be a reflector of colored light or, let us say, a piece of colored fabric, or whether it transmits colored light, for instance, a piece of colored glass. (Fig. 24.)

The spectrophotometer consists of three essential parts: first, the source of light, in which must reside all possible colors or wavelengths within the visible spectrum. This condition is admirably met by the incandescent lamp. The second element is a spectroscope-like piece of apparatus, by virtue of which light entering it may be broken up into its component colors; and to do this quantitatively, that is, so that one may be able accurately to identify which color the instrument is transmitting at a particular time. The third element is a photometer, the function of which is to measure the intensity of the one-colored light being transmitted at the instant the measurement is taken.

The spectrophotometer is fundamentally a kind of comparator as differentiated from an instrument which makes absolute measurements, but since the intensity of light originating in the incandescent lamp can be held practically constant by controlling its impressed electric current, and because of certain characteristics inherent in the design of the apparatus, the basis of comparison is always unity, so that the reading of the instrument may be reduced directly to percentage of transmission of light of any given particular wavelength.

Such an instrument is widely used by dye makers, paint manufacturers, and all people who have anything to do with the specification of color. The dyes used in tinting film must be or should be checked spectrophotometrically during development to ascertain positively the desired color, and during manufacture to guarantee uniformity of product. Of course, the filters used in all processes of colored photography must be carefully and painstakingly studied with such apparatus if satisfactory results are to be obtained in their use.

It is safe to say, therefore, that the achievement of color photography up to the present time and its further perfection will be due to the availability of spectrophotometric apparatus.

REFERENCE

[1]CONKLIN, O. E.: "Some Applications of the Comparison Microscope in the Film Industry," *J. Soc. Mot. Pict. Eng.*, **XVI** (Feb., 1931), No. 2, p. 159.

PHOTOGRAPHIC SENSITOMETRY, PART IV*

LOYD A. JONES**

The following is the fourth and final installment of Mr. Jones' paper on sensitometry, which, due to its length, was presented in part on three consecutive days at the Spring, 1932, Meeting of the Society at Hollywood, Calif. The preceding installments appeared in the JOURNALS *of October and November, 1931, and January, 1932. The paper deals in a tutorial manner with the general subject of sensitometry, its theory and practice.*

OUTLINE

I. Introduction.
- (*A*) Definition.
- (*B*) Scope of field.
- (*C*) Applications.
- (*D*) The characteristic *D*-log *E* curve.

II. Sensitometers.
- (*A*) Light sources.
  - (1) *Historical résumé.*
    - (*a*) Natural light (sunlight, skylight, *etc.*).
    - (*b*) Activated phosphorescent plate.
    - (*c*) British standard candle.
    - (*d*) The Hefner lamp.
    - (*e*) The Harcourt pentane standard.
    - (*f*) The acetylene flame.
    - (*g*) Electric incandescent lamps.
  - (2) *Spectral composition of radiation.*
    - (*a*) The spectral emission curve.
    - (*b*) The complete radiator.
    - (*c*) Color temperature of sources.
    - (*d*) Effect of color temperature on sensitivity values.
  - (3) *Modern standards of intensity and quality.*
    - (*a*) Acetylene flame plus dyed gelatin filter.
    - (*b*) Acetylene flame plus colored glass filter.
    - (*c*) Acetylene flame plus colored liquid filter.
    - (*d*) Electric incandescent plus colored filters.
  - (4) *The international unit of photographic intensity.*
- (*B*) Exposure modulators.
  - (1) *Intensity scale instruments.*

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* Presented at the Spring, 1931, Meeting at Hollywood, Calif.

** Kodak Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

- (*a*) Step tablets (*I* variable by finite increments).
- (*b*) Wedge tablets (*I* variable by infinitesimal increments).
- (*c*) Luther's crossed wedge tablet.
- (*d*) Tube sensitometer.
- (*e*) Optical systems with step diaphragms.
- (*f*) Optical systems with continuously variable diaphragms.

(2) *Time scale instruments.*

- (*a*) Exposure intermittent.
  - Finite exposure steps (discontinuous gradations).
  - Infinitesimal exposure steps (continuous gradations).
- (*b*) Exposure non-intermittent.
  - Finite exposure steps (discontinuous gradations).
  - Infinitesimal exposure steps (continuous gradations).

III. Development.

- (*A*) Developers.
  - (1) *Standards for sensitometry.*
    - (*a*) Ferrous oxalate.
    - (*b*) Pyro-soda.
    - (*c*) *p*-Aminophenol.
  - (2) *Standards for control of processing operations.*
- (*B*) Temperature control.
- (*C*) Development technic.
  - (1) *For standardized sensitometry.*
  - (2) *For control of processing operations.*

IV. The measurement of density.

- (*A*) Optical characteristics of the image.
  - (1) *Partial scattering of transmitted light.*
  - (2) *Diffuse density.*
  - (3) *Specular density.*
  - (4) *Intermediate density.*
  - (5) *Relation between diffuse and specular values.*
  - (6) *Effective density for contact printing.*
  - (7) *Effective density for projection.*
  - (8) *Color index.*
- (*B*) Fog and fog correction.
  - (1) *Source of fog.*
    - (*a*) Inherent fog.
    - (*b*) Processing fog.
  - (2) *Fog correction formulas.*
- (*C*) Densitometers.
  - (1) *Bench photometer.*
    - (*a*) Rumford.
    - (*b*) Bunsen.

(c) Lumer Brodhun.
(2) *Martens polarization photometer.*
(a) Simple illuminator.
(b) Split beam illuminator.
(3) *Integrating sphere.*
(a) For diffuse density.
(b) For diffuse and specular density.
(4) *Completely diffused illumination.*
(a) For diffuse density.
(5) *Specialized forms.*
(a) Furgeson, Renwick, and Benson.
(b) Capstaff-Green.
(c) High-intensity (Jones).
(d) Density comparators.
(6) *Physical densitometers.*
(a) Thermoelectric.
(b) Photoelectric.
(c) Photovoltaic.

V. Interpretation of Results.

(A) Speed or sensitivity.
(1) *Threshold speed.*
(a) Scheiner speed numbers.
(b) Eder-Hecht.
(2) *Inertia speeds.*
(a) H & D scale.
(b) Watkins scale.
(c) Wynne scale.
(3) *Luther's crossed wedge method.*
(4) *Minimum useful gradient.*
(B) Gamma infinity, γ_∞.
(C) Velocity constant of development, K.
(D) Time of development for specified gamma.
(1) T_d ($\gamma = 1.0$).
(E) Latitude, L.
(F) Fog, F.

VI. Spectral Sensitivity.

(A) Dispersed radiation methods.
(1) *Monochromatic sensitometers*
(2) *Spectrographs.*
(a) Ordinary.
(b) Glass wedge.
(c) Optical wedge.
(B) Selective absorption methods.
(1) *Tricolor.*
(2) *Monochromatic filters.*
(3) *Progressive cut filters.*

VI. SPECTRAL SENSITIVITY

Any treatment of the subject of sensitometry, especially in these days of great popularity of panchromatic materials, cannot be considered as complete without a discussion of the various methods used for the measurement and specification of the sensitivity of photographic materials to radiation of different wavelengths. This characteristic is usually referred to as *spectral sensitivity*. A knowledge of the way in which sensitivity is distributed throughout the spectrum, including the ultra-violet and the infra-red as well as the visual regions, is of great importance from both the practical and the theoretical points of view. The rendition of color by a photographic process is determined largely by the spectral sensitivity of the negative material. For instance, it is well known that the ordinary blue-sensitive materials, red, orange, and yellow, are rendered in about the same tone value as black, while in the case of some panchromatic materials, which have been rendered very sensitive to the longer wavelengths of visible radiation, these same colors may be rendered as almost white. The correct rendering of colored objects on the black to white tone scale, which represents the entire discrimination gamut of the photographic process, is conditioned almost entirely by the spectral sensitivity of the material. It is evident, therefore, that a knowledge of this characteristic of photographic materials is of great importance wherever orthochromatic rendering of colored objects is to be considered.

Many workers in the field of photography have studied this problem of spectral sensitivity and, in fact, its investigation dates back almost as far as the beginning of sensitometry. As early as 1882 Abney[106] studied the spectral sensitivity of photographic materials by exposing them to dispersed radiation in a spectroscope and by plotting densities, as determined by visual estimation, against wavelength obtained a curve of spectral sensitivity. Abney later improved the method until finally, in 1888,[107] he suggested a technic which involved impressing on the same plate an exposure to a spectrum and a series of known exposures to white light. The opacities of the spectrum exposures were then measured and interpolated between those of the white light exposures. He thus obtained a curve showing the equivalent spectral intensities for various wavelengths.

The exposures of the photographic material to dispersed radiation afforded by an instrument of the spectroscopic type gives information which, while it is undeniably complete, nevertheless is not conveniently expressible by simple numerical values but must be shown in graphic form. Many methods have been developed, therefore, which employ not spectroscopically dispersed radiation but spectral bands, more or less narrow, isolated by selective absorption. This may be accomplished either by using transmitting materials such as colored glass, dyed gelatin, *etc.*, or reflecting materials such as pigment coated surfaces. One of the earliest of such *color sensitometers* was also devised by Abney.[108] Since that time almost numberless methods have been proposed for the measurement and expression of color sensitivity. No attempt will be made at this time to give a complete bibliography of the subject but a few references to some of the more recent work may be of interest. Leimbach[109] has made a systematic study of the spectral energy distribution for five different emulsions in the region between 450 and 700 mμ. He found the maximum sensitivity to occur in the spectral region corresponding to 450 mμ. Luckiesh, Holladay, and Taylor[110] have published sensitivity curves of four emulsions indicating a maximum sensitivity near 450 mμ. Otashiro[111] found maximum sensitivity at about 465 mμ, the sensitivity decreasing uniformly through the blue and violet. Helmick[112] (using an emulsion of the ordinary blue-sensitive type) has measured the average number of quanta required to make a silver bromide grain developable by radiation at various isolated wavelengths ranging from 253.7 to 549.0 mμ. He found that the least number of quanta per grain are required at wavelength 549 and the maximum number at wavelength 253.7 mμ. More recently Harrison[113] has published results showing the relation between sensitivity and wavelength for six different photographic plates in the region between 200 and 450 mμ. His results indicate that sensitivity is practically constant for wavelengths greater than 250 mμ, decreasing rapidly for wavelengths less than 250 mμ. He also shows the relation between contrast (gamma) and wavelength.

All methods used for obtaining information as to the spectral sensitivity of photographic materials involve the isolation of more or less narrow spectral bands and then observing either qualitatively or quantitatively the response produced when the material is exposed to these more or less homogeneous radiations. For this purpose, a wide variety of spectral instruments—monochromatic sensitometers, spectrographs, tricolor tablets, ratiometers, color charts, and filter assemblies—have been devised.

DISPERSED RADIATION METHODS

The more refined and elegant methods involve the dispersion of radiation by some suitable element, such as a prism or diffraction grating. In this way radiation of high spectral purity may be obtained to which the photographic material may be exposed. Instruments of this type may be divided, for the sake of convenience, into

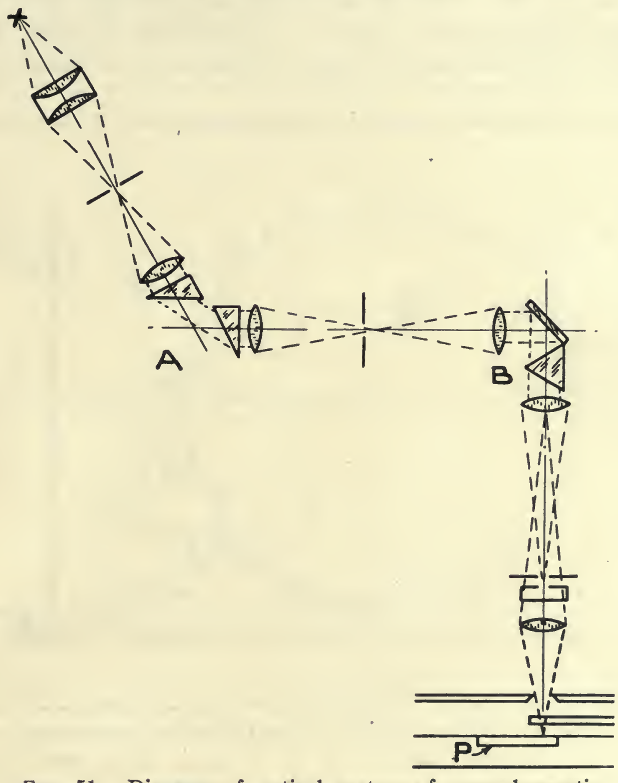

FIG. 51. Diagram of optical system of monochromatic sensitometer.

two general classes: the first including those instruments in which the photographic material is exposed to the entire spectrum at the same time; the second including those where a single very narrow band of practically homogeneous radiation is isolated, to which the photographic material is exposed in a manner similar to that used in the sensitometers already described in the earlier sections of this paper. While it is impossible to draw a strict line of demarcation, the term "monochromatic sensitometer" is usually applied to instruments of the second class, and the term "spectrograph" is used in reference to those of the first class.

Monochromatic Sensitometers.—The optical system employed for isolating monochromatic radiation of high spectral purity as used in a monochromatic sensitometer described by Jones and Sandvik[114] is shown in Fig. 51. This consists essentially of two quartz monochromatic illuminators, *A* and *B*. The radiation emerging from the exit slit of the first monochromatic illuminator, *A*, passes into the

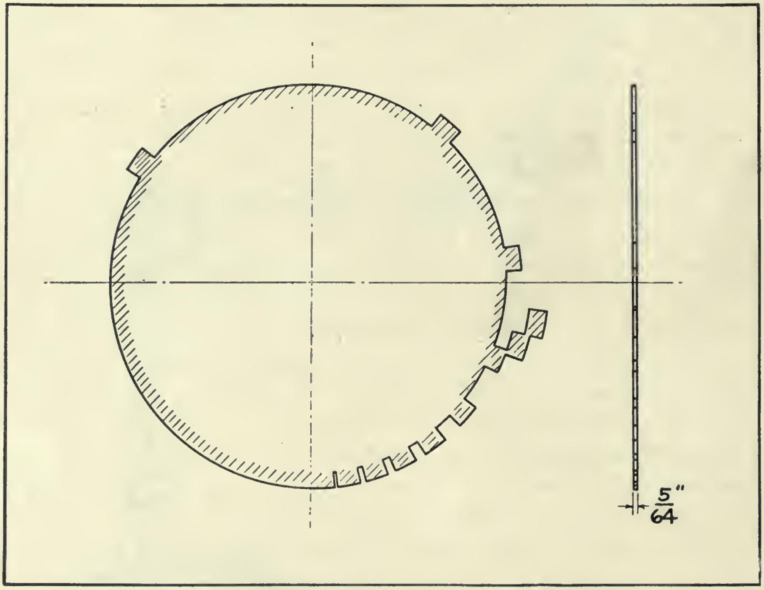

FIG. 52. The sector disk of monochromatic sensitometer.

entrance slit of the second monochromatic illuminator, *B*. In this way practically all the stray radiation may be eliminated so that the radiation emerging from the exit slit of the second monochromatic illuminator consists entirely of the wavelength as indicated by the wavelength drums of the two instruments. Great emphasis must be laid on the necessity of obtaining high purity for work of this kind, especially if it is desired to work in those spectral regions where the amount of energy obtainable from the light source used is relatively low as compared with that present in other spectral regions. For a complete discussion of this subject and of the relatively great errors which may be introduced by failure to eliminate all stray radiation, the reader is referred to the more complete discussion of the subject by Jones and Sandvik (*loc. cit.*).

After having been isolated, the homogeneous radiation is allowed to fall on the photographic plate and, by means of a suitable mechanism, the time of exposure is varied in a known manner. It is usually difficult to obtain a quantity of monochromatic radiation so that it may be spread over a sufficient area of the photographic material to permit the use of the conventional type of exposure time controlling elements. It is usually necessary, therefore, to illuminate a relatively

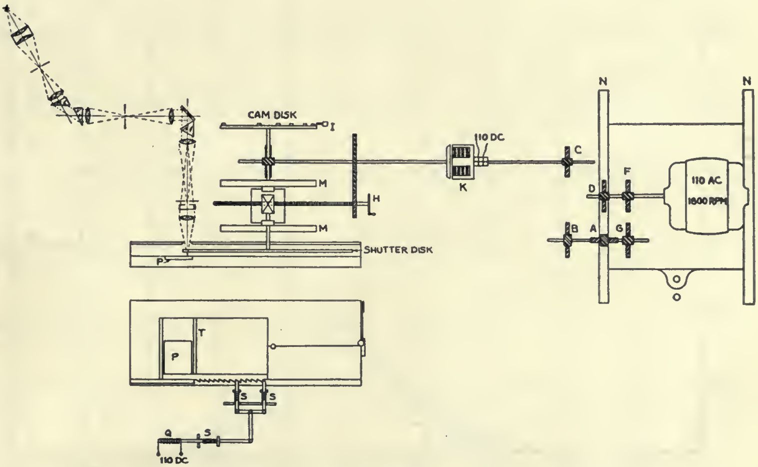

FIG. 53. Schematic diagram of monochromatic sensitometer.

small area of the photographic plate and to make the exposures of the various steps on the sensitometric strip one after the other, varying the time factor of exposure in the desired manner. The method adopted by Jones and Sandvik (*loc. cit.*) employs a sector disk of special type in which the apertures are arranged spirally around the axis of rotation, the entire disk being moved laterally, while rotating at a uniform angular velocity. The structure of this disk is shown in Fig. 52 and the arrangement of the essential parts of the exposing mechanism is shown in Fig. 53. The shutter disk as shown is keyed to the shaft carried by a movable bearing sliding between the ways *MM*. The rotation of the lead screw *H* (driven by the same shaft which imparts rotational motion to the shutter disk) moves the shutter disk laterally while it is being rotated. Mounted on the shaft carrying the shutter disk is a cam disk which carries a series of thirteen cam elements. As these cam elements rotate with the cam disk they close the electrical contact, *I*, at definitely predetermined intervals. The closing of this contact energizes the solenoid, *Q*, which, through a suitable escapement, moves the photographic plate forward one step during the time when the opaque element of the shutter disk occupies a position in the path of the exposing radiation. By utilizing the spiral arrangement of the apertures the maximum exposure time

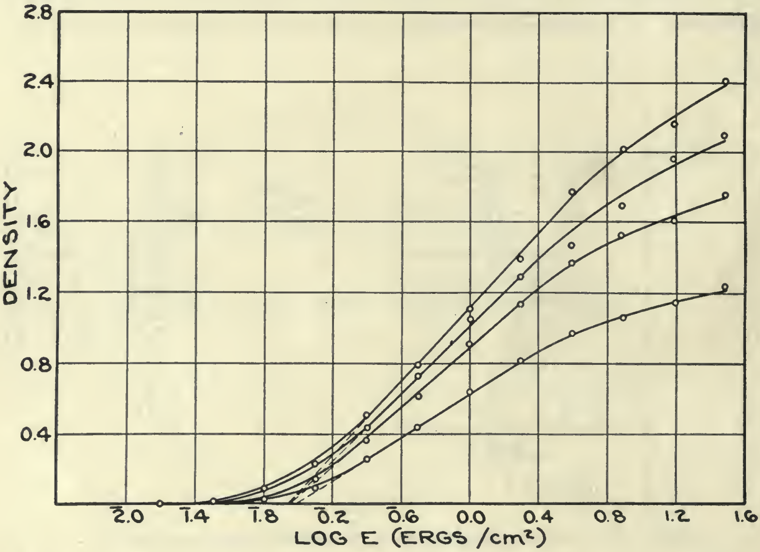

FIG. 54. *D*-log *E* curves obtained by exposing to monochromatic radiation of wavelength 350 mμ.

corresponds to an angular rotation of 720 degrees of the shutter disk. In this way twelve exposures increasing by consecutive powers of two are obtained, thus giving a range of exposure times from 1 to 2048. In this way an exposed sensitometric strip of the conventional type is obtained.

By placing a thermopile in the exposure plane of the sensitometer, that is, in the same position as that occupied by the photographic material during exposure, the energy flux density of the monochromatic radiation may be measured. Since this energy value is usually relatively small, it is necessary to use a thermopile-galvanometer combination of high sensitivity, and great care must be exercised in making the energy measurements in order to obtain reliable and precise results. The determination of these energy values with the required precision is perhaps the most difficult step in the process of obtaining absolute values of spectral sensitivity.

The monochromatic sensitometer thus gives an exposed strip of the conventional type except that the exposure values are expressed in terms of energy (ergs) per unit area. This is developed under fixed conditions, the densities read, and a curve plotted which, of course, is

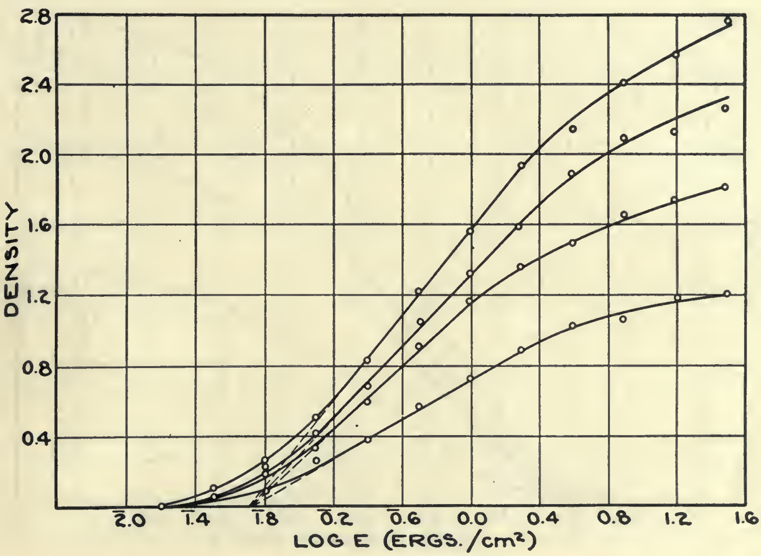

FIG. 55. *D*-log *E* curves obtained by exposing to monochromatic radiation of wavelength 450 mμ.

the density-log *E* characteristic for that particular wavelength of radiation. In making a complete study of the spectral sensitivity of the material it is necessary to expose several sensitometric strips at each wavelength. These strips are then subjected to a series of increasing development times, and in this way a complete family of characteristic curves is obtained for each wavelength. These may then be interpreted in the usual manner yielding the usual time of development-gamma curve, time of development-fog curve, *etc.*, for each wavelength. By proceeding in this manner throughout the spectrum, exposing a set of strips at a sufficient number of different wavelengths, a complete set of data is obtained from which the various spectral response curves may be plotted.

In Figs. 54, 55, 56, and 57 are shown typical families of D-log E characteristic curves obtained by exposing a panchromatic material at wavelengths 350, 450, 600, and 700 mμ, respectively. Careful comparison of these curves will show that the wavelength of radiation used in making the exposures has a profound influence upon the general shape of these curves. The development times used were 2.5, 3.5, 5, and 7.5 minutes, and it is quite evident from an inspection of

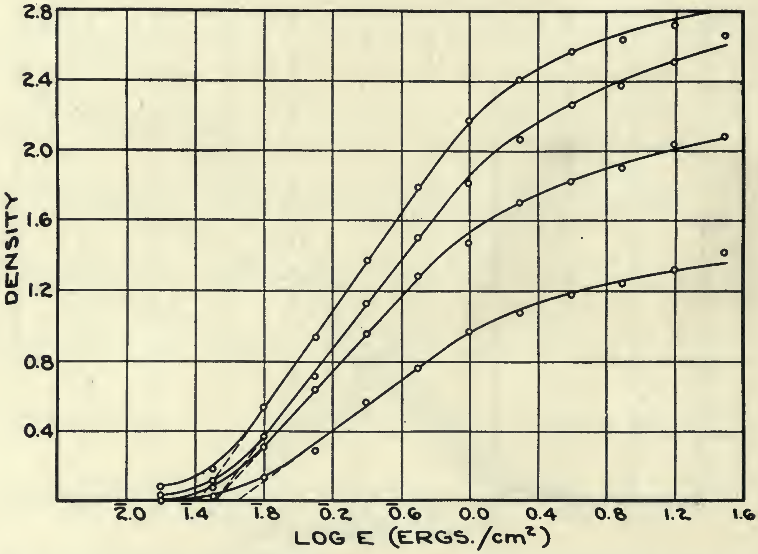

FIG. 56. D-log E curves obtained by exposing to monochromatic radiation of wavelength 600 mμ.

these figures that gamma rises to a higher value in case of the exposures made to the longer wavelengths than in case of those made to the shorter wavelengths. While photographic materials differ to a certain extent among themselves in their response to radiation of different wavelengths, the effect mentioned is rather typical, although, of course, there may be some exceptions.

In Fig. 58 are plotted the complete gamma-wavelength curves for the four times of development as mentioned previously. It is interesting to note that gamma increases from a minimum value at the short wavelength end to a maximum at approximately 550 mμ, decreasing from this point to a minimum at about 650 mμ, after which it rises again as wavelength increases. There is relatively little variation in gamma for the shortest time of development but if time of development is increased the dependence of gamma upon wavelength of the exposing radiation becomes much more marked.

In Fig. 59 is plotted a group of curves, one for each of the different wavelengths as indicated, all of these being obtained by a single time of development, namely, 5 minutes. It will be noted that there are characteristic differences depending upon the wavelength of the

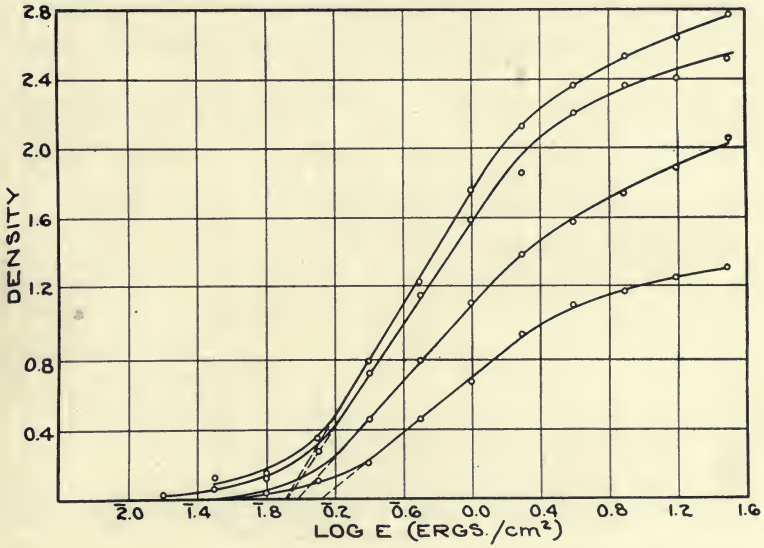

FIG. 57. *D*-log *E* curves obtained by exposing to monochromatic radiation of wavelength 700 mμ.

exposing radiation. For instance, the curves resulting from exposures to the shorter wavelengths show lower maximum densities and appreciably greater latitude than those obtained by exposures to the longer wavelengths. In plotting these curves their relative positions with respect to the log exposure axis must not be taken as indicative of the sensitivity of the material to the various wavelengths of radiation. They are assembled from left to right with increasing values of wavelength in a convenient manner to show the relative shapes. Their actual relationships to the log exposure scale are given by the values of log exposure as indicated at the intersection of the straight line portion of the characteristic curve with the log exposure axis. These values are the log exposures corresponding to the respective inertia points.

The problem of expressing sensitivity must now be considered, and it is obvious that the shape of the wavelength sensitivity curve will depend profoundly upon the manner in which sensitivity is defined. In expressing spectral sensitivity it is necessary to depart from the method which has already been defined for expressing the speed or sensitivity of a photographic material. It will be recalled that speed

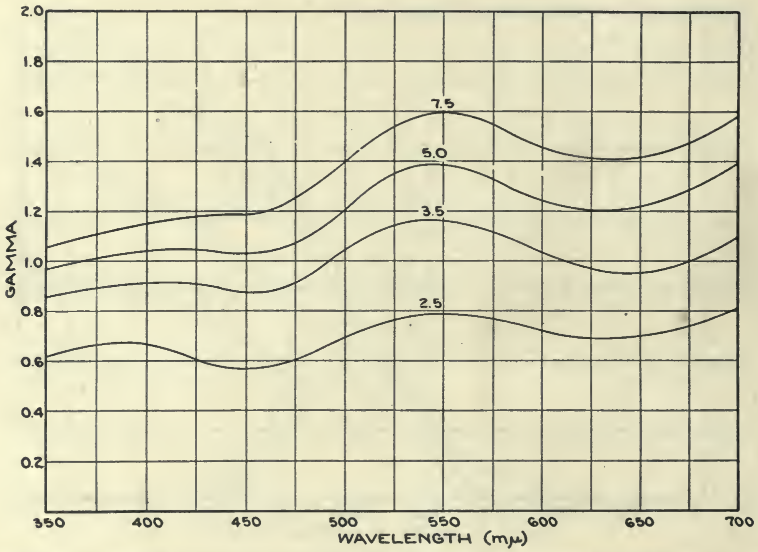

FIG. 58. Gamma-wavelength curves for various times of development as indicated.

value to heterogeneous radiation (white light) is defined, for ordinary sensitometric purposes, in terms of exposure where exposure is expressed in *meter candle seconds*. Now, the *meter candle* is a unit of illumination and is measured visually or, even if measured by some radiometric or physical method of photometry, is referred to as the unit of *luminous intensity*, the *international candle*. For the expression of monochromatic sensitometric results it is obvious that this method is quite useless. For instance, let it be assumed that monochromatic radiation of wavelength 350 mμ is used. The eye is entirely insensitive to radiation of this wavelength and hence the luminous intensity, that is, candle power, of such radiation will be zero no matter how great the radiant flux or radiant intensity (expressible in units of radiant flux or radiant flux density) may be. For the purpose of monochromatic sensitometry, it is necessary, therefore, to express exposure in terms of energy units, and the unit most usually used is the erg. Since the photographic material integrates more or less perfectly the energy which falls upon it over a period of time, it is necessary of course to include the time factor, and in expressing photographic exposure in energy units it is necessary to multiply the rate at which energy falls upon the surface (radiant flux density) by the time during which the exposure persists. Exposure, therefore, must be expressed in terms of ergs (or other suitable energy units) per unit

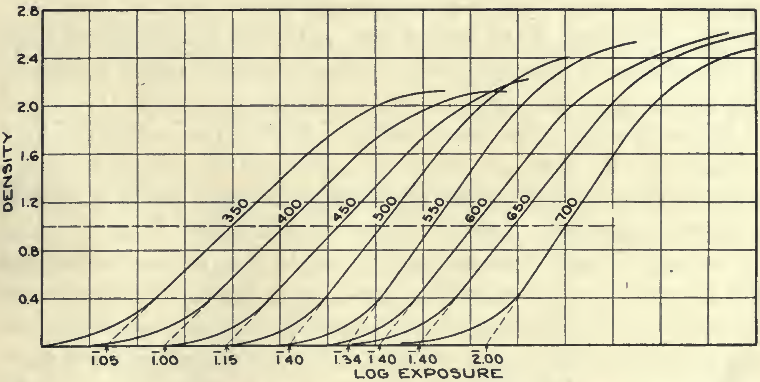

FIG. 59. *D*-log *E* curves for the various wavelengths as indicated; development time 5 minutes.

area. The abscissa values in Figs. 54 to 57, inclusive, are therefore in terms of log exposure where exposure is expressed in terms of ergs per sq. cm. We may not express the sensitivity of the photographic material for any particular wavelength in a manner analogous to that used in white light (heterogeneous radiation) sensitometry. Thus we may use the value of inertia, which now must be expressed in terms of ergs per sq. cm. as a means of deriving a sensitivity number which of course must be proportional to the reciprocal of the inertia value. Or if it is desired to use any other method of speed expression, such, for instance, as the exposure required to give a just perceptible density (threshold speed) or the exposure required to give some minimum gradient (gradient speed), this can be done; but it must be kept in mind at all times that exposure is not expressed in terms of meter candle seconds.

Having available now information as to the sensitivity of the photographic material to radiations of different wavelengths, it remains to consider a suitable method of expressing the spectral sensitivity. It is quite possible of course to compute the sensitivity at various wavelengths in terms of reciprocal inertia. By plotting these reciprocal inertia values as a function of wavelength a spectral sensitivity curve will be obtained, and for many purposes such a method of expressing spectral sensitivity seems to be quite satisfactory. It should be pointed out, however, that spectral sensitivity may be expressed in other ways, and it is possible that some of these may be somewhat more useful from the practical point of view.

Referring now to Fig. 59 it is apparent that if spectral sensitivity be defined in terms of the energy required to give a density of unity for a fixed time of development, the shape of the spectral sensitivity curve will be quite different from that based upon inertia. Moreover, if a higher density value were chosen a still further modification in the shape of the spectral sensitivity curve will be obtained. There does not seem to be any means of deciding just what mode of expressing spectral sensitivity will be found most desirable from all points of view and, in fact, it seems very probable that the method chosen must depend upon the particular problem in hand. For theoretical purposes there is considerable argument for defining spectral sensitivity in terms of the energy required to give a density of unity when development for all wavelengths is carried to a gamma of unity. For practical purposes, however, it seems that the evaluation of spectral sensitivity in terms of a fixed development time is more suitable and, in order to discount somewhat the misleading effects of gamma variation, it seems probable that the determination of the energy per unit area required to give a density of unity for a fixed time of development is most satisfactory as a mode of expressing spectral sensitivity. The most suitable development time is probably that which produces on a sensitometric strip exposed to white light a gamma approximately equal to that at which the material is usually developed in practice. In Fig. 60 is shown a spectral sensitivity curve determined in this manner. This is for high speed panchromatic motion picture film, the development time used being that which gives a gamma of 0.7 on a white light sensitometric strip.

It should be borne in mind that the spectral sensitivity curve, when plotted in accordance with the specifications given in the last paragraph, represents the characteristics of the photographic material itself, quite apart from any consideration of the energy distribution in the light source used. The curve as shown in Fig. 60 shows the response of this material when used with a light source emitting the same amount of energy at all wavelengths. In practice, light sources used for photography depart appreciably from this condition of an "equal energy" spectrum. Where it is desired to determine the effective response of a photographic material when used with a light

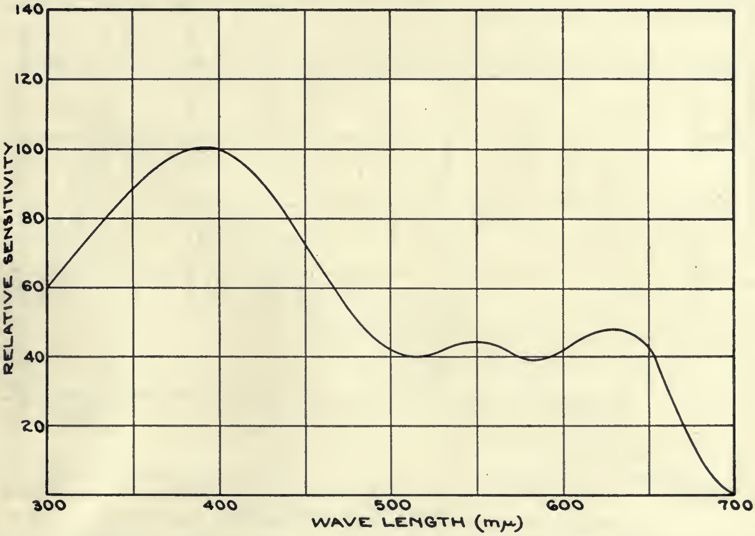

FIG. 60. Spectral sensitivity curve for a high speed panchromatic motion picture film.

source which is not emitting equal energy at all wavelengths, it is of course necessary to compute a new relationship which may be termed the *photicity* of the particular photographic material-light source combination. In considering the rendition of colored objects in practice it is very important to consider this effective response curve.

In order to illustrate the profound influence which the spectral composition of the radiation may exert on color rendition, the curves in Fig. 61 are shown. The dotted curve, *A*, represents the distribution of energy in the radiation emitted by an incandescent tungsten filament operating at a color temperature of 3000 degrees, which is an efficiency frequently met with in practice. The curve B is obtained by multiplying, wavelength by wavelength, the ordinates of curve A in Fig. 61 by the ordinates of the curve shown in Fig. 60. This then becomes the photicity curve for a 3000-degree tungsten lamp as evaluated by a high speed panchromatic material. It should be noted that the relatively small amount of energy present in this radiation at the shorter wavelengths produces a marked decrement in the *effective* response in the longer wavelength part of the spectrum. This accounts for the fact that with this combination of photographic

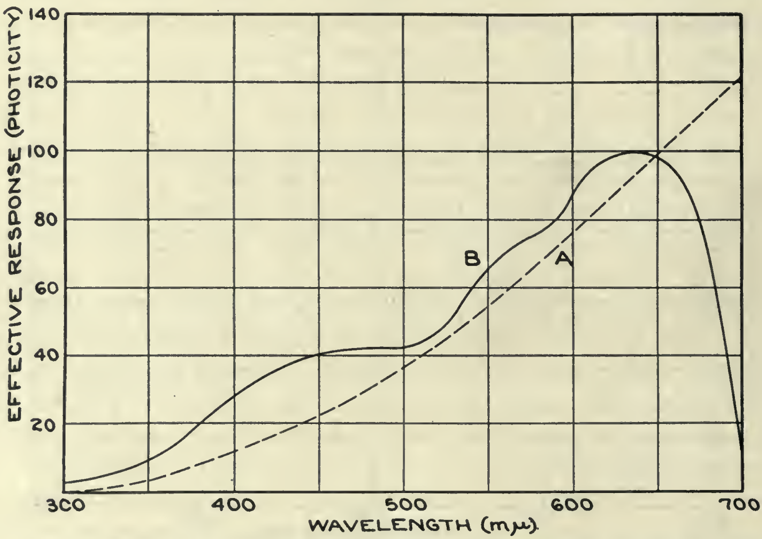

FIG. 61. Curve A, spectral energy curve of incandescent tungsten at color temperature 3000° K. Curve B, photicity curve for a 3000° tungsten lamp as evaluated by a high speed panchromatic material.

material and light source, colors such as red, orange, and yellow are rendered on the neutral tone scale by brightnesses which are relatively too high as compared with their true positions on the *visual* brightness scale.

Where a complete analysis of the spectral sensitivity characteristics of a photographic material is required, the foregoing methods are undoubtedly superior to any of the less perfect analyses which may be obtained by the use of spectrographic records or by the use of the various test chart methods relying upon selective absorption of dyes or pigments. These latter methods, however, are frequently much simpler and more rapid. In many cases they give results which are quite significant and for some practical purposes entirely adequate.

Spectrographs.—In instruments usually referred to as spectrographs the radiation from some suitable source is dispersed by means of a diffraction grating or prism, and the spectrum thus produced is allowed to fall directly upon the photographic material. The resultant spectrogram gives considerable information relative to the spectral sensitivity of the material. The method has the advantage of simplicity and rapidity. These results usually are inspected directly and estimates are made of the amount of sensitivity at various wavelengths. It is quite possible, of course, to obtain quantitative data by

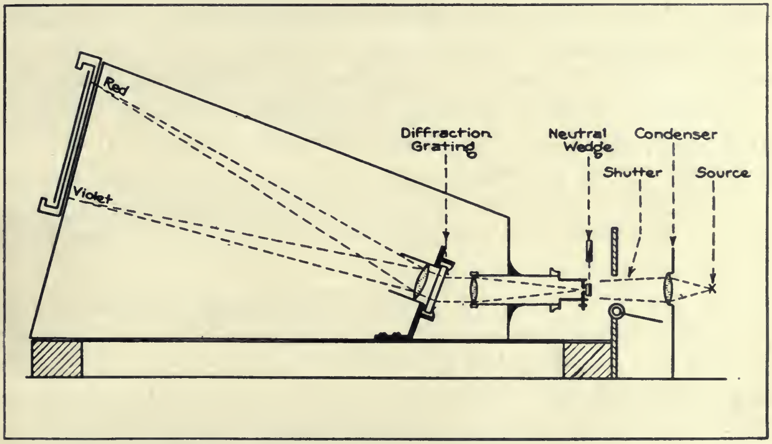

FIG. 62. Optical system of wedge spectrograph.

making densitometric measurements of the silver deposits, and under certain conditions this method may yield data of a high order of precision. The usual forms of densitometers are not adapted for reading the densities in these spectrograms and it is generally necessary to use microdensitometers which are designed to measure the density of relatively small or at least very narrow elements of the spectrogram.

It is necessary in work of this kind to know definitely the distribution of energy incident at various points on the photographic material. This may be measured directly by means of a thermopile so arranged as to pick up a relatively narrow line element in the spectrum plane. The distribution of energy may in some cases be computed. This of course presupposes a precise knowledge of the spectral emission characteristics of the light source and, furthermore, a complete knowledge of the optical characteristics of the dispersing system, such, for instance, as slit width, dispersion, losses due to reflection and scattering within the optical system, *etc.*

As stated previously, the spectrographic method is of particular utility where a graphic record meets all of the requirements of the problem. By controlling the distribution of energy incident upon the entrance slit, the spectrograph may be made to give directly a graphic representation of the effective spectral response curve of the photographic material and light source used. Instruments of this kind are usually referred to as wedge spectrographs. The distribution of radiation on the entrance slit may be controlled by a rotating sector of logarithmic form placed between the light source and the slit of the instrument. In this way the energy incident upon the slit can be made to decrease from one end of the slit to the other according to a logarithmic law. Such rotating sectors, since they must be quite small, are rather difficult and expensive to manufacture, and a better solution of the problem is obtained by using a neutral gray wedge placed directly over the slit of the spectrograph as proposed by Mees and Wratten.[115] The construction of such an instrument is shown in Fig. 62. In this a diffraction grating is used which gives normal dispersion and it is therefore considerably more convenient than prism instruments which compress into a relatively small space the long wavelength end of the spectrum and stretch out unduly the short wavelength end. A suitably engraved scale plate is placed in the plate holder so that during exposure the sensitive surface of the photographic material is in direct contact with this scale plate. In this way the wavelength scale is printed directly on the spectrogram, thus facilitating the reading of the results.

In Fig. 63 are shown examples of records obtained in the wedge spectrograph with photographic materials having various spectral sensitivities. The envelopes of the light portions constitute the spectral response curves for the various photographic materials as used with a particular light source. In the case illustrated the quality of radiation used was approximately equivalent to that of noon sunlight. It should be remembered in the interpretation of these spectrograms that the wedge used over the slit has a linear density gradient and therefore the distribution of radiation along the slit decreases logarithmically from one end to the other. These envelope curves therefore are in logarithmic form, and cannot be compared directly with spectral sensitivity curves such as are illustrated in Fig. 60 where the ordinates are relative sensitivity, not the logarithms of sensitivity.

One other fact should be kept in mind in judging these spectrograms. The apparent decrease in sensitivity at the short wavelength end is due to selective absorption in the neutral gray glass of which the wedge is manufactured. So far as the author knows, all of the so-called neutral gray glasses depart appreciably from neutrality in the wavelength region below 440 mμ, the absorption there being consider-

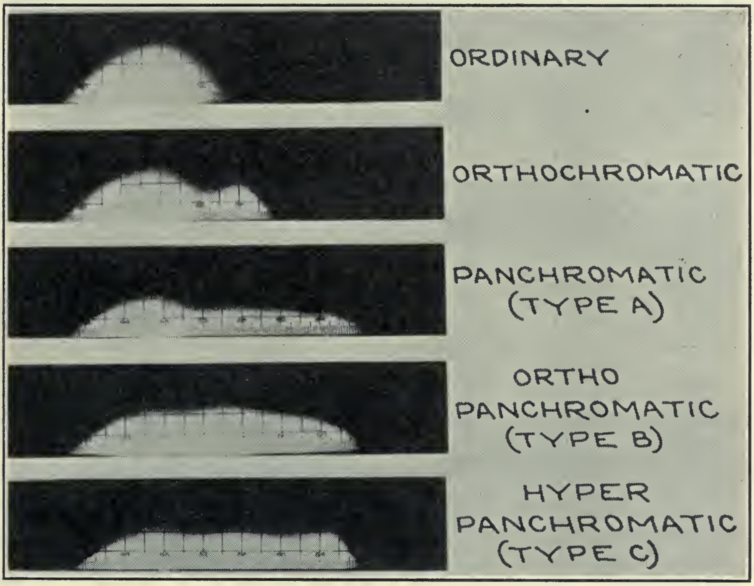

FIG. 63. Wedge spectrograms obtained with instrument illustrated in Fig. 62.

ably greater than throughout the rest of the visible spectrum. While this is inconvenient it is not particularly serious since interest is usually centered on the distribution of sensitivity for wavelengths longer than 440 mμ. It is well established also that photographic materials differ relatively little among themselves in the distribution of sensitivity in the region of shorter wavelengths. The reader should be cautioned again to remember at all times that wedge spectrograms made in this manner include not only the spectral characteristic of the material but also the spectral emission characteristic of the source used in illuminating the spectrograph.

It is possible to avoid the undesirable selective absorption characteristics of a neutral gray glass wedge by the use of a specially designed non-spherical condensing system for the illumination of the slit of the spectrograph. Such a condenser was proposed by Callier[116] and a modified form of the Callier condenser has been used by Hansen.[117] More recently Miller[118] has published a paper in which an improved form of this condenser is described. Such a condenser

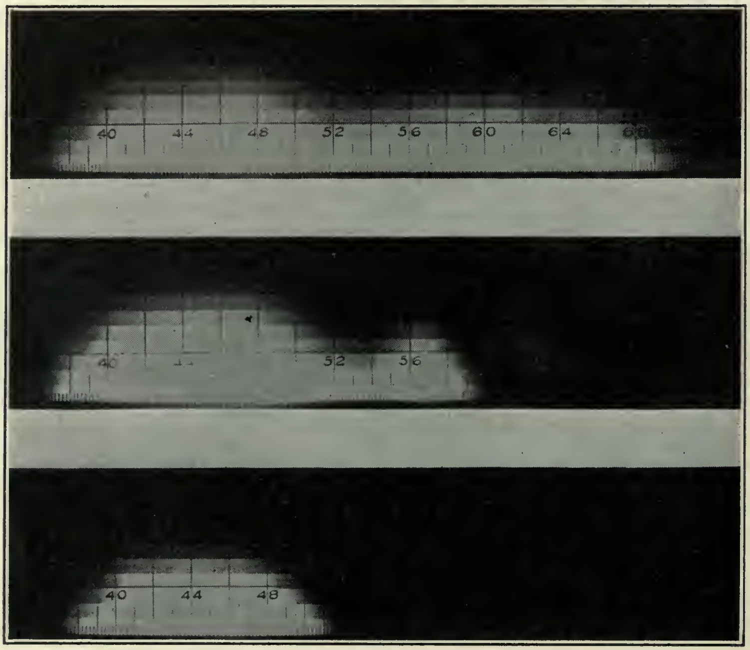

FIG. 64. Wedge spectrograms obtained with Miller's optical wedge spectrograph.

involves the use of a diaphragm which may be cut so as to give any desired distribution of illumination on the slit of the instrument. For photographic purposes a logarithmic distribution is usually most desirable and it may be made either continuous or in the form of steps as required. The form adopted by Miller is that of a stepped logarithmic diaphragm giving results as illustrated in Fig. 64 which represents the spectral sensitivity of a panchromatic, an orthochromatic, and an ordinary (blue-sensitive) photographic material. An inspection of the spectrograms in Fig. 64 will show that they carry out into the short wavelength region much better than those obtained with the neutral gray glass wedge instrument as illustrated in Fig. 63.

The use of a stepped wedge or diaphragm is particularly advantageous where it is desired to make actual density measurements and to obtain quantitative results from these wedge spectrograms. The short wavelength cut-off obtainable with an instrument of this type is determined by the absorption of the glass lenses and by the distribution of energy in the source used as an illuminant. In case it is desired to extend the work into the ultra-violet region an instrument with quartz optics may be used. In order to take advantage of this transmission, of course, it is necessary to use a light source emitting radiation throughout the ultra-violet.

An inspection of wedge spectrograms yields a great deal of information as to the distribution of sensitivity and also some qualitative idea of the variation in gamma with wavelength of the exposing radiation. They cannot be considered as satisfactory as the determinations made by methods of monochromatic sensitometry, described in a previous section, but where it is desired to have permanent comparative records which can be obtained easily and without undue labor the wedge spectrogram has much to commend it.

SELECTIVE ABSORPTION METHODS

The spectral sensitivity of a photographic material as determined by the methods of monochromatic sensitometry and by the usual spectrographic technic is most conveniently and almost necessarily expressed graphically, the usual mode being a curve showing sensitivity as a function of wavelength. It is almost impossible to express the information relative to spectral sensitivity as derived by these methods in brief numerical terms. The results of course can be shown in tabular form in which the sensitivity values are given for certain selected wavelengths, but in general such a tabulation is not particularly convenient and is too complex and voluminous for practical purposes of classification and record. In order to obtain a more simple specification of color sensitivity which can be expressed by a few numerical values, it is frequently convenient to depart from the monochromatic method and determine the response of photographic materials to relatively broad spectral bands. This may be accomplished with apparatus of the spectrographic type using, instead of very narrow spectral regions, broad bands, each embracing a relatively large proportion of the entire spectral range. If results of this type are desired it is usually much more convenient to resort to methods of selective absorption for the isolation of the desired spectral regions. Incidentally, the instrumental equipment required for this work is much less expensive than that for the spectrographic type. As mentioned previously, this method of obtaining a numerical expression for spectral sensitivity is very old, being used first probably by Abney in about 1895.[119] The test as devised by Abney consisted of a tablet made of a series of colored glasses, each transmitting a relatively broad spectral band and adjusted in such a way as to give equal illuminations. A similar method was used by Eder for testing the relative spectral sensitivity of orthochromatic plates. In his earlier work the spectrum was divided into two parts, one containing all wavelengths longer than approximately 495 mμ and the other all wavelengths shorter than this value. This wavelength represents approximately the long wavelength limit of the sensitivity of an ordinary non-color sensitized material. The values obtained by this method, therefore, give the ratio of the sensitivity due to optical sensitizing as compared to that due to the inherent sensitivity of the unsensitized silver halide. Later, Eder[120] divided the spectrum into three regions: orange-red, green, and blue-violet. E. J. Wall[121] also employed three selectively absorbing filters dividing the spectrum into three parts similar to those used by Eder. Since this early work almost numberless devices have been constructed and used, employing colored glasses, dyed gelatin, colored solutions or pigment coated surfaces for the isolation of more or less narrow spectral bands. No attempt will be made to give a complete bibliography of this subject but one or two of those methods which have been most extensively used will be described and discussed briefly.

Tricolor Filters.—Probably the most widely used method of this type involves the use of three filters having selective absorption so adjusted as to divide the visible spectrum into three approximately equal wavelength bands. As typical of such filters, the Wratten tricolor sets may be mentioned, and, in fact, since this set of filters has become almost standard throughout the world for three-color photomechanical processes, the expression of color sensitivity in terms of these three filters has become quite universal. In Fig. 65 are plotted the spectral transmission curves of the three filters in question, namely, Wratten No. 25 (*A*), red; Wratten No. 58 (*B*), green; Wratten No. 49 (*C4*), blue. The red filter (No. 25) transmits quite freely all radiation of wavelength greater than 600 mμ. It has a maximum transmission of 80 per cent, and hence is quite efficient as a means of isolating the third of the visible spectrum lying between 600 and 700 mμ. The green filter (No. 58) has a maximum transmission at wavelength 520 mμ but at this wavelength it transmits only 60 per cent of the incident radiation. Its transmission falls rapidly on both sides of this point, the lower transmission limit being approximately 480 mμ and the upper limit 600 mμ. While its total transmission computed on the basis of energy is relatively low, its transmission for white light as measured visually is relatively high since the maximum of the visual sensitivity lies at approximately 550 mμ. The blue filter (No.

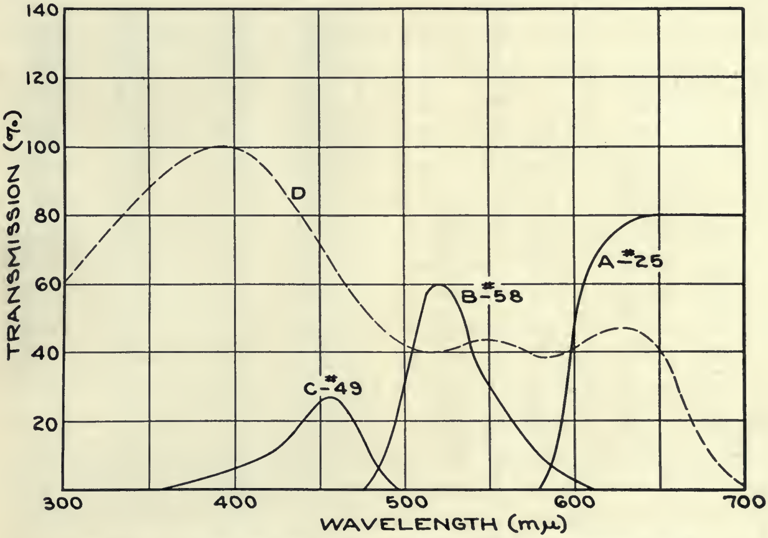

FIG. 65. Spectral transmission curves of Wratten tricolor filters.

49) has its maximum transmission at 455 mμ at which point the transmission value is only 27 per cent. For both longer and shorter wavelengths transmission decreases rapidly, the short wavelength limit being approximately 360 mμ and the long wavelength limit 500 mμ. Evaluated in terms of visual transmission for white light its efficiency is low, its transmission value determined in this manner being only 0.5 per cent. It is relatively inefficient as a means of isolating the third of the visible spectrum lying between 400 and 500 mμ, but since photographic materials in general are very sensitive in this region its photographic transmission is quite high.

For the panchromatic materials which were in use up to one or two years ago, this filter had a multiplying factor of 8 which is fairly comparable to the multiplying factors of the green and blue filters as measured in terms of these older panchromatic materials. For the panchromatic materials recently introduced, which have a much higher proportion of their total sensitivity concentrated in the green and red regions, the multiplying factor for this filter is appreciably higher, being of the order of 16.

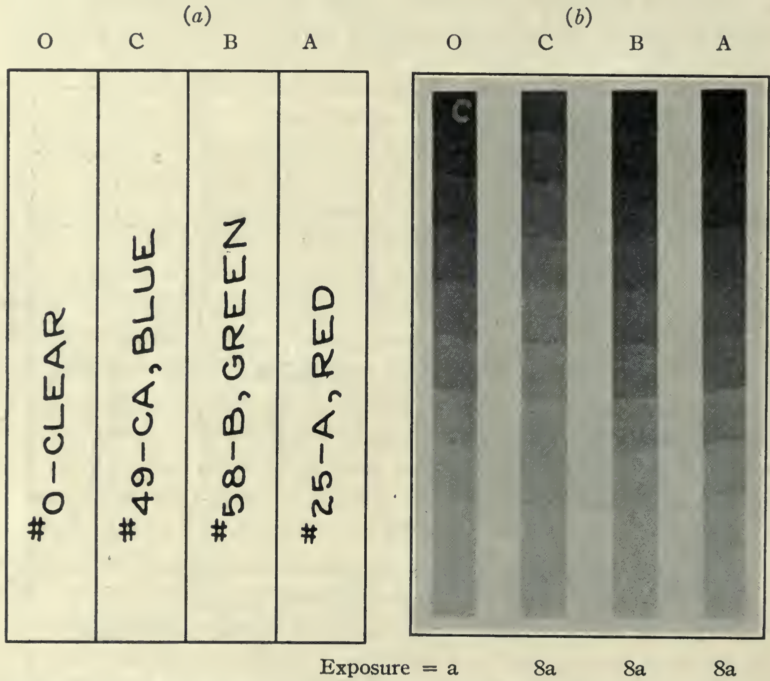

FIG. 66. (*a*) Tricolor tablet; (*b*) result obtained with tricolor filter method.

In practice, sensitometric results are obtained by using a tricolor tablet, the structure of which is illustrated at (*a*) in Fig. 66. Strips of these filters, which are manufactured in the form of dyed gelatin, together with a strip of plain (undyed) gelatin film No. 0, are cemented between two sheets of glass. The dimensions of this tablet are such that it just fits into the plate holder of a sensitometer of the ordinary *white light* type, and the strips are of such width that one sensitometric exposure is made through each of the four filters.

In order to obtain exposures through the tricolor filters, which balance fairly well with that made through the clear filter, it is customary to increase the time of the tricolor filter exposures so that it is eight times as great as that made through the clear area.

At (*b*) Fig. 66 is shown a reproduction of the result obtained by application of this method to a panchromatic material. Since the relative exposures acting on each step of the sensitometric strip are known, it is possible to estimate by inspection the relative exposures required through each of the three tricolor filters to give the same result as that obtained by the known exposure through the clear filter. This is usually and most conveniently expressed in terms of the *filter factor* for each of the tricolor filters, the filter factor being defined as the number by which the exposure incident upon the clear filter must be multiplied in order to obtain the value of the exposure which must be incident upon the filter in question so that the photographic effect on the material exposed through that filter shall be equal to that resulting from the exposure through the clear filter. In the case illustrated, the exposure increases by consecutive powers of 2 from step to step; that is, it doubles for each successive step of the sensitometric scale. The estimation of the filter factors from the sensitometric exposure made in this manner will depend to some extent on whether the equilization of density be made in the region of extremely low densities, in the region of the half-tones, or in the region of high densities. This, of course, is due to the gamma wavelength effect which, while not great in this particular case, is sufficient to affect the values of the estimated filter factors. While it may not be possible in the half-tone reproduction of this tricolor exposure to detect the small differences that were present in the original, it is quite evident from an inspection of the original that it would be necessary to multiply the exposure given through the blue filter by a factor of approximately 2 in order to make it balance the exposure through the clear filter. Since the exposure through the blue filter is already eight times that given through the clear, it follows that the exposures which would be required to produce balance between the blue and clear filter strips must be in the ratio of approximately 1 to 16. The filter factor for the tricolor blue filter, therefore, is 16. Likewise, judging the green and red exposures, also in the low density (shadow) regions, filter factor values of 8 and 6, respectively, are obtained. Now, if equilization be transferred to the half-tone regions, a somewhat different result is found. For instance, the factors for the blue, green, and red filters are 32, 6, and 4, respectively. Equilizing the response in the high density (highlight) region, values of 40, 6, and 3 for the blue, green, and red are obtained. It is customary to make this estimation of filter factor for the half-tone region, thus balancing up to a certain extent the gamma-wavelength effect.

Using this method three numbers are obtained which are a fair index of the spectral sensitivity of the material. It is possible, of course, actually to read the densities resulting from these tablet exposures and to plot the usual density-log E characteristic curves for

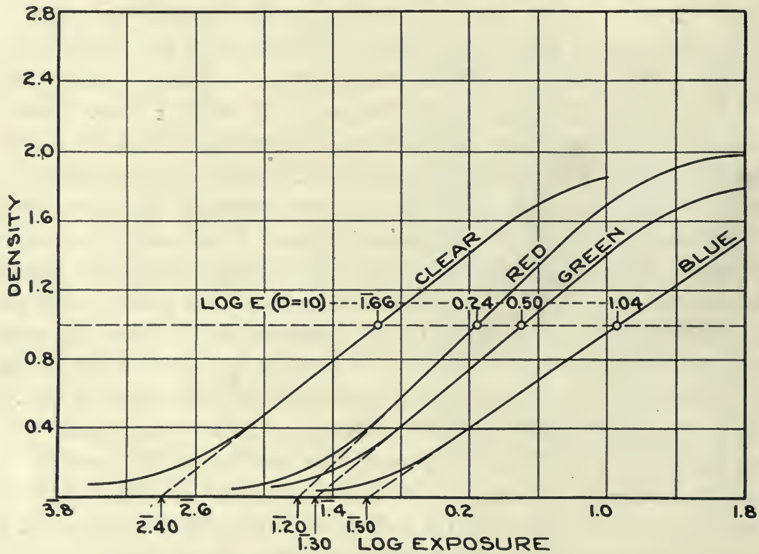

FIG. 67. Density-log E curves for the sensitometric strips illustrated in Fig. 66(b).

the four filters. This has been done for the particular sample of film from which the illustration in Fig. 66 was made. The curves obtained are shown in Fig. 67. In plotting these curves account has been taken of the fact that the A, B, and $C4$ filters had exposures eight times as long as those given through the clear filter. The curves are, therefore, placed correctly in relation to the log exposure scale. Now it is possible to determine by measurement the filter factors in terms of the inertia values, or, by drawing a horizontal line through the region of half-tones (D = 1.00 is used) and reading off the log E values where this horizontal line cuts the four characteristic curves, the evaluation of filter factor can be made in terms of the half-tone region. Results actually obtained in this manner are as follows:

Filter	Log E	$D = 0.0$ E	Factor	Log E	$D = 1.0$ E	Factor
No. 0	$\bar{2}.4$	0.0025	..	$\bar{1}.66$	0.0457	..
No. 49	$\bar{1}.5$	0.0316	12.5	1.04	1.097	24.
No. 58	$\bar{1}.3$	0.0200	8.0	0.50	0.316	6.9
No. 25	$\bar{1}.2$	0.0159	6.3	0.24	0.176	3.8

It will be noted that these do not check precisely the estimated values already given but are of approximately the same order. There is little doubt that greater precision can be obtained by reading the densities and plotting the curves as illustrated in Fig. 67, but for all practical purposes satisfactory values may be obtained by the estimation process, especially if the observer has had some experience.

In Fig. 65 the dotted curve, D, is the spectral sensitivity curve of the panchromatic material which was used in making the tricolor exposure reproduced at (b) in Fig. 66. The tricolor ratio for this material, as estimated by use of the densities lying in the half-tone region, is 16–8–6, these numbers being, as mentioned previously, the multiplying factors for the green, red, and blue filters, respectively. This conveys some idea as to the correlation existing between the spectral sensitivity of a photographic material, expressed in terms of the sensitivity-wavelength function, as derived by the methods of monochromatic sensitometry, and the tricolor ratio values, as derived by the methods of selective absorption.

In order to illustrate further the significance of these tricolor ratio values and to enable the reader to obtain a somewhat more definite correlation of these values with the spectral sensitivity functions, the data in Table XVI are given. These are the tricolor ratios obtained

TABLE XVI

Tricolor Ratios for Materials Differing in Spectral Sensitivity

Material	Filter Factors No. 49	No. 58	No. 25
Ordinary	4	..	..
Orthochromatic	6	20	..
Panchromatic (Type A)	8	14	12
Panchromatic (Type B)	10	6	10
Panchromatic (Type C)	16	8	5

by estimation in the half-tone region of tricolor exposures made on the photographic materials of which the spectral sensitivity is shown graphically in terms of wedge spectrograms in Fig. 63. For the first material which is sensitive only to blue radiation, the filter factors for the green and red filters are extremely high and of no practical interest. In the case of the second material which is sensitive only to blue and green, the filter factor for the red is of no particular interest since it is exceedingly great. For the three panchromatic materials the filter factors are as shown and a little study of these and the wedge spectrograms in Fig. 63 will show the correlation between the two modes of expressing spectral sensitivity.

Monochromatic Filters.—The general method of isolating spectral bands by means of selectively absorbing materials, as described in the previous section, may be elaborated considerably and thus provide a more detailed analysis of spectral sensitivity. For instance, it is possible to obtain filters transmitting very much narrower spectral bands than those isolated by the tricolor filters already described. The rather misleading name of *monochromatic* filters is sometimes applied to filters which transmit relatively narrow spectral bands. It is very difficult to obtain filters which transmit spectral bands less than 50 mμ wide and which at the same time have sufficiently high transmissions at the wavelengths of maximum transmission to be of use for practical purposes. By exercising great care, however, the visible spectrum extending from 400 to 700 mμ may be split into five or six non-overlapping parts and it is possible in addition to isolate one or perhaps two additional sections in the near ultra-violet between 300 and 400 mμ. Using selectively absorbing filters of this type and applying the same general sensitometric procedure which has been described under the tricolor method, six or eight numbers may be obtained, which are of course the multiplying factors for these narrow band transmitting filters. It is obvious that this gives a more complete analysis of the spectral sensitivity characteristic and from these values it is possible to obtain a fairly precise idea of the shape of the sensitivity-wavelength function. The value of such a method is somewhat doubtful since it lacks the convenience and brevity of the tricolor method, by which the result is expressed in terms of three values, and, furthermore, lacks the precision and completeness which can be obtained by the methods of monochromatic sensitometry. So far as the author is aware this method has not been applied to any great extent and it would seem wise, if high precision and complete data are required, to adopt directly the methods of monochromatic sensitometry; while, if the more convenient and simple specification in terms of filter factors is adequate for the occasion, the tricolor method seems preferable.

Progressive Cut Filters.—One other modification of the selective absorption method has been used and advocated by some workers in this field and has some merits. This involves the use of a series of filters which cut progressively at shorter and shorter wavelength values. As mentioned in the previous section, it is very difficult to obtain filters which transmit narrow spectral bands efficiently. The total transmission of such filters is usually relatively low; hence the

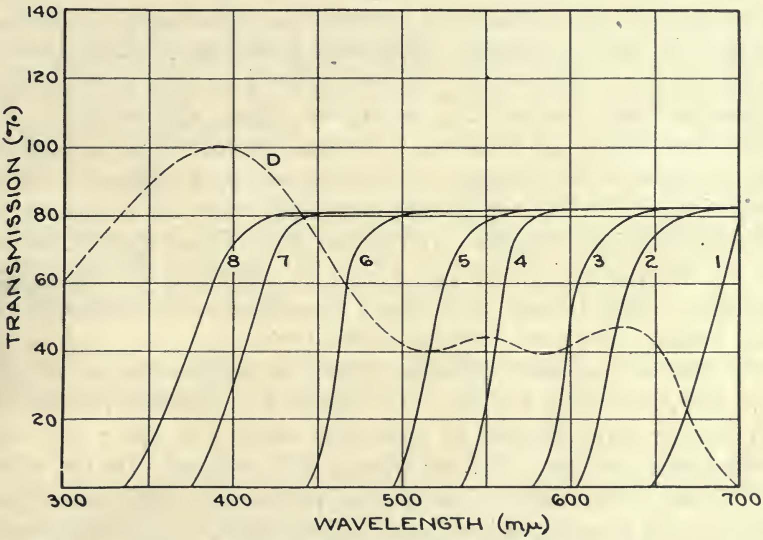

FIG. 68. Curves 1 to 8, inclusive, spectral transmission curves of a set of progressive cut filters. Curve *D*, spectral sensitivity curve of panchromatic material.

illumination which can be applied to the surface of the sensitive material is low and, therefore, exposure times are relatively long. This difficulty can be avoided by adopting the filters of the progressive cut type. Such a set is illustrated in Fig. 68. The filter represented by curve No. 1 transmits quite freely all radiations of wavelength greater than approximately 660 mμ. Exposures made through such a filter, therefore, utilize only that portion of the spectral sensitivity of the photographic material which lies on the long wavelength side of the filter cut. The dotted curve *D* (Fig. 68) again represents the spectral sensitivity curve of a highly panchromatic material, and an inspection of the figure will show to what portion of this sensitivity any exposure made through filter No. 1 is due. Filter No. 1, of course, is a deep red color. The cut of filter No. 2 moves over to approximately 610 mμ, that of No. 3 to 590 mμ, No. 4 to 540 mμ, No. 5 to 500 mμ, No. 6 to 450 mμ, No. 7 to 390 mμ, No. 8 to 350 mμ. Each filter, therefore, includes a somewhat greater portion of the spectral sensitivity of the photographic material. Exposures made through such a set of filters result in a series of sensitometric curves similar to those shown in Fig. 67. The integrated sensitivity for each successively widened spectral transmission band may be determined as previously, either in terms of the exposure corresponding to the inertia point or in terms of exposure required to give some constant density value, for instance, $D = 1.0$. By setting up a series of simultaneous equations and inserting the sensitivity values derived from the individual density-log E curves, a series of numbers can be obtained which represent the integrated sensitivity within a computed wavelength region, which, of course, depends upon the transmission characteristics of the filters. In this way a fairly good approximation to the spectral sensitivity curve may be obtained, although it is quite impossible to hope to locate all the maxima and minima which may actually occur in a function of this type.

In general, the same criticism applies to this method as to the monochromatic filter method. The results are expressed in terms of a relatively large number of numerical values and hence lack the convenience and brevity of the tricolor filter method. On the other hand, the results obtained are not as precise or complete as those derivable by means of monochromatic sensitometry. There are cases of course where the expense of the equipment required for monochromatic sensitometry is prohibitive, and in such cases the progressive cut filter method may be very desirable since it offers a somewhat more complete analysis of spectral sensitivity than can be obtained by the tricolor method.

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ERRATUM

The author regrets having to point out an error in the wording of the paragraph of the paper *Photographic Sensitometry, Part I,* on page 519 of the October, 1931, issue of the JOURNAL, beginning "A very ingenious device..." to and including "...approximately 1 to 1,000,000 for each wedge." The paragraph in question should read as follows:

"An ingenious method of obtaining directly the characteristic curve of a photographic material was suggested by R. Luther[20] in 1910, using a square neutral gray wedge behind which the photographic material under test is exposed. The resultant negative, developed preferably to high contrast, after having been rotated through 90 degrees with respect to its original position, is placed in register with the tablet through which the exposure was made so that the lines of equal density on the negative are perpendicular to the lines of equal density on the tablet. By direct observation of this tablet-negative combination the density-log E characteristic may be seen. Or, by making a print, preferably on a high contrast material, a permanent record may be obtained."

STROBOSCOPIC AND SLOW-MOTION MOVING PICTURES BY MEANS OF INTERMITTENT LIGHT*

H. E. EDGERTON**

Summary.—*In a paper published in the June issue of the* JOURNAL *the author showed that mercury-arc lamps when excited by quick violent electrical transients make a practical source of intermittent light which is very actinic and has a short duration of flash. The timing of the flashes is easily controlled.*

In this present paper, further information regarding the duration and the quality of the light are given. Also improvements upon the mercury-arc tubes are described which simplify the construction of the light-pulse tube and the electrical circuits.

Uses of intermittent light for taking motion pictures are described and illustrated by examples. There are in general two methods of using the intermittent light. One method is used to take pictures where the light is caused to flash for each frame and the film runs at a continuous speed. The second is used to take stroboscopic moving pictures of rapidly moving objects by causing the light frequency to approach the frequency of the motion of the object. Examples of the later method are shown, these being stroboscopic motion pictures of a crude motion picture claw mechanism operating at 30 fps. and of the surges in the valve springs of a gasoline engine running at 1930 rpm.

In a paper published in the June issue of the JOURNAL, the author discussed briefly some of the possibilities of the use of intermittent light in taking motion pictures and described how the mercury-arc tube could be used to produce intense light of short duration. It was shown how the method was used to study the angular swinging of synchronous machines. Since then considerable improvement has been made in the source of intermittent light and several uses for the application of the light have been made which are of interest to motion picture engineers.

Before discussing the applications of the intermittent light to motion pictures, some data will be given regarding the mercury-arc tube as a source of intermittent light.

The circuit for producing intermittent light from mercury-arc tubes has been modified so that nearly any type of mercury-arc lamp

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Massachusetts Institute of Technology, Cambridge, Massachusetts.

can be used. This circuit eliminates the necessity for the holding-arc electrodes, the auxiliary anodes, the grid around the main anode, and the mercury condensation chamber, all of which were required for tubes to be used with the circuit which was described before. Tubes now need an anode at one end, a small pool of mercury at the other, and an external electrode around the mercury pool. The shape of the tube may have practically any form. A very convenient shape to use is a long slender tube which may be placed at the focus of a parabolic reflector in order to concentrate the light.

The necessary elements and arrangement of a variable frequency source of intermittent light are shown in Fig. 1. A source of d-c. power is connected to the light-pulse tube through a choke and a resistor which are large enough to hold back the current until the tube has de-ionized, and still are small enough to allow the condenser to

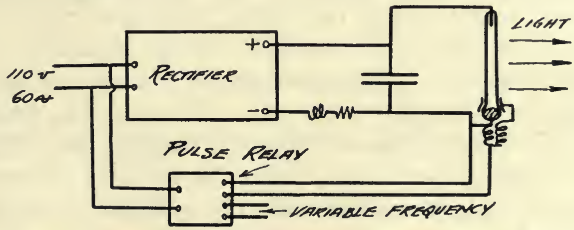

FIG. 1. Elementary wiring diagram showing an arrangement to produce intermittent light from a mercury-arc light-pulse tube.

charge in time for the next flash. The condenser is connected in parallel with the light-pulse lamp, and before a flash the condenser is charged so that the anode is positive. The tube is started by applying a sudden high voltage to the external connection around the mercury pool. This is conveniently accomplished by using a step-up transformer through which a small condenser is discharged by means of a switch or a small thyratron.

TIME DURATION OF THE FLASH OF LIGHT

One of the most important qualities of the light is the quickness of its flash. From a practical consideration the exact time of discharge is not of importance except that it must be less than a certain minimum. This minimum allowable time of flash depends upon the specific use which is being made of the tube.

If photographs of a moving object are being taken, the minimum allowable time of flash must be such that there is no appreciable motion. If motion-picture photographs are being taken or projected by means of intermittent light, the minimum allowable time of flash must be such that there is no appreciable blur on the film or screen.

Many factors influence the time of flash. Before enumerating these a brief discussion of the electrical transients, which are the source of the stroboscopic light, will be given. A condenser is charged to a certain voltage and then is discharged at the desired instant through the mercury-arc tube. This discharge is quite violent and quick and causes a pulse of light to be emitted from the tube.

When a condenser is discharged through a constant resistance the current rises to a value determined by the voltage across the condenser divided by the resistance. The current then decreases exponentially at a rate determined by the time-constant of the circuit, which is smallest for a small resistance. The mercury-arc tube acts somewhat like a small resistance and thus the condenser is quickly discharged. The light is some function of the current and thus of time. Another influencing factor in addition to the resistance of the tube and the leads is the inductance of the leads, and this tends to make the discharge oscillatory, helping to de-ionize the mercury-arc tube so that it will not conduct while the condenser is being charged for the next flash.

Factors that influence the time of discharge and which are believed to tend to increase the time are:

1. Resistance of the leads to the tube.
2. Inductance of the leads to the tube.
3. High temperature of the tube.
4. Long tube dimensions.
5. Large discharge capacity.
6. Low voltage on the condenser.

The first two do not contribute very much to the time of discharge for the usual arrangement. The third—temperature—may increase the discharge time materially but, on the other hand, a hot tube gives out much more light than a cold one for the same amount of electrical energy input to the circuit. The exact effect of tube dimensions for such transients has not been investigated thoroughly to the author's knowledge. The remaining two factors—capacity and voltage—are somewhat related since the energy of a flash is proportional to the energy stored in the condenser, that is, $E^2C/2$ joules. A large capacity requires a longer time to be discharged in a circuit of linear resistance, and it is believed that somewhat the same phenomena are involved with the mercury-arc tube. A high voltage tends to speed up the discharge especially since it aids in ionizing the gas in the tube so that it will start more quickly.

A revolving drum camera, built by Mr. C. S. Draper of the Aeronautics Department of the Massachusetts Institute of Technology, was used for the following experiments to determine the time of flash. A drum one foot in diameter was rotated at a speed of 1800 rpm. The stroboscope tube was covered, except for a narrow slit, by a piece of cardboard. The linear velocity of the periphery of the drum was $1800/60 \times 12 \times \pi = 1130$ inches per second; or one inch $= 1/1130$ sec. $= 0.00088$ sec.

The data from several runs are tabulated in Table I. These data are approximate but do show the influence of temperature.

TABLE I

Tabulation of Data Giving the Time Duration of the Light Flashes

Temperature of Tube Estimated	Capacity in Microfarads	Condenser Voltage	Length of 63% of Exposure on Film in Inches	Time Constant of Flash in Microseconds
125° C	2	1350	0.06	53
40° C	2	1350	less than 0.01	less than 9
75° C	4	1350	0.02	18

Tube dimensions: 2 ft. long, 20 mm. in diameter. Leads from condenser to tube consist of 12 ft. of lamp cord.

QUALITY OF THE LIGHT FROM THE TUBE

The spectrum of the light from a light-pulse tube is radically different from the spectrum of the light from the same tube excited with direct current. The violent electrical discharge excites many of the enhanced or spark lines in the spectrum. As a result there are ten or so additional lines in the red and a great many additional ones in the green besides other lines. The appearance of the light to the eye is yellow-white, which is quite pleasing when compared to the ghastly blue of the ordinary mercury-arc lamp.

The two spectrograms shown in Fig. 2 were taken by Mr. W. E. Albertson through the courtesy of Professor G. R. Harrison of the Physics Department of the Massachusetts Institute of Technology. These photographs show the spectrum of an ordinary mercury-arc lamp (lower) and the spectrum of the intermittent mercury-arc tube (above). The additional lines may be observed by comparing these two spectrograms. The exposures of these two spectrograms was

Red Green Blue Violet Stroboscope arc Nonex tube

Å 5461 4359 3653 3132 2804

D-C. arc in quartz tube

FIG. 2. Spectrum of the light from a quartz mercury-arc lamp and from a light-pulse stroboscope tube of nonex glass.

made so that the main arc lines of the two would have approximately the same intensity.

MOTION PICTURES WITH INTERMITTENT LIGHT

In general, there are two methods of taking motion pictures with intermittent light. One method is to synchronize the light with the position of the film so that the exposure is properly placed on continuously moving film, or so that one flash of light will occur when the shutter is open for the ordinary method of taking pictures. The second method is to synchronize the light with some rotating or vibrating object which is to be photographed. Exposures are then obtained by random coincidence of a flash of light and an open shutter, it being possible to get both more than one exposure on one frame or none, depending upon the frequency of the light flashes, the exposure angle of the shutter, and the speed of the framing mechanism. This will be discussed more completely later.

Little needs to be said of the first method. For this the intermittent light is caused to flash at the proper time by the camera mechanism so that the frames are properly spaced if they are to be projected. The flash of light needs to be short enough so that the film does not move an appreciable distance while it is on, say, for instance, one thousandth of a frame.

The upper limit of film speed for 16-mm. film with a light whose duration is ten microseconds, allowing a motion of one-thousandth of a frame, is calculated below:

The film moves 7.5/1000 mm. in 10 microseconds, whence its velocity is $(7.5 \times 10^6)/(1000 \times 10) = 750$ mm. per second, which corresponds to 100 frames per second. Allowing the film to move one-hundredth of a frame while the light is on increases the maximum allowable speed to 1000 frames per second.

The second method—that of synchronizing the light with a moving or vibrating object—is very useful in taking slow motion pictures (stroboscopic) of rapidly moving mechanisms. Say, for instance, it is desired to take a moving picture of the claw mechanism of a motion picture projector or camera while it is operating at normal speed. Obviously, it is impossible to get such a picture without a camera that will take at least eight frames while the claw mechanism completes its cycle of operations. This calls for a 192-frame-per-second camera if the speed of the claw is at 24 frames per second. The pictures would not be very clear since the claw would move quite a distance during the exposure.

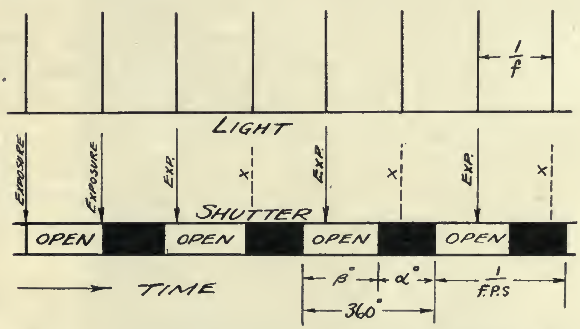

FIG. 3. Diagram showing the relation between the lowest light frequency and the camera speed and shutter exposure angle to prevent blank frames.

The motion of such claw mechanism is easily photographed with a motion picture camera if the claw is illuminated with intermittent light which has a frequency slightly different from that which corresponds to the speed of the claw mechanism. The claw is seen once each revolution in a slightly different position and as a result it appears to be moving at a slow speed. This is the well-known stroboscopic effect which has been used for studying moving mechanisms of all sorts. The mercury-arc tube is powerful enough to produce sufficient light to take motion pictures by this means.

As has been mentioned previously, the exposure of a film in an ordinary motion picture camera does not depend upon the shutter angle or speed of framing when intermittent light is used as an illumination source. The exposure is entirely determined by the amount of light in the flash from the tube. There are several possibilities which must be kept in mind regarding film speed and light frequency when taking stroboscopic motion pictures. The ideal method is to control the speed of the camera so that only one exposure occurs on each frame, but this is not possible with the constant-speed, spring-driven cameras. The exposure ratio between one and two flashes is not objectionable in a projected picture, but a blank frame causes a flicker which disturbs the continuity of the events. Fig. 3 shows the relation that exists between the light frequency and that of the camera mechanism to prevent blank frames, this relation being that the lowest frequency of the light should be equal to or greater than the frequency of the camera (frames per second) multiplied by the percentage of time that the shutter is open. This limiting condition spaces two light flashes so that if one occurs when the shutter has just opened, the other will occur when the shutter has just closed.

Since the shutter does not open and close instantaneously and because the light is practically instantaneous, it is possible to get an incomplete picture. Frame No. 12 in Fig. 4 is one of these.

FIG. 4. Stroboscopic motion pictures of a claw mechanism operating at 30 frames per second, taken with a 16 fps. camera.

EXAMPLES OF STROBOSCOPIC MOTION PICTURES (STROBOGRAMS)

The motion of a crude 35-mm. claw mechanism was photographed with a 16-mm. ciné kodak, using intermittent light which was of a slightly different frequency than the claw mechanism. The moving pictures were taken with an $f/1.9$ lens on the standard film at 16 frames per second. The claw mechanism which was photographed was operating at about 30 frames per second. Fig. 4 shows an enlarged section of this film.

The first three frames of Fig. 4 show the claw as it pulls the film down. For the frame numbered 4, the mechanism has started to pull away from the film. Frames numbered 5 to 12 show this drawing back in its various stages. The lag of the spring due to its inertia is easily observed. The next frames (13 to 21) show the return stroke of the claw. The inertia of the spring here causes it to be bent back the other way. Frame 20 shows the spring just after it has touched the guide and the end of it has bounced back. The remaining frames complete the cycle of events, showing the claw as it pulls the film down.

Twenty-four frames are shown in Fig. 4 of a phenomenon that

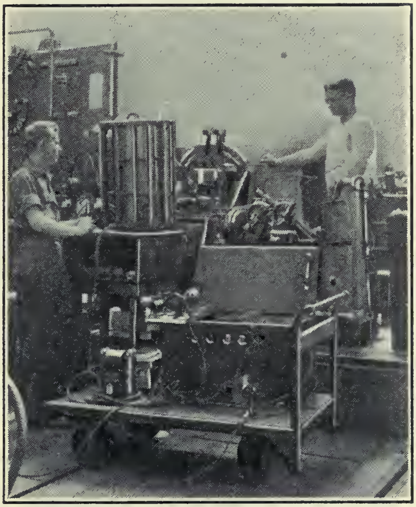

FIG. 5. Photograph of the stroboscope arranged to take motion pictures of the surges of the valve springs of an experimental engine.

occurs in one-thirtieth of a second, and so the apparent speed of the camera is 24×30 or 720 frames per second. This stroboscopic method is good only for mechanisms which are periodic, but it is very useful for this purpose.

As a second example, the oscillations or surges of a pair of valve springs were photographed in the Aeronautical Power Laboratory at the Massachusetts Institute of Technology with the coöperation of Mr. C. S. Draper and Mr. Towner. The stroboscope with its parabolic reflector is shown in Fig. 5 together with the experimental engine whose valve mechanism was photographed. The pictures show the rocker arm slowly going up and down, followed by compression waves traveling back and forth through the spring. Three enlarged pictures which were selected from a 35-mm. motion picture film are shown in Fig. 6. The top picture of the left spring shows the coils open at the top and compressed at the bottom. The

FIG. 6. Three enlarged stroboscopic photographs from a 35-mm. film of surges in a valve spring.

middle picture shows the spring still opened more between the top coils than the bottom. The lower picture shows the spring coils widely separated at the bottom and compressed at the top. The time of exposure for each of these pictures was about 0.00001 second.

SOUND IN THE LOS ANGELES THEATER—LOS ANGELES, CALIF.*

D. M. COLE**

Summary.—*The sound reproducing equipment used in the Los Angeles Theater is described in a general manner. Many refinements have been used in this installation, including aids for the hard of hearing, broadcast pick-up, and a public address system, which enable the exhibitor to furnish better entertainment and more comfort to the patrons. Means are provided for reproducing the picture and the accompanying sound in the lounge, and provision is also made for disk reproduction, in addition to film reproduction. A reproducer set is also provided for the reproduction of non-synchronous commercial records, making possible the running of continuous programs for entrance music, exit music, and sound effects.*

The trend in modern theater construction is toward larger and better equipped theaters. Mechanical and electrical devices, which enable the exhibitor to furnish better entertainment and more comfort to patrons, are being used increasingly in new theaters, refinements being added as they become available.

The Los Angeles Theater is an example which included in its construction and furnishings all available refinements. The acoustic properties of the theater were given careful consideration and, hand in hand with good sound equipment, excellent results are being achieved. In addition to the sound picture equipment, various attachments and special features have been provided. The sound facilities include sound picture reproduction, both film and disk for three projectors, hard-of-hearing aids, non-synchronous attachment, broadcast pick-up, and public address systems. Fig. 1 is a view of the equipment installed in the projection room. The amplifiers and control panels are mounted on five racks, centralizing all the panels, with the exception of the public address control equipment, which is located in a room adjacent to the projection room. Two sets of amplifiers are provided, permitting simultaneous reproduction of two programs; *i. e.*, while sound pictures are being shown in the theater auditorium, announcements

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Electrical Research Products, Inc., New York, N. Y.

can be made to other parts of the theater, if required. The duplicate set of amplifiers insures sound in the theater auditorium at all times. Switches have been used throughout in this installation, with the exception of the inputs connecting the microphones to the mixing panel, where jacks are used. Monitoring facilities for both systems are provided. Loud speakers of various types to fit the particular purpose are installed about the theater to care for the distribution of programs.

Sound Picture Equipment.—The sound picture equipment is of the largest type of Western Electric equipment supplied for *de luxe*

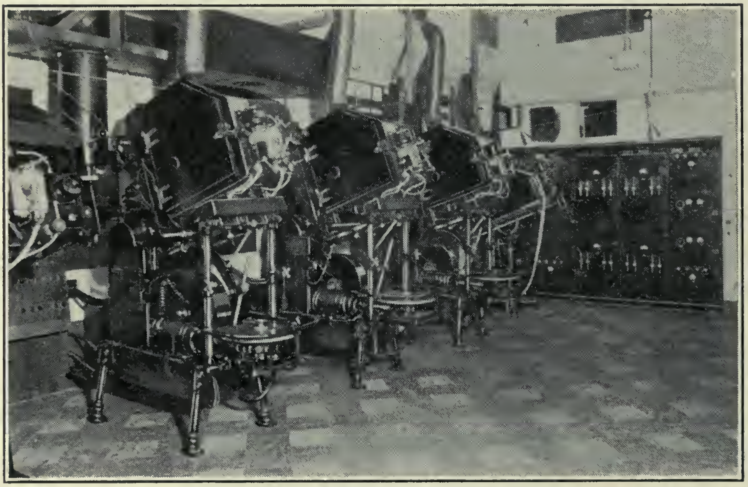

FIG. 1. View of equipment installed in projection booth.

theaters. The amplifier equipment consists of a voltage amplifier, a medium power amplifier, and two high power amplifiers. The amplifiers, with the exception of the voltage amplifiers, have "built-in" rectifiers and filters which furnish plate supply from alternating current. The plate current of the voltage amplifiers is obtained from the rectifier of the medium power amplifier with which it is associated. The filament supply for the medium and high power amplifiers is obtained from 110 volts a-c. stepped down to the proper voltage. The filament supply for the voltage amplifier is obtained from a motor generator set. Horn control panels are provided for impedance matching and testing of the horn receivers. Pick-up equipment is provided to permit the reproduction of either film or disk records on any one of three projectors. This equipment is of the universal base type.

Three shallow type stage horns, each equipped with two receivers are used behind the screen for obtaining correct illusion and distribution of sound. A large sound screen 60 by 40 feet, having a good

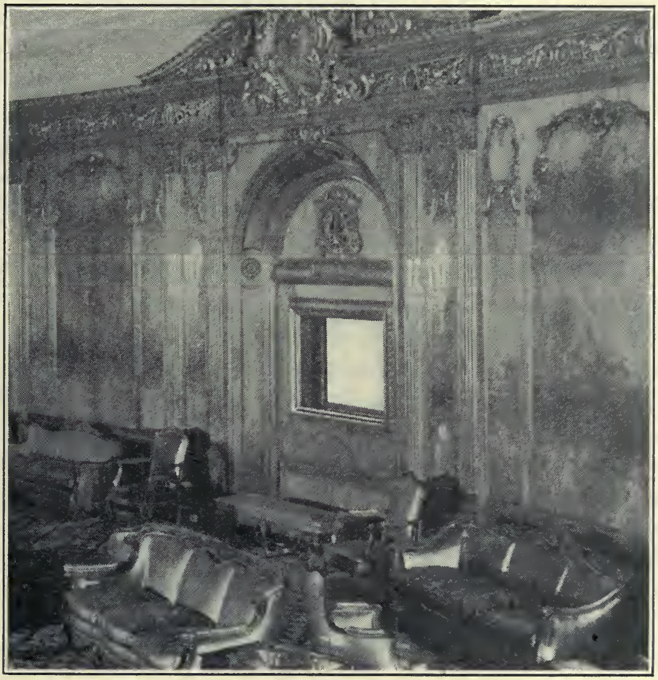

FIG. 2. View of the miniature screen which enables patrons to see in the lounge the picture simultaneously projected in the theater auditorium.

frequency transmission characteristic and good light reflecting qualities, is installed.

The volume of sound is normally controlled in the projection room but an auxiliary fader is available for use in various locations in the auditorium. The auxiliary fader is used for previews and première openings where special attention to volume is essential.

In the Grand Salon a miniature screen is provided which enables patrons to view the picture which is being shown simultaneously in the theater auditorium. This is shown in Fig. 2. The accompanying sound is reproduced by a loud speaker which is located above the screen behind the grille work.

Loud speakers are provided in two "cry rooms," enabling those viewing the picture from this point to hear the accompanying sound.

Hard-of-Hearing Aids.—Hard-of-hearing aids enable partially deaf patrons to hear both the sound picture reproduction and stage programs. Single receivers, provided with head bands, are employed. A regulating device in the cord permits the patron to adjust the volume to suit his need. The cords are equipped with plugs which are plugged into receptables installed on the arms of the seats. An a-c. operated amplifier, which obtains a small speech input voltage from one of the system amplifiers, furnishes the power for these receivers and precludes the possibility of short circuits in the hard-of-hearing aid attachment from interfering with the operation of the system with which it is associated.

Non-Synchronous Attachment.—For the reproduction of incidental music recorded at 78 rpm., a reproducer set is installed in the projection room. Two turntables with a fader make possible the running of continuous programs for entrance music, exit music, and sound effects.

Radio Broadcasting Feature.—Two amplifiers are provided to furnish programs over telephone lines to radio broadcasting stations. Programs from any of the microphone pick-up points, including the broadcasting studio, can be transmitted. The amplifiers are all a-c. operated and the necessary impedance matching and isolating transformers are provided.

Public Address.—The public address portion of this installation consists of high quality microphones of the condenser type, with their associated amplifiers, control equipment, voltage and power amplifiers, switching panels, and loud speakers of various types. Microphone outlets are provided for pick-up from the footlights, stage, the orchestra pit, broadcasting studio, foyer, check-room, and lobby. Provision is also made for a hanging type microphone over the orchestra pit. Suitable mountings are provided, depending on the location in which the microphones are used and the function which they perform. The microphones are of the same type as those used in field and studio recording. A 200-volt dry battery is provided to furnish the polarizing voltage for the condenser microphones and the plate supply for their associated amplifiers. The low voltage supply for filament currents and grid potentials is obtained from the filtered output of a motor generator set. The amplifier associated with each condenser microphone is so constructed that it is not disturbed by shocks, this being accomplished by means of spring suspension construction. The microphone pick-up control panel is located in a room adjacent to the motion picture room. From this point, the operator can observe the results of amplifying speech or music in the auditorium. The mixing facilities enable the operator of the public address equipment to blend the output of any three microphones, as required. Standard studio equipment is provided for this purpose. The public address amplifying equipment consists of two voltage amplifiers, a medium power amplifier, and two high power amplifiers. It should be noted here that additional voltage amplification over that needed for sound picture reproduction is required for public address work. The power required to operate the public address amplifiers is obtained in the same way that the power for the sound picture amplifiers is obtained. The medium power amplifier is capable of furnishing the plate supply for two voltage amplifiers.

For general reënforcement work in the theater, large horns equipped with high quality receivers, are located over the proscenium arch and in the right and left organ grilles. During operation, the volume is maintained at a point which creates the illusion to the patron that the reinforced sound is coming from the real source. The relation of the horns to the pick-up source is very important, and in general it is essential that the horns be located directly over and a little forward of this point. The dynamic loud speakers, installed in the "cry rooms," the Grand Salon, the Main Lounge, and the foyer, furnish incidental music to patrons entering and leaving the theater and to those waiting about for one reason or another.

Power Supply.—The low voltage power supply for the entire installation is obtained from two motor generator sets with associated filters. The motor generator sets can be used interchangeably and, in emergency, either would handle any load which might be required to keep the show running. They furnish low voltage to the condenser microphone amplifiers, the voltage amplifiers, the film reproducer amplifiers, signal circuits, and the fields of the horn receivers. The remainder of the equipment, including the power amplifiers, operates from the standard power supply. A voltage control cabinet is provided to care for fluctuations in the line voltage.

Conclusion.—All the equipment is of the very highest quality, from a mechanical and voice and music transmission standpoint. With the service rendered by the supplier of the equipment and the excellent work of the theater personnel, the system has been kept in operation with a minimum of trouble, in spite of the fact that the theater operates during long hours. Close coöperation between the theater management and the manufacturer of the equipment insures maximum use of the equipment, particularly the public address and special features.

There are indications that the larger first-class motion picture and legitimate theaters will soon be equipped with facilities similar to those enjoyed by the patrons of the Los Angeles Theater.

THE REDUCING ACTION OF FIXING BATHS ON THE SILVER IMAGE*

H. D. RUSSELL AND J. I. CRABTREE**

Summary.—*The extent of the reducing effect of fixing baths on the silver image during the progress of fixation is greater than has been generally supposed. For example, in sensitometric work it is dangerous to prolong the fixation of motion picture positive film in the average fresh potassium alum fixing bath beyond 5 minutes at 65°F. and with certain highly acid chrome alum baths a measurable degree of reduction occurs even in this short space of time.*

Since little or no reduction of the image occurs in an alkaline hypo solution, sensitometric tests should be checked against images fixed in a 25 per cent solution of hypo containing 1 per cent of sodium carbonate (anhydrous).

In regular laboratory work the degree of reduction which takes place in the normal time for fixation is usually of no practical importance with the baths in common use. In any given bath the rate of reduction increases with the acidity, the temperature of the bath, and degree of agitation of the film.

During use, the reducing action of a fixing bath falls off because it becomes more alkaline and accumulates silver thiosulfate which tends to retard the reduction.

In order to insure the minimum degree of reduction, baths having a minimum degree of acidity should be used although such baths have a short life and often do not harden satisfactorily. It is therefore necessary to revive such baths either by adding further quantities of acid or hardening solution at intervals during use, otherwise if the film is not rinsed in water before fixing an objectionable sludge will form in the fixing bath.

The nature of the reduction with the negative emulsions tested was found to be almost strictly proportional, and some of the more active baths enumerated could therefore be used advantageously for reducing the contrast of photographic images.

OUTLINE

I. Experimental methods.
II. Degree of reduction of the silver image in various fixing baths.
III. Effect of reduction on shape of characteristic curve.
IV. Factors affecting the rate of reduction.
  (*A*) Composition of fixing bath.
    1. Acidity (*p*H) of bath.
    2. Sulfite concentration.

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Communication No. 484 from the Kodak Research Laboratories.

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3. Hypo concentration.
4. Hardener concentration.
5. Nature of hardening agent.

(*B*) Temperature of bath.
(*C*) Degree of agitation.
(*D*) Age of bath before use.
(*E*) Nature of developer and degree of development of image.
(*F*) Concentration of exhaustion products.
(*G*) Concentration of various addition agents.
(*H*) The presence of oxygen and oxidizing agents.

V. Factors affecting the rate of reduction in solutions of plain hypo.
VI. Theoretical discussion.
VII. Summary.
VIII. Practical recommendations.

Although it is well known that under certain conditions a fixing bath may exert an appreciable reducing action on the silver image of negatives and prints, no precise data have been available on the magnitude of this effect with present-day motion picture emulsions. However, with the widespread application of sensitometry to every branch of photography and especially to the photographic recording of sound, the question of the extent of this reaction under practical conditions is of increasing importance.

I. EXPERIMENTAL METHODS

The emulsions tested are tabulated below.

Nature of Motion Picture Film	*Emulsion Number*
Panchromatic Negative, Type 2	1218
Supersensitive Panchromatic Negative, Type 2	1217
Negative	1201
Duplicating Negative	1505
Duplicating Negative	1503
Duplicating Positive	1355
Positive	1301

In the majority of the tests only a relative measure of the degree of reduction in a stipulated time was obtained when the film to be bathed was developed, fixed in the *F*-2 fixing bath, washed, and dried before treatment. In the other tests the film was developed, fixed in the bath under test for twice the time required to clear it, and then treated for a further period. A separate test strip of the film treated for twice the time to clear it was washed, and the density of the dried strip taken as the density before treatment. Film treated in this manner is termed "wet film."

The film was exposed on the Eastman sensitometer, type 2-*B*, and after processing, was bathed in the various solutions, contained in 250-cc. cylinders, for a given period of time with little or no agitation. The positive film was developed in the *D*-16* formula to a gamma between 1.0 and 1.2, and the negative film in the *D*-76** formula to a gamma between 0.6 and 0.7. All the tests were made with fresh fixing baths containing 30.0 per cent hypo unless otherwise stated.

In several experiments in which the film was agitated continuously during bathing, the film was pinned to a small drum immersed in the solution to be tested and rotated at a peripheral speed of approximately 100 feet per minute.

The progress of the reduction was determined by measuring the density removed in a given time from a step having a known density. This degree of reduction in a given time was considered as a relative measure of the rate of reduction.

The *p*H values of the solutions were determined with organic indicators in a manner similar to that described in a previous publication by the authors.[1]

II. DEGREE OF REDUCTION OF THE SILVER IMAGE IN VARIOUS FIXING BATHS

The degree of reduction of the silver image in the various fixing bath formulas published by the Eastman Kodak Company was determined with the emulsions listed previously. The constituents of the fixing baths are given in Table I in terms of grams or cubic centimeters per liter.

The degree of reduction at 70°F. with dried processed film in the fixing baths given in Table II is shown in Table II for various times of bathing. The results show that in general the rate of reduction in a

	* *D*-16	** *D*-76
Elon	0.3 gram	2.0 grams
Hydroquinone	6.0 grams	5.0 grams
Sodium sulfite (desiccated)	40.0 grams	100.0 grams
Sodium carbonate (desiccated)	19.0 grams	...
Borax	...	2.0 grams
Citric acid	0.7 gram	...
Potassium metabisulfite	1.5 grams	...
Potassium bromide	0.9 gram	...
Water to make	1.0 liter	1.0 liter

TABLE I

Constituents of Fixing Baths Used for Determining Degree of Reduction

Constituents	F-1	F-2	F-14	F-16	F-23
Hypo	300 grams	300 grams	300 grams	300 grams	300 grams
Sodium sulfite (desiccated)	15 grams	3 grams	7.5 grams	15 grams	17.5 grams
Acetic acid (glacial)	13 cc.	5 cc.	13 cc.	...	...
Sulfuric acid (concentrated)	...	...	...	2 cc.	2 cc.
Potassium alum	15 grams	6 grams	15 grams	...	...
Potassium chrome alum	...	...	...	15 grams	32 grams
Water to make	1 liter	1 liter	1 liter	1 liter	1 liter

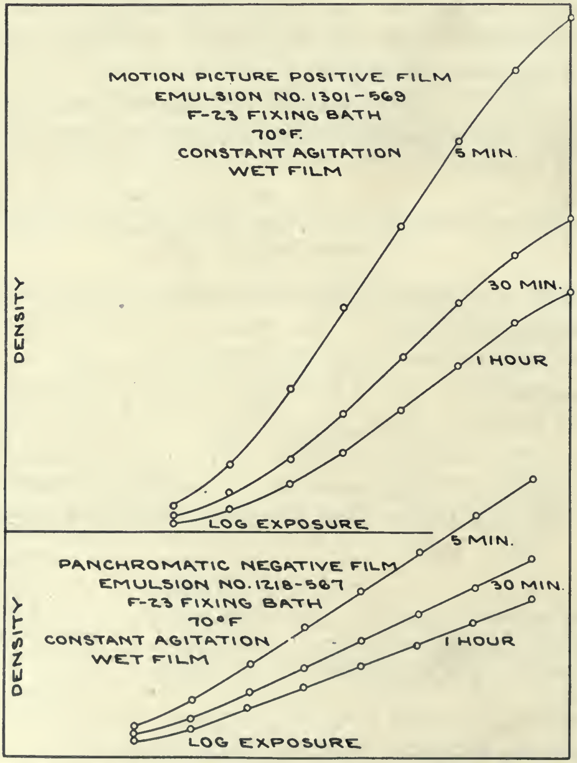

FIG. 1. Effect of reduction on the shape of the characteristic curve.

given fixing bath is dependent upon the state of division of the image. In the case of images from fine grained emulsions, the rate of reduction is much greater than with coarser grained materials such as motion picture panchromatic negative film type 2. It is also seen that the reducing action is a minimum in the case of certain potassium alum-acetic acid baths, while the maximum effect is obtained with chrome alum baths containing sulfuric acid.

III. EFFECT OF REDUCTION ON THE SHAPE OF THE CHARACTERISTIC CURVE

The effect of the *F*-23 fixing bath on the shape of the characteristic curve is shown in Fig. 1. With motion picture negative film the reducing action is almost truly proportional, while with positive film the behavior is between that of a cutting and a proportional reducer.

IV. FACTORS AFFECTING THE RATE OF REDUCTION OF THE SILVER IMAGE IN FIXING BATHS

At the outset it was considered that the rate of reduction might depend upon the following factors which were investigated.

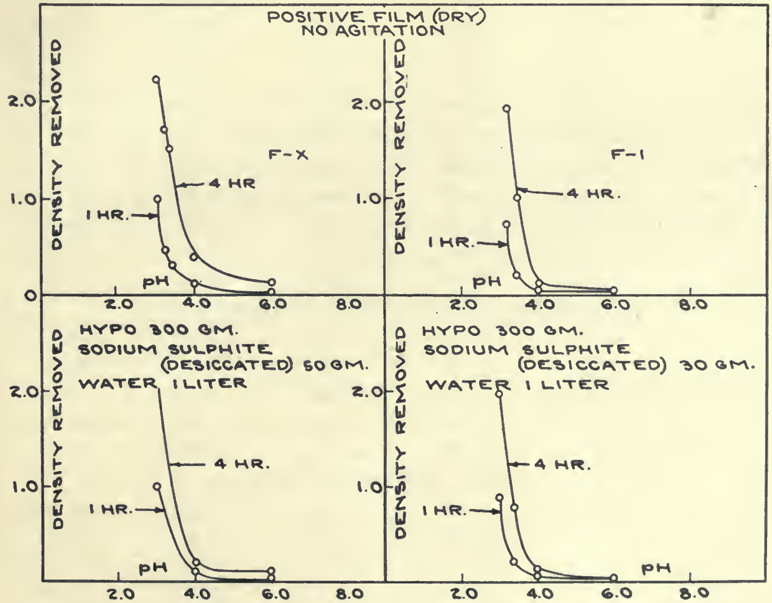

FIG. 2. Effect of *p*H on the degree of reduction in various fixing baths.

A. Composition of Fixing Bath.—1. Effect of pH on the Rate of Reduction.—The effect of the *p*H of the bath on the rate of reduction in the *F*-1 and several experimental formulas is shown in Fig. 2. The bath numbered *F-x* was an experimental bath employed in several of the tests throughout the paper and contained 30 per cent hypo, 3 per cent chrome alum, and 3 per cent sodium bisulfite. The *p*H values of the baths were varied by the addition of either sulfuric acid or sodium hydroxide. The graphs show that the rate of reduction increases rapidly for a given solution as the *p*H value is decreased below a value of 4.0. As the *p*H increases to values greater than 4.0 the rate decreases more or less rapidly depending upon the composition of the fixing bath.

TABLE II

The Degree of Reduction of the Silver Image from Different Emulsions in Various Fixing Baths

Fixing Bath	Original Density	Density Removed for Different Times of Bathing at 70°F. 30 Min.	60 Min.	3 Hours	6 Hours
		Positive Film, Emulsion 1301			
F-2	1.60	0.04	0.20	0.34	0.64
F-16	1.60	0.16	0.36	0.64	1.24
F-23	1.60	0.20	0.46	1.42	1.58
F-1	1.60	0.10	0.24	0.40	0.68
F-14	1.60	0.10	0.30	0.50	0.70
		Supersensitive Panchromatic Negative Film Type 2, Emulsion 1217			
F-2	1.36	0.06	0.06	0.16	0.30
F-16	1.36	0.06	0.16	0.24	0.36
F-23	1.36	0.12	0.44	0.60	0.98
F-1	1.36	0.08	0.10	0.20	0.40
F-14	1.36	0.08	0.10	0.22	0.42
		Panchromatic Negative Film Type 2, Emulsion 1218			
F-2	1.50	0.06	0.08	0.20	0.30
F-16	1.50	0.06	0.18	0.30	0.40
F-23	1.50	0.10	0.22	0.70	1.18
F-1	1.50	0.08	0.10	0.16	0.30
F-14	1.50	0.08	0.10	0.20	0.40
		Negative Film, Emulsion 1201			
F-2	1.50	0.08	0.10	0.16	0.26
F-16	1.50	0.10	0.30	0.40	0.50
F-23	1.50	0.16	0.30	0.70	1.28
F-1	1.50	0.08	0.10	0.20	0.30
F-14	1.50	0.10	0.18	0.28	0.40

TABLE II *(continued)*

The Degree of Reduction of the Silver Image from Different Emulsions in Various Fixing Baths

Fixing Bath	Original Density	Density Removed for Different Times of Bathing at 70°F. 30 Min.	60 Min.	3 Hours	6 Hours
		Duplicating Negative Film, Emulsion 1505			
F-2	1.24	0.04	0.12	0.20	0.42
F-16	1.24	0.08	0.20	0.32	0.96
F-23	1.24	0.10	0.30	0.82	1.14
F-1	1.24	0.04	0.14	0.24	0.52
F-14	1.24	0.10	0.18	0.34	0.60
		Duplicating Negative Film, Emulsion 1503			
F-2	1.40	0.04	0.12	0.20	0.38
F-16	1.40	0.10	0.20	0.42	0.98
F-23	1.40	0.16	0.34	0.90	1.26
F-1	1.40	0.06	0.10	0.16	0.36
F-14	1.40	0.10	0.16	0.26	0.50
		Duplicating Positive Film, Emulsion 1355			
F-2	1.64	0.08	0.14	0.24	0.40
F-16	1.64	0.14	0.24	0.40	0.84
F-23	1.64	0.14	0.34	0.86	1.40
F-1	1.64	0.06	0.14	0.34	0.50
F-14	1.64	0.10	0.24	0.40	0.64

2. *Sulfite Concentration.*—The effect of the concentration of sulfite was determined by the addition of increasing quantities of sodium bisulfite to a solution containing 30 per cent hypo. The results in Fig. 3 are given for two *p*H values. The value of 4.4 was that of the plain solutions, while the value of 3.0 was chosen arbitrarily and was obtained by the addition of sulfuric acid. The data indicate that for a solution containing 300 grams of hypo per liter an increase in the sulfite concentration at a constant *p*H value increases the rate of reduction of the silver image. The rate of reduction was very much greater at a *p*H value of 3.0 than at 4.4. Similar results were obtained when equivalent quantities of sodium sulfite were substituted for sodium bisulfite.

3. *Hypo Concentration.*—A decrease in the concentration of hypo for a given sulfite concentration and *p*H value decreased the rate of reduction as is shown by experiments 3, 4, 5, and 6 in Table III-A. Tests were also made which indicated that with concentrations of hypo greater than 30 grams per liter the rate of reduction decreases.

TABLE III-A

The Effect of Various Reagents on the Degree of Reduction of the Silver Image in Fixing Baths

No.	Nature of Bath	Hypo (Grams per Liter)	Sodium Bisulfite (Grams per Liter)	Sulfuric Acid 10% (Cc. per Liter)	Time of Bathing at 70°F. (Hrs.)	*p*H	Original Density	Density Removed	Color of Image	Remarks
1		300	50	0.0	1.0	4.4	3.08	0.45	Black	
2		300	50	40.0	1.0	3.2	3.08	1.94	Brown	
3		300	10	0.0	1.0	4.4	3.08	0.17	Black	
4		300	10	40.0	1.0	3.2	3.08	1.20	Brown	
5		10.0	10	0.0	1.0	4.4	3.08	0.10	Black	
6		10.0	10	40.0	1.0	<3.0	3.08	0.12	Black	Sulfurized
7*		300	50	40.0	1.0	3.2	3.06	2.00	Brown	
8*		75.0	12.5	40.0	1.0	3.2	3.06	1.40	Black	
9*		37.5	6.25	20.0	1.0	3.0	3.06	0.70	Black	
10*		18.75	3.12	20.0	1.0	3.0	3.06	0.46	Brown	
11	*F*-1	..	..	..	1.0	3.8	3.08	0.16		
12	*F*-1	..	..	10.0	1.0	3.6	3.08	0.20		
13	*F*-1	..	..	20.0	1.0	3.4	3.08	0.35		
14	*F*-1	..	..	40.0	1.0	3.0	3.08	1.58		Sulfurized

* Equal ratio of sulfite and hypo.

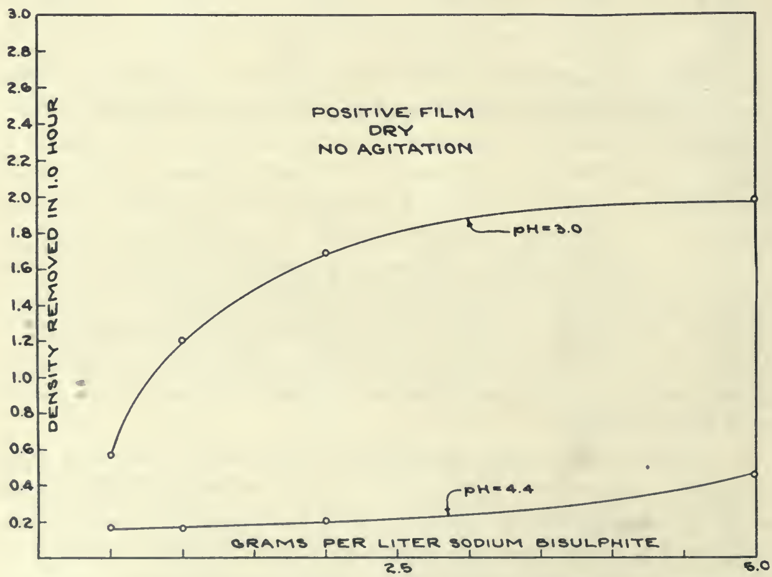

FIG. 3. Effect of sulfite concentration on the degree of reduction.

TABLE III-B

The Effect of Various Reagents on the Degree of Reduction of the Silver Image in Fixing Baths

No.	Nature of Bath	Nature of Substance Added	Conc. of Substance Added (Grams per Liter)	Time of Bathing at 70°F. (Hrs.)	*p*H	Original Density	Density Removed	Color of Image
15	*F-x*			1.0	3.0	3.08	1.94	Brown
16	*F-x*	Silver Iodide	1.0	1.0	3.0	3.08	1.55	
17	*F-x*	Silver Iodide	10.0	1.0	3.0	3.08	0.30	
18	*F-x*	Silver Iodide	100.0	1.0	3.0	3.08	0.10	
19	*F-x*	Silver Bromide	1.0	1.0	3.0	3.08	1.90	
20	*F-x*	Silver Bromide	10.0	1.0	3.0	3.08	1.20	
21	*F-x*	Silver Bromide	100.0	1.0	3.0	3.08	0.10	
22	*F-x*	Potassium Bromide	1.0	1.0	3.0	3.08	2.00	Brown
23	*F-x*	Potassium Bromide	10.0	1.0	3.0	3.08	2.30	Brown
24	*F-x*	Potassium Bromide	100.0	1.0	3.0	3.08	2.55	Brown
25	*F-x*	Potassium Iodide	1.0	1.0	3.0	3.08	1.94	Brown
26	*F-x*	Potassium Iodide	10.0	1.0	3.0	3.08	2.50	Brown
27	*F-x*	Potassium Iodide	100.0	1.0	3.0	3.08	3.08	Brown
28	*F-x*	Ammonium Chloride	10.0	1.0	3.0	3.08	2.08	
29	*F-x*	Ammonium Chloride	100.0	1.0	3.0	3.08	2.50	
30	*F-x*	Ammonium Sulfate	100.0	1.0	3.0	3.08	1.00	
31	*F-x*	Sodium Chloride	100.0	1.0	3.0	3.08	1.10	
32	*F-x*	Methylene Blue	10.0	1.0	3.0	3.08	1.20	

Further tests were made to determine if the rate of reduction was dependent upon the concentration or ratio of sulfite to hypo. The results of experiments 7, 8, 9, and 10 in Table III-A indicated that the rate of reduction decreased as the concentration of hypo and sulfite were decreased in equal proportions.

4. Hardener Concentration.—The effect of hardener concentration on the rate of reduction, degree of hardening, and *p*H value of the *F*-1* and *F*-2** formulas is shown in Fig. 4 from which it is seen that, if the hardener concentration is decreased to one-half its normal value, the degree of reduction is also decreased approximately one-half,

* *F*-1.—For use add 125 cc. *F*-1*a* hardener to 1.0 liter of hypo solution.

** *F*-2.—For use add 50 cc. *F*-2*a* hardener to 1.0 liter of hypo solution.

	Hardener Formulas	
	F-1*a*	*F*-2*a*
Sodium sulfite (desiccated)	120 grams	60 grams
Acetic acid (glacial)	105 cc.	100 cc.
Potassium aluminum alum	120 grams	120 grams
Water to make	1 liter	1 liter

while the degree of hardening is not seriously affected. A further decrease in the hardener concentration does not produce a corresponding decrease in the rate of reduction and lowers the degree of hardening to a value which is too low for practical purposes.

5. *Nature of Hardening Agent.*—In Table IV are given figures comparing the extent of the reduction, obtained with the *F*-1 and *F*-16 formulas, for equal *p*H values. The *p*H values were adjusted by the addition of either sodium hydroxide or sulfuric acid.

The results in Table IV indicate that the rates of reduction were

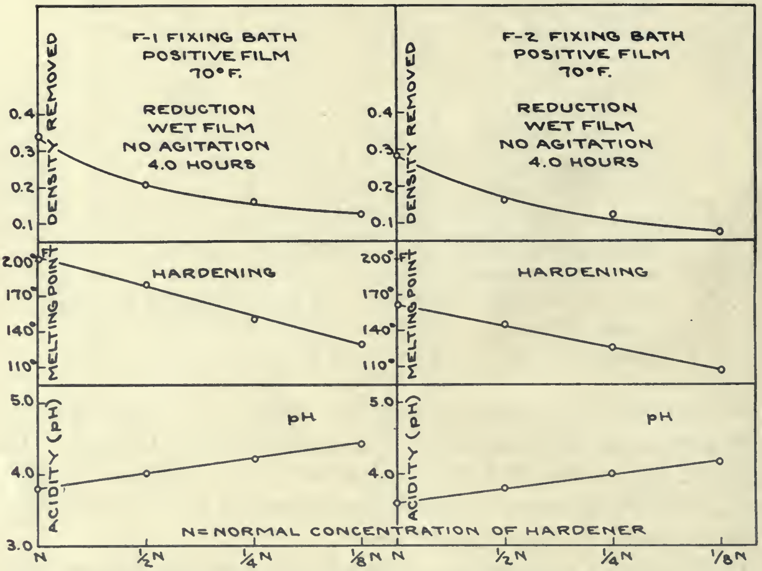

FIG. 4. Effect of the hardener concentration on the degree of reduction, degree of hardening, and *p*H of the *F*-1 and *F*-2 formulas.

similar for potassium alum and chrome alum baths for equal sulfite concentrations and *p*H values.

B. Effect of Temperature on the Rate of Reduction.—The effect of temperature on the rate of reduction of the silver image with dry motion picture positive film is shown in Fig. 5 for the *F*-2 and *F*-23 fixing baths. The results indicate that as the temperature is increased from 50° to 90°F., the rate of reduction also increases and the effect of temperature was much greater with the *F*-23 formula than with the *F*-2 formula. In the *F*-23 bath the degree of reduction in a given time was increased approximately ten times for an increase in tempera-

TABLE III-C

The Effect of Various Reagents on the Degree of Reduction of the Silver Image in Fixing Baths

No.	Nature of Bath	Treatment with Gas	Nature of Substance Added	Conc. of Substance Added (Grams per Liter)	Time of Bathing at 70°F. (Hrs.)	*p*H	Original Density	Density Removed	Color of Image
33	*F-x*	None			2.0	3.0	3.08	2.30	
34	*F-x*	Air			2.0	3.0	3.08	2.54	
35	*F-x*	Carbon Dioxide			2.0	3.0	3.08	2.38	
36	*F*-1	None			2.0	3.8	3.08	0.80	
37	*F*-1	Air			2.0	3.8	3.08	1.80	
38	*F*-1	Carbon Dioxide			2.0	3.8	3.08	1.40	
39	*F*-1	.....			6.0	3.8	3.17	0.30	Black
40	*F*-1		Sodium Perborate	10	6.0	3.8	3.17	0.50	Black
41	*F*-1		Hydrogen	100 cc.	6.0	3.8	3.17	0.45	Black
42	*F-x*		Peroxide		1.0	3.0	2.10	0.90	Brown
43	*F-x*		Sodium Sulfate	10	1.0	3.0	2.10	0.70	Brown
44	*F-x*		Sodium Sulfate	100	1.0	3.0	2.10	0.36	Black
45	*F-x*		Sugar	10	1.0	3.0	2.10	0.90	Brown
46	*F-x*		Sugar	100	1.0	3.0	2.10	0.70	Brown
47	*F-x*		Glycerin	10	1.0	3.0	2.10	0.80	Brown
48	*F-x*		Glycerin	200	1.0	3.0	2.10	0.50	Brown

TABLE IV

A Comparison of the Degrees of Reduction in Potassium Alum and Chrome Alum Fixing Baths

Fixing Bath	Concentration of Alum (Grams per Liter)	Concentration of Sulfite (Grams per Liter)	*p*H	* Time of Bathing (Hours)	Original Density	Density Removed
F-1	15	15	3.8	4.0	1.60	0.30
F-1	15	15	3.6	4.0	1.60	0.40
F-1	15	15	3.4	4.0	1.60	0.94
F-1	15	15	4.0	4.0	1.60	0.22
F-1	15	15	4.8	4.0	1.60	0.16
F-16	15	15	3.4	4.0	1.60	0.96
F-16	15	15	3.2	4.0	1.60	1.40
F-16	15	15	3.0	4.0	1.60	1.50
F-16	15	15	4.0	4.0	1.60	0.30
F-16	15	15	4.4	4.0	1.60	0.18

* Positive film (wet).

ture from 65° to 95°F., while with the *F*-2 formula the increase was only about four times.

C. Effect of Agitation on the Rate of Reduction.—The effect of agitation on the rate of reduction with wet and dry film is shown in Table V.

TABLE V

Effect of Agitation on the Rate of Reduction at 70°F.

Fixing Bath	Emulsion	Original Density	Time of Bathing	Density Removed: Constant Agitation Wet Film	Density Removed: Constant Agitation Dry Film	Density Removed: No Agitation Wet Film	Density Removed: No Agitation Dry Film
F-2	1301	1.70	30 Min.	0.14	0.10	0.00	0.00
F-2	1301	1.70	4 Hrs.	1.40	1.16	0.60	0.30
Hypo 30%	1301	1.70	1 Hr.	0.50	0.60	0.06	0.08
Hypo 30%	1301	1.70	4 Hrs.	1.30	1.30	0.16	0.19
F-23	1218	1.34	30 Min.	0.34	0.18	0.12	0.06
F-23	1218	1.34	1 Hr.	0.52	0.36	0.32	0.14

The results indicate that with constant agitation, as compared with no agitation, the amount of reduction in the case of positive film was increased about ten times, while with negative film the rate was approximately doubled. Also, the degree of reduction obtained was much greater with the wet film previous to drying than with the dry film.

D. Effect of Age before Use.—The effect of age of the fixing baths before use on the rate of reduction is shown in Table VI, from which it is seen that: (1) the rate of reduction in potassium alum fixing baths did not change appreciably on storage for 10 days before use, and (2) the reducing action of the chrome alum fixing baths decreased with age owing to an increase in the *p*H value of the solutions.

TABLE VI

Effect of Age before Use on Rate of Reduction

Fixing Bath	Age (70°F.)	*p*H	*Time of Bathing	Original Density	Density Removed
F-1	Fresh	3.8	4.0 Hrs.	1.54	0.30
F-1	10 days	3.8	4.0 Hrs.	1.54	0.28
F-2	Fresh	3.6	4.0 Hrs.	1.54	0.26
F-2	10 days	3.6	4.0 Hrs.	1.54	0.26
F-16	Fresh	3.4	4.0 Hrs.	1.54	0.98
F-16	10 days	3.8	4.0 Hrs.	1.54	0.60
F-23	Fresh	3.2	4.0 Hrs.	1.54	1.22
F-23	10 days	3.6	4.0 Hrs.	1.54	0.80

* Positive film (dry).

E. Effect of Nature of Developer and Degree of Development.—At the outset it was considered that the rate of reduction under any given conditions would depend on the size of the silver grains which, in turn, is determined by (*a*) the nature of the emulsion, (*b*) the nature of the developer, and (*c*) the degree of development or "gamma."

Motion picture panchromatic negative film was developed in formulas *D*-16 and *D*-76 to equal gammas and then bathed in the *F*-23 fixing bath. From the results in Table VII it is seen that equal degrees of reduction were obtained for equal densities regardless of the degree of development or the nature of the developer.

TABLE VII

Effect of Degree of Development and Nature of Developer on the Degree of Reduction

Developer	Fixing Bath	Time of Dev. (Min.)	Gamma	Original Density	Density Removed	* Time of Bathing
D-16	*F*-23	2.5	0.30	0.60	0.10	1.0 Hr.
D-76	*F*-23	4.0	0.30	0.60	0.08	1.0 Hr.
D-16	*F*-23	5.0	0.80	0.60	0.10	1.0 Hr.
D-76	*F*-23	15.0	0.80	0.60	0.11	1.0 Hr.

* Negative film (emulsion 1218) wet.

F. Effect of Exhaustion Products on Rate of Reduction.—With use the chemical nature of the fixing bath changes. The undeveloped silver halide grains are dissolved from the emulsion and accumulate in the bath as complex silver thiosulfates and sodium halides. Experiments 15 to 21, inclusive (Table III-B), indicate that the addition of silver bromide or silver iodide to the *F-x* fixing bath decreases the rate of reduction.

Practical exhaustion tests were made with the *F*-2 and *F*-23 formula in order to determine the effect of exhaustion with developed and undeveloped positive film on the rate of reduction. The results are shown in Fig. 6 from which it is seen that the rate of reduction is less in a bath exhausted with developed film than in one exhausted with undeveloped film. In the case of the bath exhausted with undeveloped film, the *p*H value remained practically constant, while with the developed film the *p*H of the bath gradually increased during exhaustion, which may have caused a decrease in the rate of reduction.

The effect of removing the silver from an exhausted fixing bath on the rate of reduction was investigated. The silver was removed by an electrolytic method similar to that used in actual practice.[2] The

F-2 fixing bath was exhausted with undeveloped motion picture panchromatic negative film (type 2) to the extent of 250 feet per gallon when the silver content was 7 grams per liter. The silver was then removed by electrolysis and the bath exhausted further to 200 feet per gallon or a total footage of 450 feet per gallon which is equivalent to 13 grams of silver per liter. The *p*H value and sulfite

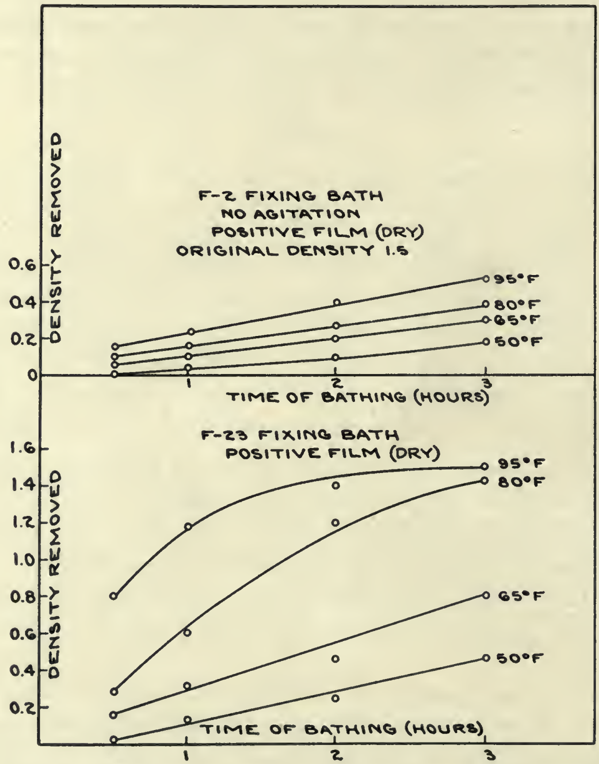

Fig. 5. Effect of temperature on the degree of reduction with the *F*-2 and *F*-23 fixing baths.

concentration of the solution changed during the electrolysis but were maintained constant by additions of sulfite and alkali. The reduction tests were made with wet motion picture positive film during the last stage of the electrolysis, that is, when the solution contained less than 3 grams of silver per liter and also after all the silver was removed. The tests in every case indicated that the degree of reduction obtained in an exhausted *F*-2 fixing bath from which the silver had been removed was less than that obtained in the fresh solution.

The fixing bath also becomes contaminated during use with partially exhausted developer, which in the case of a hydroquinone developer consists of sodium halides, sodium sulfite, hydroquinone sulfonates, and alkali. The hydroquinone sulfonates are the result

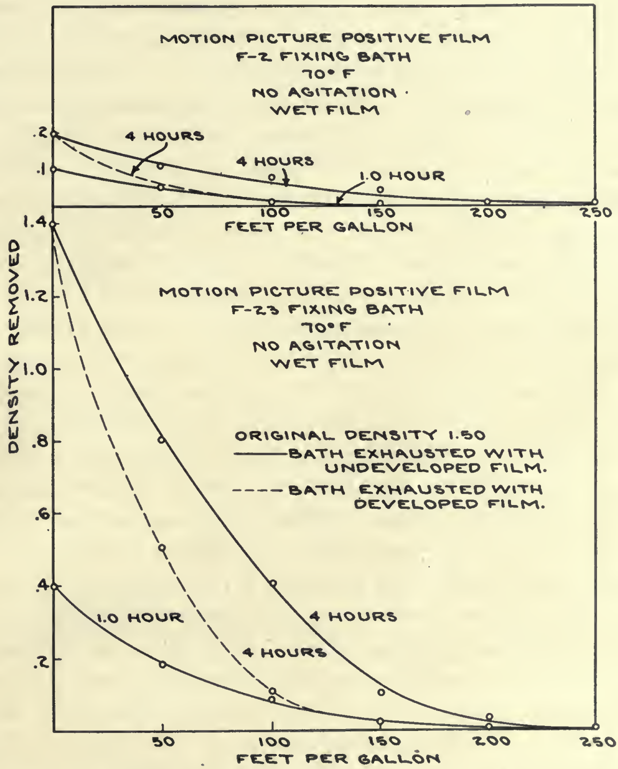

FIG. 6. Effect of exhaustion on the degree of reduction with the *F*-2 and *F*-23 fixing baths.

of the reaction between quinone and sulfite, quinone being an end-product of the reduction of the exposed silver halide by hydroquinone. The alkali in the developer decreases the acidity of the fixing bath, in which case the rate of reduction would also decrease.

The effect of the addition of an exhausted developer on the rate of reduction was tested by the addition of: (1) an oxidized *D*-16 developer, and (2) quinone to the *F-x* fixing bath. The *D*-16 developer was oxidized by bubbling air through the solution until it would no longer develop. Two hundred cubic centimeters of such a developer were evaporated by boiling to a volume of 20 cc., and added to 250 cc. of the fixing bath. A comparison made between this solution and one containing 1 per cent quinone for equal *p*H values indicated that these products have very little, if any, effect on the rate of reduction.

G. Effect of Miscellaneous Addition Agents.—Various chemicals which are not usually considered as oxidizing agents for silver were added to the *F-x* fixing bath as described below. Potassium bromide and potassium iodide were added in concentrations ranging from 0.1 per cent to 10 per cent (experiments 22–27, Table III-B). Both chemicals increased the rate of reduction, the potassium iodide being more effective for a given concentration than the potassium bromide.

Ammonium chloride increased the rate of reduction for concentrations between 1 per cent and 10 per cent while the addition of 10 per cent sodium chloride or 10 per cent ammonium sulfate had little or no effect on the reaction (experiments 28–30, Table III-B). Since ammonium chloride and ammonium sulfate both tend to decrease the clearing time in a fixing bath, further tests were made. The effect of these salts on the rate of reduction and clearing times of undeveloped positive and negative film is given in Table VIII for the *F*-2 and *F*-23 formulas, from which it is seen that the addition of either ammonium chloride or ammonium sulfate increased the clearing time of positive film, while in the case of negative film the clearing time was decreased. A concentration of either salt between 2.5 per cent and 5.0 per cent produced the greatest decrease in the clearing times, the chloride being more effective than the sulfate. The above concentrations of ammonium chloride also increased the rate of reduction to the greatest extent, while an equal quantity of the sulfate did not affect the reaction. With the *F*-23 formula, the rate of reduction increased up to a concentration of 300 grams per liter, but beyond this concentration the rate began to decrease.

This critical point does not correspond with the concentration of 400 grams per liter of hypo which gives a minimum clearing time with motion picture panchromatic negative film.

The addition of restraining agents such as sodium sulfate, sugar, and glycerin decreased the rate of reduction (experiments 43–48, Table III-C). Sodium sulfate in this respect was more effective than either of the other chemicals for equal concentrations.

TABLE VIII

Effect of Ammonium Chloride and Ammonium Sulfate on the Degree of Reduction in the F-2 and F-23 Formulas

Bath	Per Cent Ammonium Chloride	* Time of Bathing (Hours)	Original Density	Density Removed	Time to Clear Positive (Sec.)	Time to Clear Negative (Sec.)
F-23	0	4	1.60	0.76	35	240
F-23	1.0	4	1.60	0.86	35	115
F-23	2.5	4	1.60	1.10	35	95
F-23	5.0	4	1.60	0.96	40	85
F-23	10.0	4	1.60	0.90	50	100
	Per Cent Ammonium Sulfate					
F-23	0	4	1.60	0.76	35	240
F-23	1.0	4	1.60	0.60	35	125
F-23	2.5	4	1.60	0.70	40	105
F-23	5.0	4	1.60	0.60	50	130
F-23	10.0	4	1.60	0.48	60	170
	Per Cent Hypo					
F-23	30	4	1.60	0.75	35	240
F-23	40	4	1.60	0.60	50	120
F-23	60	4	1.60	0.56	70	220
F-23	80	4	1.60	0.40	80	>300
	Per Cent Ammonium Chloride					
F-2	0	4	1.60	0.30	35	240
F-2	1.0	4	1.60	0.30	35	115
F-2	2.5	4	1.60	0.40	35	95
F-2	5.0	4	1.60	0.40	40	85
F-2	10.0	4	1.60	0.20	50	100
	Per Cent Ammonium Sulfate					
F-2	0	4	1.60	0.30	35	240
F-2	1.0	4	1.60	0.30	35	125
F-2	2.5	4	1.60	0.30	40	105
F-2	5.0	4	1.60	0.22	50	130
F-2	10.0	4	1.60	0.10	60	170

* Positive film (dry).

II. Effect of Oxygen and Oxidizing Agents.—The effect of oxygen on the rate of reduction in the *F-x* and *F*-1 fixing baths is shown in Table III-C (experiments 33 to 38, inclusive). In the tests, air and carbon dioxide were bubbled through the fixing baths for two hours. The results indicated that the effect of bubbling air is probably a result of the increased agitation. The rate of reduction, however, was slightly greater with air than with carbon dioxide.

Further tests were made in which wet positive film, which was flashed to a uniform density and developed in the *D*-16 formula, was bathed in the *F*-2 and *F-x* formulas. The strips were suspended above the baths in such a manner that only part of the film was totally immersed. The part above the solution was moistened with the solution at 1-minute intervals throughout the time of bathing. With the *F*-2 formula the density above the solution was decreased to a greater degree than that which was immersed in the bath, while with the *F-x* formula the reverse effect was obtained.

The addition of oxidizing agents such as hydrogen peroxide and sodium perborate slightly increased the rate of reduction, as shown by experiments 39–41, Table III-C. The effect on the silver image of the addition of methylene blue to hypo solutions has been determined by one of the authors,[3] who found that under certain conditions methylene blue produced reversed dye images. The effect of methylene blue on the rate of reduction of the silver image was determined when added to the *F-x* formula and the fixing solution recommended in the above publication. In each case the low densities of the sensitometric strips were reduced very rapidly, while with the high densities, the rate was similar to that of the bath without methylene blue. Methylene blue produced the greatest effect when strips were bathed in a solution of the dye previous to immersion in the fixing solution.

To Summarize:—From the above tests it was concluded that for a given fixing bath containing alum, sulfite, acid, and hypo, (1) the rate of reduction increased rapidly if the *p*H value of the bath was reduced below 4.0, (2) for *p*H values greater than 4.0 the degree of reduction was of a much lower order of magnitude, (3) for a given hypo concentration and a *p*H value less than 4.0, an increase in the sulfite concentration increased the rate of reduction, (4) for a given sulfite concentration and a *p*H value less than 4.0 an increase in the hypo concentration up to 300 grams per liter increased the rate of reduction but with concentrations of hypo greater than 300 grams per liter, the rate of reduction decreased.

V. FACTORS WHICH INFLUENCE THE RATE OF REDUCTION IN SOLUTIONS OF PLAIN HYPO

The chemicals and reagents listed in Table III-A, -B, and -C were added to a solution containing 300 grams of hypo per liter, but no noticeable increase in the rate of reduction was observed. From these experiments it was concluded that the nature of the reducing action in plain hypo solutions was different from that in acid sulfite fixing baths.

The greatest increase in the rate of reduction was obtained when oxygen or air was bubbled through the solution. The effect of bubbling various gases through plain hypo solutions is shown in Table IX.

TABLE IX

Effect of Various Gases on the Rate of Reduction of the Silver Image in Hypo Solutions

Gas	* Time of Bathing	Original Density	Density Removed	*p*H Before Treatment	*p*H After Treatment
1. None	2 Hrs.	2.10	0.10	6.0	6.0
2. Air	2 Hrs.	2.10	1.08	6.0	7.5
3. Air	2 Hrs.	2.10	0.86	11.0	11.0
4. Oxygen	2 Hrs.	2.10	2.00	6.0	7.5
5. Nitrogen	2 Hrs.	2.10	0.05	6.0	6.0
6. Carbon Dioxide	2 Hrs.	2.10	0.20	6.0	5.2
7. Sulfur Dioxide	2 Hrs.	2.10	0.30	6.0	3.4

* Positive film (dry).

All the gases were bubbled through 250 cc. of the solution at a rate equal to 200 cc. per minute. Throughout the period of bathing sulfur dioxide was bubbled through the solution until the hypo sulfurized, which required about 15 minutes. The slight increase in the rate of reduction with carbon dioxide and sulfur dioxide is possibly due to the decrease in *p*H value.

Further experiments were made in which the air and other gases were removed from a 30 per cent solution of plain hypo by means of a vacuum pump. An image on positive film bathed in this solution was not reduced in 10 hours, while a density of 0.44 was removed from a density of 1.10 in a similar solution from which the air had not been removed.

The above tests indicate that air or oxygen is a very important factor in the bleaching action of solutions of plain hypo. It was also observed that when air or oxygen is bubbled through a solution of plain hypo in which a silver image is being reduced, the solution becomes more alkaline. The changes in alkalinity take place only in the presence of a silver image. When air or oxygen was bubbled through a solution of hypo without a silver image, no increase in alkalinity occurred. The change in alkalinity probably results from the oxidation by oxygen of the finely divided silver to silver oxide, which is dissolved by the hypo, forming complex silver thiosulfates and sodium oxide. The sodium oxide would exist in such a solution as sodium hydroxide, which is very alkaline.

In experiment 3, Table IX, the hypo solution was made alkaline by the addition of sodium hydroxide. A comparison of the rate of reduction with that in experiment 2 indicates that the reduction in alkaline hypo is less than that in plain hypo.

The effect of the concentration of hypo on the rate of reduction of the silver image in solutions of plain hypo is shown in Table X.

TABLE X

Effect of Concentration of Hypo on Rate of Reduction

Concentration of Hypo (Grams per Liter)	Original Density	Density Removed 18 Hours	Density Removed 36 Hours
800	2.06	0.00	0.00
400	2.06	0.18	0.34
300	2.06	0.26	0.62
200	2.06	0.36	0.70
100	2.06	0.36	1.00
10	2.06	0.12	0.16
1	2.06	0.00	0.00

The results indicate that the rate of reduction of the silver image in plain hypo solutions increases as the concentration of hypo is decreased from 800 grams per liter to 100, and then decreases for a further decrease in the hypo concentration.

VI. THEORETICAL DISCUSSION

The chemical reaction involved in the reduction of the photographic image in an acid fixing bath is probably one of oxidation of the silver to a soluble compound. The reaction may be represented by the following equation:

$$(I.)\quad \underset{\text{Silver}}{2Ag} + \underset{\text{Thiosulfuric Acid}}{H_2S_2O_3} + \underset{\text{Oxidizing Agent}}{O} \rightleftharpoons \underset{\text{Silver Thiosulfate}}{Ag_2S_2O_3} + \underset{\text{Water}}{H_2O}$$

The silver thiosulfate formed readily dissolved in the excess hypo.

Although the exact chemical nature of the oxidizing agent is unknown, F. Foerster[4,5,6,7,8] and his colleagues have shown that addition compounds of certain sulfur acids with sulfur dioxide can exist in a fixing bath and H. Bassett and R. G. Durrant[9] have suggested that these probably react as oxidizing agents.

Foerster and Vogel[8] have prepared the yellow addition compound ($K_2S_2O_3.SO_2$) by the action of sulfur dioxide on a potassium thiosulfate solution. They claim that the yellow color of an acidified sulfite and hypo solution is due to such compounds rather than colloidal sulfur.

Other yellowish colored addition compounds of sulfur dioxide are recorded in the literature such as:

1. $H_2S_2O_3(SO_2)x$
2. $H_2SO_3.(SO_2)x$
3. $HCNS.(SO_2)x$
4. $(HO)_2S.(SO_2)x$
5. $HI.(SO_2)x$

The effect of these compounds on the silver image was investigated. Various concentrations of the potassium salts were added to a 5 per cent solution of sodium sulfite acidified with sulfuric acid. The results are given in Table XI from which it is seen that an acidified solution of sulfite and iodide reduced the silver image very rapidly, while a similar solution containing potassium bromide did not affect the image to any great extent. From the standpoint of chemical composition bromide forms an addition compound with sulfur dioxide similar to that of the iodide, which is colorless.

The effect of the iodide-sulfur dioxide compound on the silver image explains the increase in the rate of reduction obtained when potassium iodide was added to the *F-x* fixing bath. A similar increase, although not as great, was obtained when potassium bromide was added to the *F-x* bath, which cannot be explained on the basis of the formation of these addition compounds.

The rate of reduction with the addition of potassium thiocyanate to an acidified solution of sulfite was considerably less than that with the addition of potassium iodide. The mixture of sulfite and thiocyanate without acid attacked the gelatin and removed the emulsion from the support. The solution of 5 per cent sodium sulfite with acid did not attack the silver image and even a highly concentrated yellow solution of metabisulfite (experiment 3) did not reduce the silver image, which indicates that this addition compound is not an oxidizing agent for silver.

TABLE XI

The Effect of Addition Compounds with Sulfur Dioxide on the Reduction of the Silver Image

Exp. No.	Substance Added	Grams per Liter	Sodium Sulfite (Grams per Liter)	Sulfuric Acid 10% (Cc. per Liter)	Time of Bathing at 70° F. (Hrs.)	pH	Original Density	Density Removed	Color of Solution	Color of Image
1			50	200	1.0	3.0	2.84	0	Colorless	Black
2			50	...	1.0	9.0	2.84	0	Colorless	Black
3	$K_2S_2O_5$	400	..	50	1.0	3.0	2.84	0	Yellow	Black
4	KBr	10	50	200	1.0	3.0	2.84	0.12	Colorless	Black
5	KBr	100	50	200	1.0	3.0	2.84	0.14	Colorless	Black
6	KBr	10	..	4.0	1.0	3.0	2.84	0.0	Colorless	Black
7	KBr	10	50	...	1.0	9.0	2.84	0.0	Colorless	Black
8	KBr	100	50	...	1.0	9.0	2.84	0.0	Colorless	Black
9	KI	10	50	200	1.0	3.0	2.84	2.50	Yellow	Yellow
10	KI	100	50	200	1.0	3.0	2.84	2.74	Yellow	Yellow
11	KI	10	50	...	1.0	9.0	2.84	0.36	Colorless	Black
12	KI	100	50	...	1.0	9.0	2.84	0.02	Colorless	Black
13	KI	10	..	4.0	1.0	3.0	2.84	0.00	Colorless	Black
14	KI	100	..	4.0	1.0	3.0	2.84	Gelatin was removed		
15	$Na_2S_2O_4$	250	50	200	1.0	...	2.84	1.42	Yellow	Brown
16	Hypo	300	50	200	1.0	3.0	2.84	1.70	Yellow	Brown
17	Hypo	300	50	...	1.0	9.0	2.84	0.20	Colorless	Black
18	Hypo	100	50	200	1.0	3.0	2.84	1.32	Yellow	Brown
19	KCNS	10	50	200	1.0	3.0	2.84	0.00	Yellow	Black
20	KCNS	100	50	200	1.0	3.0	2.84	0.30	Yellow	Black
21	KCNS	100	50	...	1.0	9.0	2.84	Gelatin was removed		
22	KCNS	100	..	4.0	1.0	3.0	2.84	Gelatin was removed		

$K_2S_2O_5$ = Potassium Metabisulfite
KBr = Potassium Bromide
KI = Potassium Iodide
$Na_2S_2O_4$ = Sodium Hydrosulfite
KCNS = Potassium Thiocyanate

Sodium hydrosulfite forms a permanent yellow solution when acidified in the presence of sulfite, and this is due to a thiosulfate-sulfur dioxide complex, according to Bassett and Durrant.[9] The presence of this compound probably accounts for the reduction of the silver image in a solution of sodium hydrosulfite (experiment 15, Table XI).

If the addition compounds between sulfur dioxide and hypo are oxidizing agents for silver, the reaction represented by the following equation *II* readily explains why the factors previously mentioned control the rate of reduction of the silver image in a solution of acid, sulfite, and hypo.

$$(II.) \quad H_2S_2O_3 + H_2SO_3 \rightleftharpoons H_2S_2O_3.SO_2 + H_2O$$

The application of the mass action law to the equation indicates that the formation of $H_2S_2O_3(SO_2)$ depends upon the acidity, and the concentrations of sulfite and hypo. The tendency to form this compound increases with an increase in the acidity, and the concentration of sulfite and hypo, and hence causes an increase in the rate of reduction. A corresponding decrease in the acidity, or the concentration of sulfite and hypo, decreases the concentration of the compound which also decreases the rate of reduction, which is in accord with experimental evidence.

Bassett and Durrant[9] have shown that methylene blue acts as an oxidizing agent in the presence of hypo solutions which explains the fact that the dye increases the rate of reduction of the silver image. The reaction may be represented by the following equation:

$$(III.)\quad 2\,Ag + \underset{\substack{\text{Methylene}\\\text{Blue}}}{C_{16}H_{18}N_3SCl} + H_2S_2O_3 \rightleftharpoons \underset{\substack{\text{Leuco}\\\text{Base}}}{C_{16}H_{19}N_3S} + Ag_2S_2O_3 + HCl$$

The silver thiosulfate formed in the reaction readily dissolves in the excess hypo present.

Silver halides decrease the rate of reduction of the silver image in the fixing baths, probably owing to the formation of complex silver anions with the thiosulfate ion, thereby saturating the solution with silver.

The reaction involved in the reduction of the silver image in a solution of plain hypo is probably different from that in acid fixing baths, since experimental evidence indicates that the rate of reduction for a given hypo concentration is only affected by oxidizing agents and oxygen.

Oxygen possibly converts the silver image into silver oxide which is readily dissolved by the hypo.

The reactions may be represented by the following equations:

$$(IV.)\quad 4Ag + O_2 \rightleftharpoons 2Ag_2O$$

$$(V.)\quad Ag_2O + Na_2S_2O_3 + H_2O \rightleftharpoons 2\,NaOH + Ag_2S_2O_3$$

The silver thiosulfate formed in equation *V* readily dissolves in the excess hypo present. Equation *V* also indicates that the solution becomes alkaline when silver oxide is dissolved by hypo which is in accord with the experimental facts.

VII. SUMMARY

The object of this investigation was to determine some of the factors which control the rate of reduction of the silver image in fixing baths.

(1) The degree of reduction in a given time was determined for images obtained from various emulsions bathed in different fixing baths. The emulsions tested included motion picture panchromatic negative film type 2, emulsion 1218, and supersensitive panchromatic negative film, emulsion 1217, motion picture positive film, emulsion 1301, motion picture negative film, emulsion 1201, motion picture duplicating negative films, emulsions 1505 and 1503, and motion picture duplicating positive film emulsion 1355.

The fixing baths tested were the *F*-1, the *F*-2, *F*-14, *F*-16, and *F*-23, and several experimental formulas.

(2) The rate of reduction in a given fixing bath was greater with images from fine grained emulsions than with coarser grained materials. The fixing bath having the lowest rate of reduction was the *F*-2 formula, while the highest rates of reduction were obtained with fixing baths containing a relatively high concentration of sulfite and acid.

(3) The rate of reduction increased with an increase in temperature.

(4) The factor which affected the rate of reduction to the greatest degree in an ordinary acid fixing bath was the acidity of the bath. For a given bath the rate increases rapidly for pH values below 4.0.

(5) The rate of reduction was increased for pH values less than 4.0 with an increase in either the sulfite or hypo concentration. The rate of reduction was decreased with concentrations of hypo greater than 30.0 per cent.

(6) The exhaustion products which accumulate in a fixing bath such as silver halides and developer decreased the rate of reduction. Developer oxidation products which also accumulate to a small extent did not affect the rate of reduction.

The rate of reduction in an exhausted *F*-2 fixing bath from which the silver had been removed by an electrolytic process was less than in a fresh bath.

(7) Ammonium chloride, potassium bromide, and potassium iodide increased the rate of reduction, while ammonium sulfate, sodium chloride, sodium sulfate, glycerin, and sugar produced the opposite effect.

(8) Oxygen and oxidizing agents such as the peroxides have no apparent effect on the rate of reduction in highly acid fixing baths. The tests indicated, however, that the presence of oxygen increased

the rate of reduction in fixing baths containing a low concentration of sulfite and acid such as the *F*-2 formula and was largely responsible for the reduction in solutions of plain hypo.

(9) From a theoretical standpoint most of the factors which control the rate of reduction in an acid fixing bath can be accounted for by assuming that an oxidizing agent for silver is formed by reaction of the hypo and the sulfite. The general formula for such compounds is represented by $H_2S_2O_3(SO_3)x$ and they have been shown[9] to exist in an acid solution of sulfite and hypo.

Other sulfur compounds as well as the halides formed similar addition compounds which did not attack the silver image, with the exception of the iodide and the hydrosulfite compound. In solutions of these compounds, however, the reduction might have been due to the $H_2S_2O_3$-$(SO_2)x$ complex present as an impurity, or as a decomposition product.

VIII. PRACTICAL RECOMMENDATIONS

The extent of the reducing effect of fixing baths on the silver image during the progress of fixation is greater than has generally been supposed. For example, in sensitometric work it is inadvisable to prolong the fixation of motion picture positive film in the average fresh potassium alum fixing bath beyond 5 minutes at 65°F. and with certain highly acid chrome alum baths a measurable degree of reduction occurs even in this short space of time.

Since little or no reduction of the image occurs in an alkaline hypo solution, sensitometric tests should be checked against images fixed in a 25 per cent solution of hypo containing 1 per cent of sodium carbonate (anhydrous). The film should be rinsed in water and agitated on first immersing in the bath in order to prevent the formation of dichroic fog.[10]

In regular laboratory work the degree of reduction which takes place in the normal time for fixation is usually of no practical importance with the baths in common use. In any given bath the rate of reduction increases with the acidity, the temperature of the bath, and degree of agitation of the film, so that with certain chrome alum baths used under tropical conditions, the decree of reduction is excessive, especially with fine grained emulsions. For high temperature processing, if a minimum of reduction is required the use of a chrome alum hardening stop bath after development, followed by a fixing bath consisting of plain hypo containing 1 per cent sodium bisulfite, is recommended.[1]

During use, the reducing action of a fixing bath falls off because it becomes more alkaline and accumulates silver thiosulfate which tends to retard the reduction.

In order to insure the minimum degree of reduction, therefore, baths having a minimum degree of acidity should be used though such baths have a short life and often do not harden satisfactory. It is therefore necessary to revive such baths either by adding further quantities of acid or hardening solution at intervals during use; otherwise, if the film is not rinsed in water before fixing an objectionable sludge will form in the fixing bath.[11]

The desirable range of acidity lies between *p*H values of 4.0 and 4.5. At higher values the bath does not harden, and below this there is danger of reduction of the image.

Exposure of the film to air during fixation has little or no effect with acid baths, except those containing a relatively low concentration of sulfite and acid, in which case the rate of reduction is greatly increased. Air also accelerates the rate of reduction in solutions of plain hypo which are seldom used in practice.

The addition of restraining agents such as sodium sulfate, glycerin, and sugar to the acid fixing bath decreases the degree of reduction but their use is not recommended because they also decrease the rate of fixation.

In some laboratories the acidity of the fixing bath is maintained by passing sulfur dioxide gas into the bath. Under these conditions, if an excess of the gas is used, a strongly reducing fixing bath is produced.

The nature of the reduction with the negative emulsions tested was found to be almost strictly proportional and some of the more active baths enumerated could therefore be used advantageously for reducing the contrast of photographic images.

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ABSTRACTS

The views of the readers of the JOURNAL relative to the usefulness to them of the abstracts regularly published in the JOURNAL will be appreciated. Favorable views are of particular interest. In the absence of a substantial body of opinion to the effect that these abstracts are desired by the membership, their discontinuance may be considered.

Experiments with Visual Aids in High School Classes. W. LEWIN. *Visual Instr. News*, **5**, Nov., 1931, p. 9. Another quite independent experiment to test the efficacy of motion pictures in teaching, the subject being high school physics. Preliminary intelligence, reading, and physics tests showed the control groups to have a very slight advantage. Motion pictures were presented to the experimental group during their preparatory period while the control group met for supervised study. It was concluded that motion pictures impart more information in a given time and also contribute to retention of information. The gain in the test grades of the experimental group over the control group was three times the standard error while at the end of the term, 50 per cent more pupils of the experimental group passed the course. R. P. L.

A Modern Theater for the Classics. N. BEL GEDDES. *Theater Management*, **26**, Nov., 1931, p. 8. A theater specially designed for the staging of Dante's *Divine Comedy* at the Chicago World's Fair has a seating capacity of 5000 and is similar to the ancient Greek theater. Its plan is a half-circle facing the stage without balconies or galleries. No proscenium or curtain divides the auditorium from the stage. The absence of balconies and galleries allows a steeper ramp and better vision from all seats. The stage is circular and composed of steps. In the center is a pit, at the far side of which the slope rises to a height of 50 feet. On the near side, the slope terminates in a ledge only one-fourth as high, which steps down toward the audience in a series of terraces until it reaches the level of the bottom of the pit where it terminates in a valley running half-way around the circle. A 7-foot wall separates the valley from the audience. Mention is made of two other theaters also planned for the World's Fair in which the absence of transverse aisles is notable, the rows of seats being given liberal spacing instead. L. E. M.

Room Noise Reduction for Improved Sound Reception. V. A. SCHLENKER. *Theater Management*, **26**, Nov., 1931, p. 3. A study of the relations of speech, music, and room noise in the theater indicates that the noise level should be reduced below 30 decibels for the speech, and music must be uncomfortably loud to be heard above the noise level of 40 to 50 decibels. Excessive treatment of the theater proper should be avoided in view of a possible interference with the proper reverberation period which is considered essential to the proper diffusion of sound to all parts. The room noise can generally be controlled to suitable value by decreasing street and lobby noise through maximum treatment in the lobby and foyer. L. E. M.

A Clockwork Driven Slow-Motion Camera. *Kinemat. Weekly,* **178,** Dec. 17, 1931, p. 38. A new type of slow-motion picture camera which is actuated by clockwork is claimed to expose 100 feet of 35-mm. film with one winding of the mechanism. The speed can be varied from 40 to 120 frames per second and a reversed fitting allows dissolving to be carried out while the film is being exposed. A pick-up speed has been developed which permits only 18 inches of film passage before full rate is obtained. Stopping and starting can be accomplished with a loss of less than 2 feet of film. A reflex focusing device permits accurate focusing when taking close-ups, and the enclosed view finder is fitted with a device to allow for parallax when the object is near the camera.

A standard speed camera designed similarly to the slow-motion model, but capable of exposing 200 feet of film at speeds from 10 to 24 frames, has also been introduced. A special tripod is used with these models. C. H. S.

Effect Lighting. J. H. KURLANDER. *Theater Management,* **27,** Jan., 1932, p. 10. Suitable lighting effects are proposed for the theaters having a straight sound picture program so as to relieve the show of monotony. A description of equipment required for effect lighting is given. The uses of effect projectors, shutters, framing devices, masks, slides, special screens, *etc.*, for producing different effects are discussed. Color effects, animated scenic effects, silhouettes, trick effects, and others may be used as the occasion suggests. W. J. W.

Diminishing the Fire Hazard. J. J. GREILSHEIMER. *Theater Management,* **27,** Jan., 1932, p. 16. The use of concrete vaults or sheet metal lockers, even though equipped with sprinkler systems and vents, is deemed inefficient in preventing film fires because of the large quantity of film concentrated in one compartment. Several requirements for a safe and efficient film storage cabinet are enumerated. A description is given of a cabinet designed to meet these rigid requirements. The cabinet is constructed in sections featuring individually insulated and ventilated compartments of 10 pounds capacity which are sealed tightly with automatically closing and latching doors. A number of fire tests were carried out on the cabinet filled with film to determine its safety. Detailed results of the tests are given. W. J. W.

Advances in Sound Reproduction Demonstrated to Motion Picture Engineers. *Theater Management,* **27,** Jan., 1932, p. 5. Reproductions of organ, orchestral, and vocal music, which closely approached the quality and volume of the original, were effected by the use of disk records cut by the vertical method. This method employs grooves which vary in depth instead of wavering back and forth along the spiral path as in the commonly used lateral method. The moving element of the electrical reproducer is made of light-weight materials so that it is able to follow vibrations up to 10,000 per second with fidelity. A tiny permanent sapphire point is used which rides smoothly up and down in the grooves. Finished records are pressed in cellulose acetate which has a surface of extremely fine texture. Mr. H. A. Frederick of the Bell Telephone Laboratories made the demonstration. W. J. W.

Television Talkiola. *Theater Management* **26,** Nov., 1931, p. 34. This apparatus incorporates mechanisms for producing six different types of entertainment within a single cabinet, namely, television with synchronized sound, talking motion pictures (16-mm. or silent pictures), phonograph, short wave radio, and standard broadcast radio. A $^1/_{16}$-horsepower synchronous motor operates the perforated scanning disk used for television, giving a 6- by 8-inch picture. Rear projection is used for the 16 mm.-projector. G. E. M.

New Type Record. *Theater Management*, **26**, Nov., 1931, p. 34. This new disk record is made of much thinner material and is much less easily broken than the old type shellac record. Although only 12 inches in diameter, as compared with the older 16-inch record, the new disk will record sufficient sound for 1000 feet of film. This has been accomplished by employing a lower amplitude of recording, smaller grooves, and by placing the grooves nearer together. G. E. M.

Novel Loud Speaker. R. H. CRICKS. *Kinemat. Weekly*, **173**, July 9, 1931, p. 69. New principles are claimed in the construction of a novel loud speaker which has recently been demonstrated in London. Known as the Cinemavox, it is stated to combine the principles of the piano and violin by providing a large tuned area for the dissemination of sound. A number of speaker armatures are distributed at the back of a sounding board some 5 feet square, and are connected to struts, which are parts of various wooden sections, each having its own natural resonance frequency. A frequency range of from 13 cycles to 17,000 cycles with extremely even response is claimed. The sound output is stated to be almost non-directional. *Kodak Abstract Bulletin*

New "Jofa" Studio. P. HATSCHEK. *Filmtechnik*, **7**, Sept. 19, 1931, p. 6. A description is given of the new "Jofa" sound film studio of Jahannisthal, Berlin, which is the most up-to-date in the city. There are three large studios, 840, 1155, and 840 square meters in area, each associated with a smaller studio, respectively, 480, 480, and 450 square meters in size, and a large number of dressing-rooms, and smaller rooms for operators, technicians, actors, *etc.* There are two studios for re-recording, dubbing, and synchronizing, four projection rooms, two cutting rooms, and a number of work-shops. Thirty thousand square meters of land are available for outdoor work, and an additional seventy thousand meters (the local aerodrome) are at hand if required. The three large studios have enormous sliding doors opening on the outside lots. This provides a natural background for studio sets, if desired, and permits a continuation of the studio action outdoors. For sound-proofing, air spaces are provided between studios, the floors are insulated from the walls by coke-ash, walls and doors are all double, and are packed with sound-absorbing material. Doors are provided with a novel "double-fold system" which is described, and there is a new treatment of the roof. The electrical supply and the projection and cutting rooms are also described. A pool, 35 by 15 meters wide and 2.5 meters deep, is provided. *Kodak Abstract Bulletin*

Modern Effect Lighting. J. H. KURLANDER. *Mot. Pict. Proj.*, **5**, Jan., 1932, p. 18. A descriptive article on the production of stage and screen lighting effects, including information on lamp and lens equipment, types of screen and screen materials, and the use of color filters, slides, and design glasses. A. A. C.

Projected Background Cinematography. R. G. FEAR. *Amer. Cinemat.*, **12**, Jan., 1932, p. 11. A method of composite photography is described in which the foreground action takes place in front of a screen placed so as to receive from a projector an image of the background desired. Translucent screens in back of the action are now often used for this purpose with a standard camera and projector. The background picture must be absolutely steady on the screen, illuminated to the highest possible extent, and must be synchronized with a camera shutter if good results are to be secured. After a discussion of means of fulfilling these requirements, the author suggests modifications that may prove useful, and gives a list of patents relating to the process. A. A. C.

New Filters for Exterior Photography with Super-Sensitive Film. EMERY HUSE AND GORDON A. CHAMBERS. *Amer. Cinemat.*, **12**, Dec. 1931, p. 13. Two new filters, the 3 *N*5 and 5 *N*5, are combinations of yellow dyes with a neutral density filter of 32 per cent transmission. They combine, in a single unit, a means of decreasing exposure and a color filter suited to the super-sensitive emulsion. This means of reducing light intensity has been found preferable to using a lens diaphragm or a change in shutter opening A. A. C.

Projector Drive Motors. ALBERT PREISMAN. *Mot. Pict. Proj.*, **5**, Jan., 1932, p. 10. Since the advent of sound, the projector drive motor has assumed a greater importance than ever before. Ease and precision of control, affording a constant and definite speed, are imperative. The article discusses the underlying principles of the common types of projector motors and explains how the new demands are met in modern motor design. A. A. C.

Reverberation Time Measurements in Coupled Rooms. CARL F. EYRING. *J. Acoust. Soc. Amer.*, **III**, No. 2, Part I, Oct., 1931, p. 181. The paper presents experimental data on the decay of sound intensity level in acoustically coupled rooms, together with a theoretical study of the subject.

The type of problem investigated is illustrated by one of the experiments, which was a study of the sound decay in an enclosure which consisted of a small live room connecting through an open window into a large dead room. Data were taken with the sound source in the large room and microphone in the small room, and *vice versa*, and with both source and micrpohone in each room. Combinations of other types of rooms are included.

Theoretical equations of decay for acoustically coupled rooms are developed, and are applied to describe the data. The application of these equations to an idealized theater is shown. W. A. M.

Audible Frequency Ranges of Music, Speech, and Noise. W. B. SNOW. *J. Acoust. Soc. Amer.*, **III**, No. 1, Part 1, July, 1931, p. 155. "The program of listening tests described in this paper was undertaken primarily to establish the audible frequency ranges of the sounds most often encountered in sound reproduction. . . ." The sound sources studied included twenty separate musical instruments, an orchestra, male and female speech, and certain noises.

Qualitative observations by the crew of listeners are tabulated for each sound source. Quantitative results are given in a table. Two general conclusions are as follows: "An upper cut-off of 10,000 cycles did not affect the tone of most of the instruments to a marked extent, but every instrument except the bass drum and tympani was affected by the 5000 cycle cut-off. A frequency range of 100 to 10,000 cycles was shown to be entirely satisfactory for speech." ". . . . transmission of the entire audible range would seem much more important for noise reproduction than for reproduction of musical sounds."

The paper contains a great amount of experimental data. W. A. M.

Plane Sound Waves of Finite Amplitude. R. D. Fay. *J. Acoust. Soc. Amer.*, III, No. 2, Part I, Oct., 1931, p. 222. The principal object of the analysis is to find the change in type of periodic plane waves of sound of finite amplitude propagated in free air.

A solution of the exact equation of motion is obtained as a Fourier series. Due to the non-linear relation between pressure and specific volume there is found to be a gradual transfer of energy from components of lower frequency to those of higher frequency. Since the effect of viscosity is to attenuate the higher frequency components more than the lower, there is always a wave form having the harmonic components in a stable relation such that the decrease in relative magnitude of any component due to viscosity is compensated by the relative increase due to non-linearity. The conditions for stability vary with intensity. There is therefore no permanent wave form, but the stable wave will change its form more gradually than any other wave of the same intensity and wavelength. The change in type of any wave is toward this stable form. There is a marked departure from the sinusoidal in the stable type even for waves of very moderate amplitude. AUTHOR

A Planetary Reduction Gear System for Recording Turntables. A. V. Bedford. *J. Acoust. Soc. Amer.*, III, No. 2, Part I, Oct., 1931, p. 207. "The present paper has two objects: to present an example justifying the use of a detailed numerical application of electrical circuit analysis to mechanical rotational systems, and to describe a new planetary turntable drive system that promises increased steadiness."

The conclusion of an analysis of a simple gear system is that, ". . . the error of the turntable position at any moment is about as great as the fundamental error in the angular tooth pitch in the lowest speed gear."

In the planetary gear system described no gear runs as slow as $33^1/_3$ rpm. with respect to its meshed mate, and also no gear in the system runs at a speed lower than 375 rpm. Therefore, disturbances due to errors in gears and irregularities in bearing friction are of a relatively higher frequency than in a simple gear system and consequently can be more easily filtered out.

An experimental model of a planetary gear system drive "exhibited less than 0.03 per cent variation in turntable speed at turntable revolution frequency."

W. A. M.

ABSTRACTS OF RECENT U.S. PATENTS

The views of the readers of the JOURNAL relative to the usefulness to them of the Patent Abstracts regularly published in the JOURNAL will be appreciated. Favorable views are of particular interest . In the absence of a substantial body of opinion to the effect that these Patent Abstracts are desired by the membership, their early discontinuance may be considered. If, after two weeks from the date of mailing the March issue of the JOURNAL, no letters concerning the continuance of the department will have been rcceived, the Patent Abstracts will be discontinued.

1,828,798. **Film Treating Apparatus.** G. C. BEIDLER. Oct. 27, 1931. The film is delivered edgewise to means for removing the film from the receptacle in which a submerging device is located and other guiding means operate to prevent lateral movement of the film as it is being moved. Means are provided for regulating tension or pressure on the film by coacting rollers which operate to move the film and at the same time exert pressure upon the film to remove fluid, in order to prevent film from carrying an excess amount of fluid from the receptacle in which the film was treated. At the bottom of the coils where they coact, means are provided for moving the film to eject it from a receptacle, an assembly of rollers and conveying bands being provided for continuously directing the film.

1,828,749. **Motion Picture Screen.** A. L. RAVEN. Oct. 27, 1931. The projection screen comprises a plurality of wavy horizontal strips arranged in overlapping relation with the hollows of the waves of adjacent strips opposite one another and forming sound passages extending upwardly from the rear toward the front of the screen between the strips. The sound from the sound reproducer behind the screen freely passes through the screen at the same time that a proper reflection surface is provided for the screen.

1,828,768. **Film Guide.** A. DINA. Assigned to International Projector Corp. Oct. 27, 1931. One set of guide members is rigidly mounted for positively locating the film edge with respect to the projection aperture and comprises a plurality of sections spaced longitudinally of the film for permitting dust and accumulations of foreign material to escape therebetween. The other set of guide members comprises a plurality of disks rotatably mounted with their axes transverse to the film and held in firm engagement therewith by means of suitable spring members. The disks are capable of rotating as the film is moved through the projection head thereby eliminating sliding friction and reducing the wear on the film.

1,828,867. **Scanning Device.** C. FRANCIS JENKINS. Assigned to Jenkins Laboratories. Oct. 27, 1931. The film image is enlarged by projection and directed through a scanning disk thereby permitting (1) the apertures in the scanning disk to be larger, so that diffraction bears a lesser relation to the aperture area; (2) the disk may be positioned in a free air, removed from the proximity of the film, and, therefore, does not clog up with dirt and/or oil; and (3) the apertures may be made square, increasing the light efficiency.

1,828,875. **Electroöptical Translation System.** C. H. W. NASON. Assigned to Jenkins Television Corp. Oct. 27, 1931. A method of employing photoelectric variations to control the resonance characteristic of an oscillatory circuit supplied from a source of carrier current. The frequency spectrum of the transmitted carrier waves is substantially independent of the frequency variations of the light impulses incident upon the light-sensitive device under control of a film. The light passing through each elemental area of the film is projected upon the photoelectric cell, preferably of the Elster-Geitel type, comprising a light-sensitive electrode and another electrode. The electrostatic capacity of such a cell undergoes variations in value as the coating is subjected to different degrees of illumination.

1,828,940. **System for Correcting Sound Records.** R. J. POMEROY. Oct. 27, 1931. A method and system for making a distortion corrected record, by introducing to the original record correction distortions that are compensatory of, or have a neutralizing effect on, the distortions which are introduced by reproduction. This is done by recording the distorted reproduced sound, and utilizing this distorted record to modify the original record in such a manner that the distortive effects of the system are compensated in the modified record, and accurate reproduction is thus obtainable.

1,828,941. **System for Correcting Sound Records.** R. J. POMEROY. Oct. 27, 1931. A method and system for making a distortion corrected record, and this is done by introducing, to the record, correction distortions that are compensatory of, or have a neutralizing effect on, the distortions which are introduced by reproduction. A sound current representing the distortion record is combined with a sound current representing the original undistorted record, and this combination is so effected that the resultant current carries variations which represent only the difference between the two records or, in other words, the distortion. A record of this current may be made upon a film and subsequently printed above an original record. In either case, the result is a distortion corrected record from which sound may be finally reproduced without the distortions of recording and reproduction.

1,828, 942. **Production of Corrected Sound Records.** R. J. POMEROY. Oct. 27, 1931. A method and system for making a distortion corrected record, and this is done by introducing to the record correction distortions that are compensatory of, or have a neutralizing effect on, the distortions which are introduced in recording and reproduction. This is accomplished in the present instance by making a photographic distortion corrected sound record, or photographic sound record compensated for distortions, and from this making a distortion corrected mechanical record from which distortionless reproduction is obtainable.

1,828,974. **Photographic Film with Visible Reproducible Inscriptions.** H. LUMMERZHEIM AND E. SCHNITZLER. Assigned to Agfa Ansco Corp. Oct. 27, 1931. An ink is provided for continuous printing on a photographic film, the ink comprising a mixture of cerasine-red in glycol acetate. A photographic film provided on the rear side with inscriptions by means of the said dye-ink may be polished as usual in the photographic film industry; it may be exposed, developed, and finished in the usual manner without fading of the impressed symbols.

1,829,095. **Film Reel.** W. G. KING AND M. E. KRAUSE. Oct. 27, 1931. An endless film may move continuously or intermittently in a continuous path from the inner convolution of a roll of film revolving about the circularly grouped rollers onward through the mechanism of a projector and past the lens and back onto the outer convolution of a roll of film without undue strain or intricate twists or loops in the film by the provision of yieldable film guides.

1,829,103. **Loading Device for View Taking Cinematographic Apparatus.** A. N. MERLE. Assigned to Pathé Cinema, Anciens Établissements Pathé Frères. Oct. 27, 1931. The cover is provided with a bevelled part corresponding to that of the cover and is formed on the face of the loading case coacting with the cover. This bevelled part is situated outwardly of the film-holding chamber. The said bevelled part may extend upon the whole periphery of the said chamber or upon only a certain portion thereof. The loading case may be readily opened to allow access to the hollow interior of the box for the insertion or removal of the film.

1,829,121. **Sound Recording Apparatus.** E. R. VINSON. Oct. 27, 1931. An electromagnetic vibratile device for moving a light valve in the form of a *V*-shaped notch in the path of a beam of light for varying the exposure of the film according to impressed sound vibrations.

1,829,359. **Picture Projecting Machine Cabinet.** R. W. KITTREDGE. Oct. 27, 1931. Cabinet for a motion picture projecting machine, and a projection screen and stand therefor which is removably stored on the cabinet in such a manner as not to decrease materially the space afforded in the cabinet for the reception or storage of other articles such as a projecting machine, related apparatus, and film, which permits the quick and convenient storing of the screen and stand on the cabinet and removal of the same therefrom, and which does not detract from the appearance of the cabinet or require an unattractive shape thereof for use in the home to form an attractive and convenient article of furniture.

1,829,475. **Projection Lamp Holder.** G. H. CUSHING. Oct. 27, 1931. A tubular holder for an incandescent lamp by means of which a standard electric light bulb may be positioned in an accurately designed reflector, so that the filament of the bulb will be located at the focus of the reflector.

1,829,482. **Motion Picture Film Reel.** Oct. 27, 1931. A. C. Hayden. A film reel for motion picture apparatus comprising a pair of plates and a hub between said plates adapted to have a film wound thereon, one of said plates having a hole therein and the other of said plates having a cup integral therewith, pressed thereform and in axial alignment with the hole, said hole and cup being adapted to receive a spindle of motion picture apparatus, said hole being formed for driving engagement with the spindle, and said cup insuring application of the reel to the spindle with the hole plate in advance of the cup plate.

1,829,633. **Taking or Projecting Panoramic Views or Views Extending in Height.** H. CHRETIEN. Assigned to Société Anonyme Française Dite Société Technique D'Optique et de Photographie. Oct. 27, 1931. Method of photographing or projecting which consists of reducing optically the space occupied by the images on a sensitized surface, by compressing them in one single direction, either in height, or in width, or in any inclined direction selected, this result being obtained by disposing, in front of the photographing objective, a special optical combination, referred to as a local anamorphoser, suitably oriented about the optical axis of the objective. The process also consists in restoring or projecting these images through an optical combination similar to that which has served for obtaining them and similarly directed, which has the result of reëstablishing the images in their exact proportions on a screen of suitable dimensions and arrangement.

1,829, 634. **Optical Compression of Film Pictures.** H. CHRETIEN. Oct. 27, 1931. A film which includes a series of pictures thereon of uniform dimensions and proportions which are optically compressed, some in one dimension and some in another, so as to obtain when projected and restored views which are considerably extended but only in the one dimension or the other.

1,829,791. **Device for Recording Sound on Film.** H. A. DEVRY. Assigned to Q. R. S.-De Vry Corp. Nov. 3, 1931. Incandescent lamp having a bulb, part of which is opaque except for a minute slit in the tip end thereof. The lamp is adapted to be positioned with respect to feeding or winding mechanism for the film so that the beam of light emanating from the slit strikes against one of the side margins of the film and forms on the film, as the latter is driven by the feed mechanism, an exposed portion of strip-like conformation.

1,829,912. **Sound Picture Film and Method of Making the Same.** D. G. SHEARER. Assigned to Metro-Goldwyn-Mayer Corp. Nov. 3, 1931. Continuous picture film and sound record comprising a strip of film bearing pictures between rows of sprocket holes made therein, and a continuous photographic sound record on film stock attached to one longitudinal edge of the picture film, one edge of the picture film being stepped and the stepped edges cemented together whereby the combined picture film and sound record are of substantially equal thickness transversely thereof.

1,830,082. **Color Attachment for Cinema Projectors.** W. R. BECKLEY, A. E. CHURCH AND J. F. MERKEL. Assigned to Beckley and Church, Inc. Nov. 2, 1931. A rotatable disk is placed upon the front of the projector and arranged in front of the lens and adapted to present various differently colored transparent segments thereof in the axis of the lens, selectively, so that the projected rays will be colored or filtered in a manner such as will protect the eye of the observer from the glare of the image as projected upon the screen and also when desired to impart a colorful effect simulating, for instance, moonlight, twilight, *etc.*

1,830,121. **Color Attachment for Cinema Projectors.** J. F. MERKEL. Assigned to Beckley & Church, Inc. Nov. 3, 1931. A carrier for a lens plate is mounted on the projector and a vari-colored ray screen rotatably and reversibly mounted on the shaft in operative relation to the lens for the reproduction of images in color.

1,830,158. **Film Trap and Film Trap Door.** A. DINA. Assigned to The Precision Machine Co., Inc. Nov. 3, 1931. Construction of film guide and film trap door in which the door is closed upon the film against impact absorbing means which prevents transmission of shocks to parts of the projector. A resilient contacting pad is provided against which the door is moved to closed position.

(Abstracts compiled by John B. Brady, Patent Attorney, Washington, D. C.)

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L. C. PORTER, General Electric Co., Nela Park, Cleveland, Ohio
E. I. SPONABLE, 277 Park Ave., New York, N. Y.

SOCIETY ANNOUNCEMENTS

SPRING, 1932, MEETING

The Spring, 1932, Convention of the Society is to be held at Washington, D. C., with headquarters at the Wardman Park Hotel. Excellent service is assured and plenty of space is available for accommodating the members without crowding. The Congressional Country Club and the Indian Spring Country Club are both available to the visiting members. In addition, the four tennis courts maintained by the hotel and riding facilities provide additional recreation.

As the Convention is to be held at the height of the activities of the Washington Bi-Centennial celebration, there will be much to attract members to Washington in addition to the technical and social activities of the Society. Sight-seeing tours will be provided for visiting points of historic and diplomatic interest, such as the Capitol, the Treasury, the Smithsonian Institution, the Congressional Library, the Pan-American Building, the new Museum, Scottish Rite Temple, Tomb of the Unknown Soldier, the Amphitheater, and other points of interest at Arlington, Mount Vernon, and Annapolis.

An especially attractive program of technical papers is being prepared by the Papers Committee, under the chairmanship of Mr. O. M. Glunt; and Mr. W. C. Kunzmann and his Convention Arrangements Committee are sparing no efforts to make the social aspects of the Convention a success. The technical sessions will be held in the Little Theater of the Wardman Park Hotel, and special film programs for the evenings are being arranged by Mr. J. I. Crabtree.

The semi-annual banquet of the Society will be held in the Gold Room of the hotel on Wednesday, May 11th, at 7:30 P.M. In addition to an attractive and entertaining program, an unusually interesting group of speakers is expected to address the members.

NEW YORK SECTION

On February 11th, the members of the New York Section were invited by the Illuminating Engineering Society to attend its February meeting held at the plant of the Sperry Gyroscope Company, Brooklyn, N. Y. A paper entitled "The Theory of the Arc, and the Carbon Arc as a Projection Source" was presented by Mr. Bassett, of that company.

The members of the Section were also invited by the New York Section of the American Institute of Electrical Engineers to attend its meeting held on February 26th, at the Engineering Societies Building, New York, N. Y. The meeting was devoted to "The New Music of Electrical Oscillations," and included demonstrations of the electronic organ-piano, developed by Mr. Benjamin Miessner and the Ranger tone electric organ, developed by Captain Richard Ranger. Professor Leon Theremin demonstrated the three types of theremin—the space theremin, the new keyboard theremin, and the new fingerboard theremin.

CHICAGO SECTION

At a meeting of the Section, held on January 7th, papers were presented by Mr. R. W. Fenimore, entitled "Educational and Commercial Films with Sound on Disk," and by Mr. L. D. Minkler, on "Disk Recording for Motion Pictures."

At another meeting held on February 11th, Mr. R. F. Mitchell presented a paper entitled "New Improvements in Camera Construction."

The next meeting of the Section will be held March 3rd at the Electric Association, Chicago, Ill. Mr. H. Shotwell will present a paper on the subject of "Portable A-C. Amplifiers."

STANDARDS COMMITTEE

At two meetings of the subcommittee of the Committee on Standards and Nomenclature, which deals with the establishment of dimensional standards for 16-millimeter sound film, on January 28th and February 8th, two lay-outs were made, which are to be submitted to the entire Standards Committee for consideration and appropriate action. The one lay-out, providing for a single row of perforations, is to be submitted for adoption as a recommended standard of film lay-out; the other, providing for two rows of perforations, is also to be submitted to the Standards Committee, with the suggestion that this be published (somewhat as in the nature of a minority report) as a non-recommended standard, to be followed if future developments of the art so indicate.

Drawings of the two lay-outs are being prepared, showing all details and tolerances, which will be submitted to the Standards Committee at its next meeting, to be held in the near future. Upon ratification of these lay-outs, as submitted or modified, they will be published in the next succeeding issue of the JOURNAL.

SOUND COMMITTEE

At a meeting held on December 10, 1931, an outline of the work to be prosecuted by the Committee during the current year was formulated, and included a considerable amount of study of the acoustical properties of auditoriums and studios, with particular reference to the influence these properties exert in the recording and reproducing of sound. An attempt will be made to define an optimum theater, that is, one whose properties may be regarded as reference standards which will indicate the factors to be considered in making auditoriums acceptable for the reproduction of sound. Among the other items included in the agenda are: (1) the accuracy and application of testing methods and formulas; (2) absorption data of acoustic materials; (3) wide-range recording and reproducing of sound; (4) sources of ambient or interfering noises, and their correction; (5) the relation between the acoustical properties of studios and theaters; (6) the influence of the light slit and of the methods of processing film on the frequency characteristic of reproduction; (7) the desirability of increasing the range of volume of reproduction; and (8) variations in negative exposures.

Various subcommittees have been appointed to study these several subjects outlined, the reports of which subcommittees are to be submitted at a meeting of the entire Committee in the near future.

JOURNAL AND PROGRESS AWARDS

At a meeting of the Board of Governors held May 24, 1931, it was decided that the following actions of the Board, relating to the Journal Award and the Progress Medal, should be published annually in the JOURNAL.

JOURNAL AWARD

The motion was made and passed that "an award of $100.00 shall be made annually, at the Fall Convention of the Society, for the most outstanding paper published in the JOURNAL of the Society during the preceding calendar year. An appropriate certificate shall accompany the presentation.

"The Journal Award Committee shall consist of not less than six Active members of the Society, to be appointed by the President subject to ratification by the Board of Governors. The Chairman of the Committee shall be named by the President and a two-thirds vote is necessary for election to the award. (Proxies are permitted.)

"The Committee shall be required to make its report to the Board of Governors at least one month prior to the Fall Meeting of the Society, and the award must be ratified by the Board. A list of five papers shall also be recommended for honorable mention by the Committee. These rules, together with the titles and authors' names, shall be published annually in the JOURNAL of the Society."

PROGRESS MEDAL

"The Board of Governors may consider annually the award of a Progress Medal in recognition of any invention, research, or development, which in the opinion of the Progress Award Committee shall have resulted in a significant advance in the development of motion picture technology.

"The Committee shall consist of not less than six Active members of the Society, to be appointed by the President subject to ratification by the Board of Governors. Names of persons deemed worthy of the award may be proposed and seconded, in writing, by any two Active members of the Society and shall be considered by the Committee during the month of June; a written statement of accomplishments shall accompany each proposal.

"Notice of the meeting of the Progress Award Committee must appear in the March and April issues of the JOURNAL. All names shall reach the Chairman not later than April 20th.

"A two-thirds vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing. The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

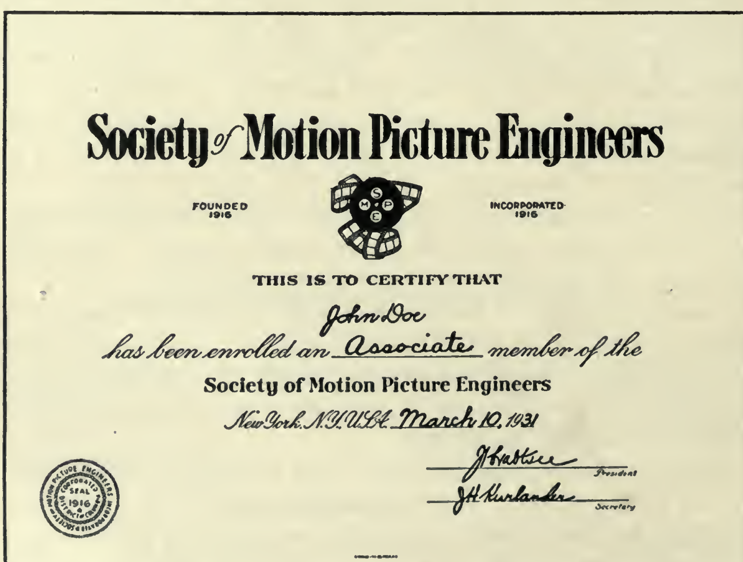
"Recipients of the Progress Medal shall be asked to present their portraits to the Society, and, at the discretion of the Committee, the recipients may be asked to prepare a paper for publication in the JOURNAL of the Society. These regulations, the names of those who have received the medal, the year of each award, and a statement of the reason for the award shall be published annually in the JOURNAL of the Society."

Active members of the Society are invited, according to the above, to propose names of those deemed worthy of receiving the Progress Medal Award, which proposals should be seconded by another Active member and forwarded to the Chairman of the Committee, Dr. C. E. K. Mees, addressed to the General Office of the Society. A written statement of accomplishments should accompany each proposal, which should reach the Chairman not later than April 20th.

The two committees have this year been amalgamated into a single committee known as the "Committee on Journal and Progress Medal Awards."

MEMBERSHIP CERTIFICATE

Associate members of the Society may obtain the membership certificate illustrated below by forwarding a request for the same to the General Office of the Society at 33 W. 42nd St., New York, N. Y., accompanied by a remittance of one dollar.



Society of Motion Picture Engineers

FOUNDED 1916 INCORPORATED 1916

THIS IS TO CERTIFY THAT

John Doe

has been enrolled an Associate member of the

Society of Motion Picture Engineers

New York, N.Y. U.S.A. March 10, 1931

President

Secretary

LAPEL BUTTONS

There is mailed to each newly elected member, upon his first payment of dues, a gold membership button which only members of the Society are entitled to wear. This button is shown twice actual diameter in the illustration. The letters are of gold on a white background. Replacements of this button may be obtained from the General Office of the Society at a charge of one dollar.

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Carrier Engineering Corp.
Case Research Laboratory
Du Pont Film Manufacturing Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted. The cost of all the available *Transactions* totals $46.25.

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1917	3	$0.25
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1926	25	1.25
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Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.50 each, a complete yearly issue totalling $18.00. Single copies of the current issue may be obtained for $1.50 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society, 33 West 42nd Street, New York, N. Y., and should be accompanied by check or money-order.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII APRIL, 1932 Number 4

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton Pa., under the Act of March 3, 1879.

THE PROBLEM OF PROJECTING MOTION PICTURES IN RELIEF*

HERBERT E. IVES**

Summary.—*The essential conditions for producing pictures in stereoscopic relief are two: First, separate pictures must be made from different points of view, corresponding to the two eyes; second, each eye of the observer must receive its appropriate view. No compromise with these fundamental requirements appears possible.*

If stereoscopic projection is to be achieved in such a form that a large group of observers may simultaneously see the projected picture in relief, the distribution of the appropriate views to the two eyes must be accomplished for each observer. There are two places where the distribution may be made: the first is at the observers' eyes; the second is at the screen on which the picture is projected.

If the first method be employed, two separate images must be provided on the screen, and every observer must have means for directing one image to the right eye and one to the left eye.

If distribution of the images is to be made at the screen, two images are no longer sufficient. Theoretically an extremely large number must be provided, a separate one for each position that can be occupied by any eye in the audience.

Several methods of utilizing the parallax panoramagram method are discussed. It appears that from the theoretical standpoint the problem of relief projection is entirely soluble, and experimental tests of still picture projection have been successfully made. Practically, the solution of relief projection of motion pictures will depend upon the use of apparatus involving excessive speeds of operation, great multiplicity of taking or projecting units, projection screens containing minute ridged reflecting or refracting elements of extreme optical perfection, projection lenses of extraordinary defining power, microscopic accuracy of film positioning, and photographic emulsions of speeds at present unknown.

The perception of relief in vision, that is, the location of different objects in the field of view at their proper relative distances from the eyes, is contributed to by a number of factors. We may list among these: geometrical perspective, according to which objects decrease in angular extent with the distance from the eyes; aerial perspective, by which distant objects are more or less veiled by intervening atmospheric haze; the effort of focusing or accommodating the eyes to

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Bell Telephone Laboratories, New York, N. Y.

objects at different distances; and, when the observer can move, by the different relative angular motion of near and distant objects. All these factors have been utilized to stimulate relief by makers of pictures both still and moving. The most important factor, however, and the only one that needs discussion as a problem still awaiting practical solution is binocular vision, which is peculiar to man and certain of the higher animals, because of the location of the eyes side by side, both receiving images of the same objects. I shall, therefore, in this discussion, proceed at once to binocular or stereoscopic relief, and our problem will be to consider the ways and means by which motion pictures might be projected so as to exhibit relief of this character.

BINOCULAR OR STEREOSCOPIC RELIEF

While the complete explanation of the process by which we appreciate relief when the two eyes receive images which are somewhat, but not too different, in character, has not been worked out to the satisfaction of psychologists, the essential physical conditions of stereoscopic relief are simply stated. They are as follows: (1) Separate pictures must be available, made from different points of view, corresponding to the two views that are seen by the right and left eyes. (2) Each eye of the observer must receive its appropriate view. These conditions are essential and inescapable. No compromise with them appears possible. No scheme which calls for a single picture or series of pictures taken from one point of view will meet the first requirement. No scheme which does not provide means for distributing the appropriate views to the two eyes will meet the second requirement. Once stated, these requirements appear obvious, and they have indeed been clearly understood by students of optics for approximately 100 years. In spite of this, however, would-be inventors continue with surprising regularity to announce schemes for projection in relief which they claim require no special camera or form of picture, or, if they propose taking two pictures in order to meet the first requirement, evade the provision of means for separating these pictures in the process of viewing.

Having now cleared the ground, we are prepared for a straightforward discussion of our problem. For purposes of presentation, we may conveniently discuss it in three steps: The first step will be the production of relief pictures by processes which do not involve projection. The second step will take up relief pictures produced by projection processes, but in the form of "stills," that is, not embodying motion. The third step will be to consider the projection of relief pictures in motion.

METHODS OF MAKING RELIEF PICTURES

In accordance with the requirements as stated above, the first piece of special apparatus which is needed in order to produce a picture in relief is some form of camera (we shall, of course, assume that the process of producing pictures is photographic), which can produce pictures from a number of points of view. In the simplest case, the number of points of view will be two, one for each eye, the apparatus consisting of a pair of similar cameras whose lenses may be separated by approximately the distance between the two eyes.

Pursuing this simplest method of making relief pictures, that is, simple stereoscopic pictures of the old and well-known form, we may now go over to the viewing end and consider means of meeting the second requirement: namely, the distribution of the two pictures to the appropriate two eyes. The simplest apparatus for viewing two pictures, one at each eye, consists of no apparatus at all, but lies in the proper directing of the two eyes. Holding up a pair of stereoscopic prints in front of the eyes, with the right eye view at the right and the left eye view at the left, one can, by practice, learn to diverge the optic axes and see one picture with each eye; or, if the two pictures are mounted side by side, but in the reversed relative positions to those just considered, one can, by converging the optic axes to a point between the eyes and the pictures, again see one picture with each eye, and thus produce a picture in stereoscopic relief.

Next in order of complexity of viewing device is some form of stereoscope. This may consist of mirrors or prisms placed one over each eye, and so directed or of such angle as to present one view to each eye, the eyes being in their normal unconverged or undiverged position. The stereoscope is an instrument very familiar to students of optics, and in a previous generation achieved wide popularity as a form of entertainment. In our present more feverish age, the appeal of pictures without action, even though possessing another aspect of naturalness, is so slight that it is now not unusual to find people who have never looked through a stereoscope.

Another means of distributing the pictures to the appropriate eyes is provided by utilizing color. In the anaglyph, the two elements of the stereoscopic pair are printed in complementary colors, and special spectacles are provided for the observer with a screen of different color for each eye, whereby only one picture is seen through either element of the spectacles.

The revolutionary idea that the distribution of the different views to the two eyes might be made, not at the eyes of the observer, but at the picture itself, was introduced by Frederic E. Ives about thirty years ago in the invention of the parallax stereogram. This device, since it is the direct ancestor of the most interesting projection methods which I shall describe, demands careful description and comprehension. According to requirement (1), as stated above, two pictures are taken,

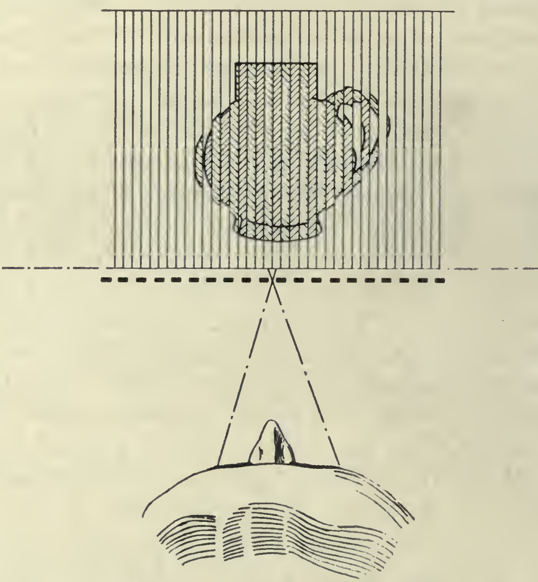

FIG. 1. The principle of the parallax stereogram.

from two points of view. Instead, however, of being mounted side by side as in the ordinary stereogram, these pictures are divided into very narrow strips, these strips being juxtaposed so that the left-hand strip of a pair is from the right eye view, and the right-hand strip from the left eye view. Close to this picture of alternate strips, which is in the form of a transparency, is mounted an opaque line grating with its clear spaces approximately half the width of its opaque spaces. This grating is mounted at such a distance in front of the stripped picture and in such relative lateral positioning of its lines that at a certain distance from the observer's face, the right eye strips are entirely concealed from the left eye and the left eye strips are entirely concealed from the right eye. Each eye then sees only a single view composed of a series of strips which, however, are made of such fineness (say, 100 to the inch) as to be invisible or unobjectionable at the viewing distance. This parallax stereogram, when held directly in front of the face, parallel to the two eyes and at the proper distance, exhibits stereoscopic relief without the interposition of any viewing device located at the observer's eyes. The principle of the parallax stereogram is illustrated in Fig. 1, and Fig. 2 is a photomicrograph of a small portion of an actual parallax stereogram transparency.

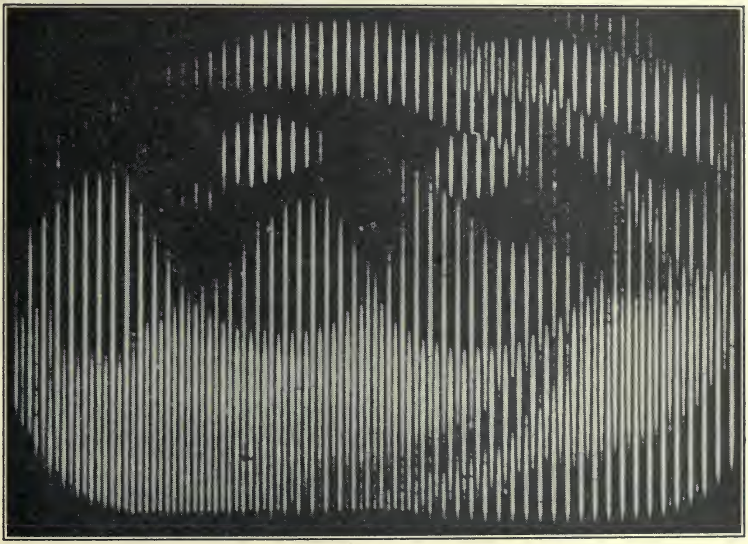

FIG. 2. Photomicrograph of portion of parallax stereogram showing alternating juxtaposed strips from right and left eye images.

A limitation of the parallax stereogram is that it must be viewed from a single definite direction and distance. While this detracts but little from the appeal of the picture if only one observer is to be considered, it is a serious defect if, as must be the case when we come to discuss means for projecting pictures visible to an audience, a large number of people, variously placed, must observe the relief picture simultaneously. In order to achieve a relief picture which shall be visible at any distance from any direction of observation, it is necessary to break away from the idea that stereoscopic relief is essentially a matter of *two* images. Consider that the picture is to be viewed not by one person in one position, but by any number of people in any possible positions. It is obvious at once that while each of these observers needs only two images to satisfy *his* two eyes, the total number of eyes to be satisfied may be very great. This demands at the taking end that some camera arrangement be adopted which will make the pictures from a very large number of points of view. At the receiving end it demands that the grating, or its equivalent, have relatively extremely narrow clear spaces so that, as an observer's eye takes up different angular positions, an entirely new composite view will be seen. In short, in place of the two strips which are behind each grating of the stereogram, there must be an extremely large number of minute strips behind each very narrow grating opening, and since these strips are (in the horizontal direction) little panoramas, I have proposed the name of "parallax panoramagram" for this kind

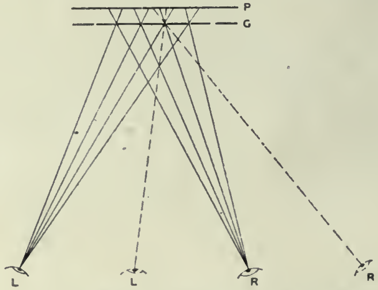

FIG. 3. The principle of the parallax panoramagram.

of picture which shall exhibit relief from any angle or direction of observation. The principle of the parallax panoramagram is illustrated in Fig. 3. Fig. 4 shows, greatly enlarged, a portion of a parallax panoramagram positive suitable for viewing through a grating with very narrow clear spaces.

It is evident that the problem of making parallax panoramagrams with their large number of points of view, must inevitably call for bulky or complicated apparatus. Several methods have been proposed. The most obvious is to provide a battery of cameras, arranged, say, in an arc about the object, with their lenses in close juxtaposition. If these cameras are then subsequently used as projectors for the pictures made in them, and are all directed to a sensitive plate placed behind a grating having very narrow clear spaces, the resultant photographic print will, with its grating, constitute a parallax panoramagram. In order to avoid the very large number of cameras and printing projectors required by this elementary scheme, the alternative has been proposed of using a motion picture camera which is moved about the object at a slow rate, while the requisite large number of views are taken in succession upon a motion picture film. Upon projecting the developed film from a projector similarly moved, on a sensitive plate behind a grating, a parallax panoramagram is obtained with considerable simplification of apparatus, but at the cost of the greater time required for the

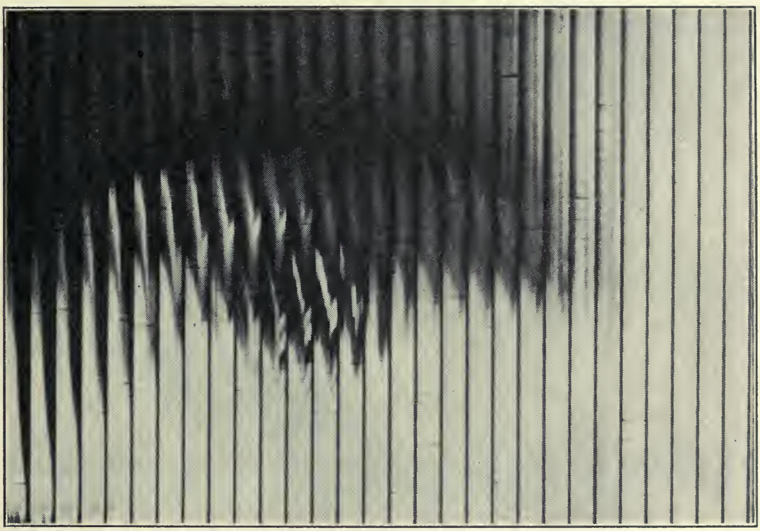

FIG. 4. Photomicrograph of portion of parallax panoramagram showing panoramic strips which are placed opposite the narrow spaces of the viewing grating.

successive as contrasted with the simultaneous exposures of the first scheme.

Another method of making parallax panoramagram negatives consists once more of a moving camera, but uses a grating in front of the sensitive plate and develops the minute panoramas behind the grating as the camera is moved relatively to the object, either by moving the grating during exposure by the width of its spacing (a method due to C. W. Kanolt) or by separating the grating and plate, and depending on the sweeping of the beam of light through the grating slit across the plate behind it as the relative positions of lens, grating, and plate are altered during the exposure. This method, like the one using a motion picture camera, requires a sufficient time for exposure for the camera to be moved through an arc or other suitable path about the object.

A third, optically ideally simple, method of making parallax panoramagram negatives consists in using a single very large diameter lens or concave mirror for providing the different points of view. This method requires that the lens or mirror subtend an angle from the object as large as it is desired that the final picture be visible in relief. For an angle of 60 degrees this requires that the lens or mirror have a diameter as great as the distance from which the object is photographed. Practically, in order to obtain such angles as this, a concave mirror is the only feasible device. An arrangement which

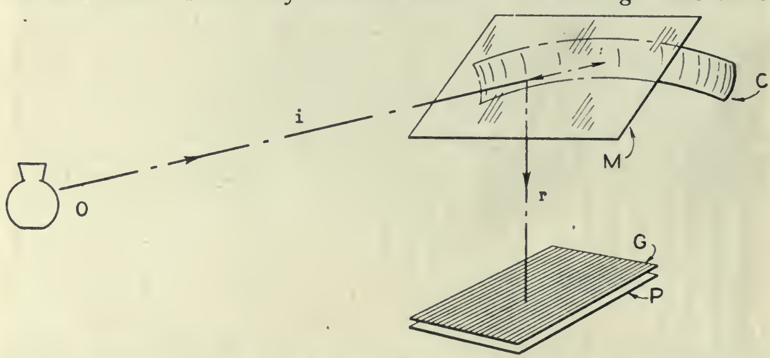

FIG. 5. Method of using a large concave mirror for making parallax panoramagrams.

has been used successfully for this purpose is shown in Fig. 5. It consists of a strip from a 4-foot diameter concave mirror, in front of which is placed a half-silvered plane mirror at 45 degrees. The light passing from the object to the concave mirror is reflected back to the 45-degree mirror and then downward to the sensitive plate, which is placed slightly behind a grating having clear spaces $^1/_{50}$ the width of the opaque. Each element of the concave mirror sees the object from a different point of view, and reflects an image in a definite direction through the grating lines. By using this scheme, a parallax panoramagram negative may be made at a single exposure. A certain price must be paid for such simplification, which is that the perspective relations are disturbed; infinitely distant objects are imaged at the focus of the mirror, which lies a relatively short distance behind the picture plane, thus restricting the method practically to objects near that plane. This restriction is, however, already present in any practical parallax panoramagram since the definition in the panoramic strips necessary to differentiate clearly objects far away from the picture plane is much beyond that possible by the "pinhole" action of the grating spaces.

Before going on to the question of projection, a few points with regard to still relief pictures of the parallax panoramagram type may be noted. As above described, the pictures are transparencies viewed through an opaque line grating. The form of grating described with

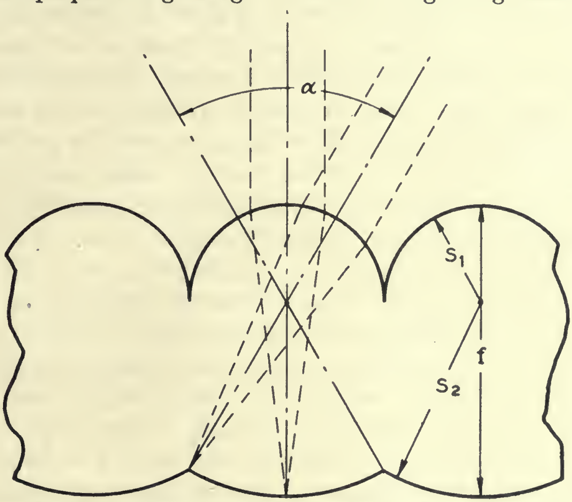

FIG. 6. Section of parallax panoramagram structure suited for viewing by reflected light. The same structure is used for several forms of screen for projecting parallax panoramagrams.

its extremely narrow clear spaces is quite wasteful of light. In its place may be substituted a grating composed of convex ridges of such curvature as accurately to focus parallel rays on the panoramic strips. In order to realize the full advantages of such convex ridges, however, it is necessary that the strip picture be printed, not on a flat surface, but on a series of surfaces which are concave with respect to the ridges already considered. This means that the parallax panoramagram should consist of a sheet provided with front and back convex ridges, each of different curvatures, as shown in Fig. 6. The curvatures for this purpose are easily computed, and if the technical difficulties of preparation are overcome, will provide parallax panoramagrams which are not wasteful of light, and in which the panoramagrams are visible equally well from all directions of observation. Another point to be mentioned in passing is that while only transparencies have been considered, the form of picture just described with its ridged structure may be made up as a picture for viewing by reflected light, provided the photographic emulsion be backed by some white reflecting material, the picture being printed, of course, to low density. Light incident on this doubly ridged structure can only come off from any given narrow element of a panoramic strip in a certain definite direction, thus meeting the essential conditions.

One further point must be touched upon as presenting an ever-present technical problem. In making pictures for the ordinary stereoscope, the photographic lenses, of course, invert each element of the stereoscopic pair. It is accordingly necessary when stereoscopic pictures are made on a single plate, that the prints be cut in two, and each separately inverted. If this be not done, the pictures will exhibit in the stereoscope, not stereoscopic, but pseudoscopic relief, that is, solid objects sink in instead of stand out. Now, in the preparation of parallax stereograms and panoramagrams are involved similar inverting operations which must be done by some optical inverting device. As an illustration, the pictures made by means of a large lens or mirror show pseudoscopic relief if the picture is viewed through the grating. In order to obtain stereoscopic relief, the expedient is adopted in this case of viewing the grating through the picture. In every form of taking and viewing device used for parallax panoramagrams, a close watch must be kept in the inversions due to the optical elements, and means must be adopted for assuring that the relief is stereoscopic instead of pseudoscopic.

PROJECTION IN RELIEF

Taking up now the problem of projecting pictures in relief, the logical order is first to study projection of still pictures, leaving until the end a discussion of the peculiar difficulties introduced by motion. In general, all the methods which we have discussed for producing relief pictures are available, with certain modifications for projection. The essential feature of projection is, of course, that in place of a picture fixed in the plane which is observed, the actual picture used is placed in a lantern or other projecting device, and an image, usually enlarged, is thrown upon the observing plane, which for convenience may be spoken of as the screen.

Following the same outline as that used in the previous section, we note, first of all, that the simplest method of projecting pictures in relief is to throw upon the screen the two elements of a stereoscopic pair, and to look at them directly without interposing an optical instrument, diverging or converging the optic axes so that each eye appreciates only one picture. All that is necessary, therefore, to achieve projection in relief is to project pairs of pictures, and to train our audiences to control their optic axes by making themselves temporarily cross-eyed, or the reverse, during the projection period. While this method of stereoscopic projection is entirely feasible for an audience of optical experts who have had a little training and practice, it does not appear promising for popular use.

Proceeding next to apparatus to be placed before the eyes of each observer, we note that each person in the audience may wear the equivalent of a stereoscope of either the mirror or prism form. Next in order is the anaglyph scheme, in which the two pictures are projected in different colors, and each member of the audience wears colored spectacles. This scheme has been used with success in numerous demonstrations; it suffers from the limitation that it is not applicable to projection in natural colors. Two other schemes, which might conceivably be used for non-projected pictures, are nevertheless specially feasible with projection and are to be ranked among the practical methods of this sort. These are, respectively, projection of the two images with polarized light, and projection of the two images in quick alternation. In the first of these methods, the two images are projected by two projectors, one with light polarized, say, in the horizontal plane; and the other with light polarized in the vertical plane. Each observer is then provided with a pair of polarizing prisms, the prisms being mounted in front of the eyes, one vertical and the other horizontal, with respect to its plane of polarization. By this means, perfect separation of the two images is obtained. In the alternate projection method, the two images are thrown on the screen alternately in such rapid succession that they appear continuous by persistence of vision. In front of each observer's eyes are then placed shutters which expose the two eyes alternately, operated in such phase that each eye sees its appropriate image as projected. This method of relief picture projection has been successfully demonstrated to a full theater audience.

These methods of relief projection, which call for separate viewing apparatus for each member of the audience, are, optically speaking, simple and reasonably satisfactory, and are easily adapted to motion pictures. However, the goal of speculation in relief picture projection has always been some means of achieving relief without subjecting the observers to the inconvenience of special individual spectacles or the picture producer to the expense of the multiple viewing apparatus demanded. While it is at present doubtful whether schemes which provide the distribution of images to the different observers at the screen can approach, in simplicity and feasibility, these methods which divide the images at the eyes, they are of great optical interest, and I shall proceed forthwith to a discussion of them.

In discussing projection schemes of this general type, I shall adopt an order of presentation which is not perhaps logical, but which ties in most closely with the results of our study of non-projected relief pictures. I shall proceed at once to the problem of projecting parallax panoramagrams in their most fully developed form. Let us imagine that instead of putting behind the opaque line grating a transparency print from a parallax panoramagram negative (made with its panoramic strips properly oriented to be placed behind the grating), we put

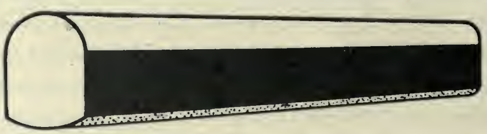

FIG. 7. Perspective view of glass or celluloid rod from which a translucent projection screen can be built up for projecting parallax panoramagrams.

a translucent screen, and that we remove our parallax panoramagram print to a projection lantern placed at an appropriate distance behind the grating and screen; we then project this parallax panoramagram print upon the screen in exquisite focus and in accurate registration as to size, position, and inclination of the panoramic strips behind the slits of the grating. If this operation can be performed with the requisite accuracy, an observer stationed anywhere in front of the grating will see a relief picture which will be indistinguishable from the ordinary parallax panoramagram.

The opaque line grating which we have assumed will, of course, be very wasteful of light, and in its place it is preferable to use a ridged structure such as has already been discussed. In the case of projection we are, of course, interested in much larger pictures than, for instance, in show window transparencies. In a screen several feet across containing 200 or 300 ridges, the individual ridges may be as large as a quarter-inch in diameter. This relatively large size makes it feasible to consider building up the screen of separate rods of transparent material, such as glass or celluloid. These rods will have a cross-section consisting of two flat sides, a front surface of one radius of curvature, and a back surface of another radius of curvature such that all points of the real surface are in the sharp focus of the lens formed by the front surface and the body of the rod. This rear surface must

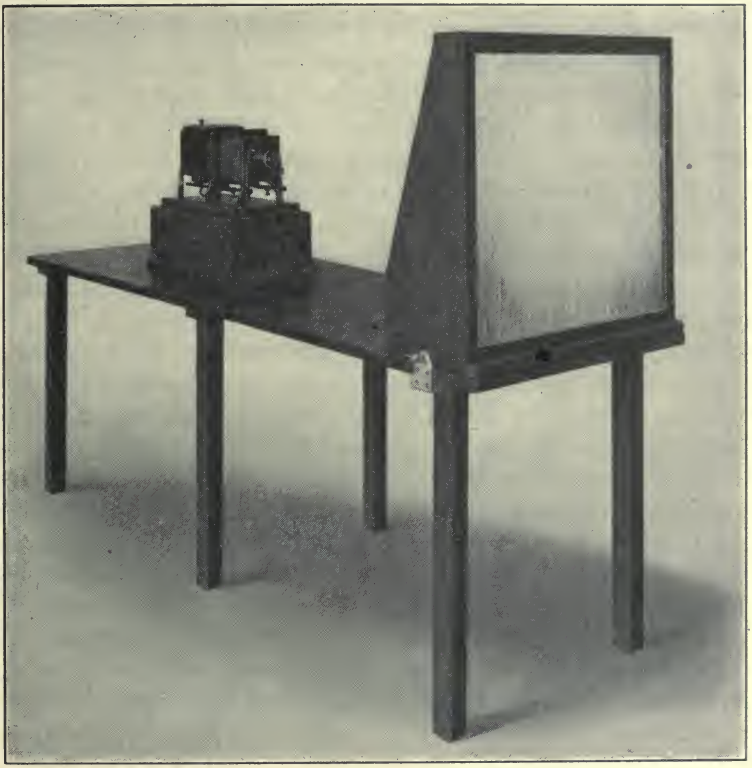

FIG. 8. Experimental arrangement for projecting parallax panoramagrams upon a translucent screen.

then be given a frosted or other diffusing finish. When a large number of these rods are clamped together they form a screen of the desired type, on the back of which the parallax panoramagram print can be projected. A single rod for such a screen is shown in Fig. 7. An experimental screen, built up of 200 rods, of this form is shown in Fig. 8, together with the projection lantern used in an experimental demonstration of relief projection by this method.

Postponing for the present a discussion of how the slide containing the several hundred panoramic strip images is to be made, we can discuss the practical difficulties which must be faced in projection of this sort. Assuming that the picture to be projected is of ordinary lantern slide size and that the picture is to be divided into 500 narrow panoramic strips, which would correspond to a screen 10 feet across with $^1/_4$-inch rod elements, we must have on our lantern slide something like 150 panoramic strips per inch. Each one of these strips must be a complete little panorama containing enough sharply defined elements to provide separate images for each pair of eyes in an audience spread out through at least 60-degrees angular position in front of the screen. As a working figure, if we assume 100 differentiable strip elements in each panoramic strip (this corresponds to a separate view for each eye 20 feet from the screen, lying within 10 feet from the center line of the auditorium), we must have a lantern slide in which the resolving power is of the order of magnitude of $^1/_{15,000}$ of an inch, approximating a wavelength of visible light. Proceeding now to the projection lens, this must, of course, give an accurately rectilinear image, in order that the panoramic strips on the slide may be accurately positioned on the back of the projection screen. Next, the defining power of this lens must be such that it images the panoramic strips on the backs of the screen rods with exquisite fidelity. Proceeding now to the rod screen, it is obvious that the individual rods must be figured with an accuracy comparable with that found in good optical lens work if line elements of approximately one-hundredth the width of the rod are to be focused from the back diffusing surface into parallel beams to be passed into the observing space. It may be mentioned in passing that in place of the transmission screen which has been discussed, forms of reflecting screen are also possible in which concave or convex cylindrical rods are used. In every case, however, the requirements as to extraordinary perfection of all the optical parts obtain.

From this rough discussion of the requirements, it is obvious that the projection of a parallax panoramagram by this method calls for most extraordinary refinement of all the elements concerned. On a crude scale, however, it has been found by experiment that the procedure can be carried through, and relief projection has been accomplished experimentally in this way.

Taking up now the problem of how to produce the "lantern slides" for projection by this method, it may be said in general that any of the methods which have been described, such as those employing multiple lenses, moving lenses, and so on, may be used. However, looking ahead toward a procedure which might be applicable to motion pictures, the most desirable method would be one in which the pictures are made by a single exposure on a single plate. The one method which is now available for this is to use a large concave mirror as already described. When it comes to making pictures for projection, however, a complication is introduced, which is, briefly, that the mirror method produces pictures which are too large for insertion into an ordinary projection lantern. Due to the physical impossi-

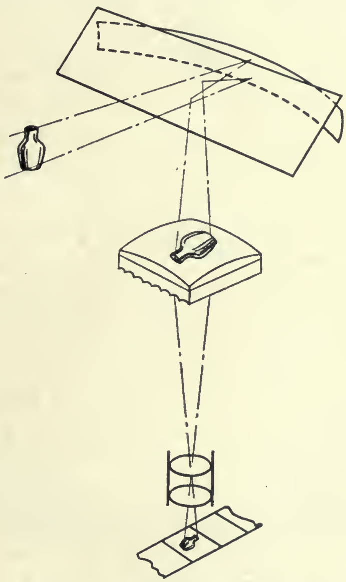

FIG. 9. Arrangement for producing parallax panoramagram negatives of convenient size.

bility of producing a lens or mirror which shall be both of such large size as to subtend a large angle with ordinary objects, and at the same time of such short focus as to produce images as small as a lantern slide, the mirror method is, generally speaking, only successful in making pictures of natural size. Thus, for making portraits, a mirror having a radius of curvature of four feet, with the face and the sensitive plate each placed four feet from the mirror, is a practical arrangement. If larger or more distant objects are to be photographed, the size of the mirror must increase in proportion, as well as the size of the picture which is obtained.

To overcome this difficulty, the parallax panoramagram negative made with a large mirror must be reduced in size, by some photographic procedure. The preferred way to do this is to re-photograph the strip images, formed behind the grating upon a diffusing glass, directly, in the first picture-taking operation. A more satisfactory method of obtaining the strip images is to substitute for the grating and diffusing glass, a transparent ridged screen. The ridges, in order to assure that the final picture shall be stereoscopic instead of pseudoscopic, must be of the correct direction of curvature for the kind of projection screen

FIG. 10. Method of projecting pictures in relief using a large number of projections and two gratings at the screen.

which is to be used. For a projection screen of the type we have been discussing, the screen in the camera should have concave cylindrical ridges, which form minute virtual panoramic images. When a photographic lens is placed behind this screen at the proper distance with respect to its focal length, as illustrated in Fig. 9, a second reduced image is formed which may be made of any desired size, such as that of a lantern slide. Prints made from this negative are then suitable for projection. It is again obvious that the optical quality of the concave ridged screen and of the photographic lens just described must be of extraordinary perfection. Also, that the photographic emulsion used must be of exceedingly high resolving power.

The system of relief projection which has just been described is, from the strictly scientific standpoint, bearing in mind its limitation to objects near the picture plane, a complete solution of the problem of projecting still pictures in relief.

Before going on to discuss the peculiar problems of motion picture projection, we may consider some suggestions for evading the severe requirements which the ideally complete method just described involves; in particular, the great practical difficulties of exact registration of the projected panoramic strips on the screen elements, and the necessity for extraordinary resolving power in the photographic emulsion. There are several ways of escaping from these requirements which, however, demand giving up the single projector or the single image. One method which has been experimentally demonstrated consists in projecting images from a battery of projectors. If, for instance, a translucent screen is mounted with an opaque line grating both in front of and in back of it, and a multiplicity of images are projected from different directions through the rear grating upon the translucent screen, the space in front of the screen will present relief pictures from any position or direction. (Fig. 10.) The registration of these multiple images upon the screen is a matter of relatively insignificant difficulty compared with the registration problem above considered. A more practical form of screen is one of the reflection type which is exactly similar to the translucent screen above described, except that the back surface of the rods is given a diffuse reflecting finish as, for instance, with aluminum paint. Such rods have the property of reflecting light exactly in the direction from which it is incident. A screen built of such rods, therefore, will exhibit to each eye in an audience only that picture which originates at the projector lying in its line of sight produced backward. With a battery of juxtaposed projectors in front of the screen, observers in the space between the projectors and the screen see the pictures in relief. An experimental apparatus for demonstrating relief projection of this sort is shown in Fig. 11.

Another means of avoiding the accurate registration problem and also of avoiding the necessity for a large number of projectors is to use a single projector, projecting a rapid succession of images, as from a motion picture film, but with the projector arranged to move rapidly from side to side through a sufficient distance to sweep through the whole observation angle. This scheme is obviously not very practicable because of the mechanical difficulties involved. It is possible to imagine some optical means by which the beam of light from the projector could fall upon the screen from different angles without the projector itself moving, but these again demand very large rapidly moving parts, and are of little promise.

Still another scheme, which may be described as a hybrid method, may be mentioned. Suppose that we again use a single motion picture projector, projecting in rapid succession a series of views

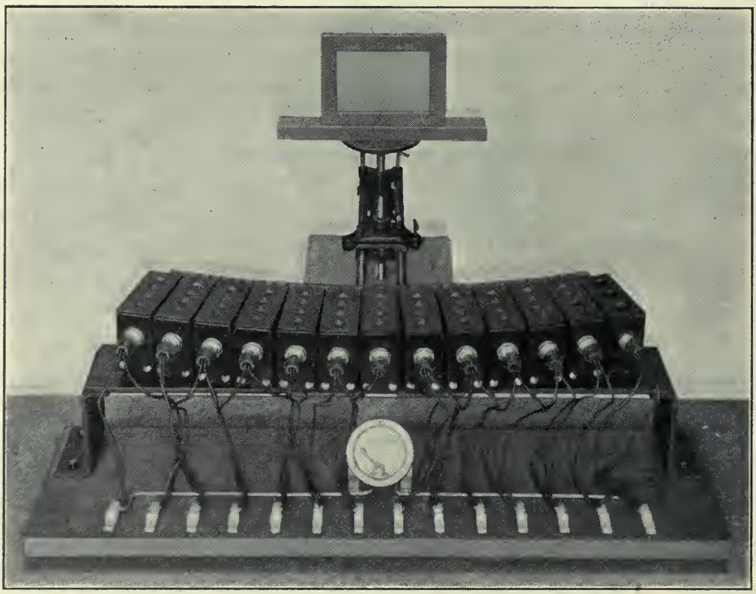

FIG. 11. Experimental apparatus for projecting pictures in relief, using a battery of projectors and a ridged reflecting screen.

which have been taken from different directions as, for instance, with a moving lens camera. Suppose that we place immediately behind the translucent rod screen, an opaque line grating with very narrow clear spaces, and that we move this grating laterally back and forth so that each succeeding projected image falls in a series of extremely narrow bright lines upon the rear surfaces of the rod elements of the screen. (Fig. 12.) If the pictures are projected with sufficient rapidity, and if the opaque line grating oscillates in exactly the phase relations required, we shall, by persistence of vision, again have a projected motion picture in relief. A modification of this scheme consists in removing the opaque line grating from immediately behind the screen to the projection lantern, placing it immediately in front of the motion picture film, and imaging it accurately upon the back of the rod screen. We have here again a problem of very perfect image registration, but the problem has to be faced only once with a built-in element instead of with every picture.

There are probably other combinations of apparatus which might be devised, but the point which I wish to make is, I think, sufficiently clear—that our fundamental problem is one of providing a vast number of images, and that in order to do this we are inevitably forced either to make these images of excessively small size or to resort to a multiplicity of apparatus or to a multiplicity of projections in time. The whole problem is, philosophically speaking, a manipulation of

FIG. 12. A "hybrid" projection scheme, using a large number of images projected in rapid succession.

space and time elements comparable in many ways with the problems presented in television.

PROJECTION OF MOTION PICTURES IN RELIEF

Because of what has gone before, the discussion of the specific problem of projecting motion pictures in relief can be made quite brief. All that is necessary is to take one of the methods which have been outlined for still picture projection in relief, and to increase its speed to the point where the required number, say, 20, complete pictures are projected per second. This calls for all the multiplicity of apparatus, all the accuracy of the constituent parts and other features which have been discussed, together with the additional difficulties of obtaining greater sensitiveness of the photographic materials and of performing the accurate registration operations at high speed.

The specific case of the most scientifically complete method may be gone into in some detail in order to illustrate what these requirements amount to. Let us assume that the original film is to be made by means of the large concave mirror in conjunction with the transparent ridged screen and photographic lens. (Fig. 9.) With this apparatus as set up for making still pictures for projection of lantern slide size, a ridged screen of approximately 200 ridges has been found by experiment to photograph down to lantern slide size with some success, provided the objects to be photographed lie very closely in the plane of the picture. With an intense but practicable illumination, the exposure necessary with this apparatus is about one minute, due to the small photographic aperture of the mirror and the loss of light occasioned by the semi-transparent mirror used for throwing the image to one side. For the process to be applicable to motion pictures at 20 frames per second, the speed of the photographic emulsion would have to be increased by approximately a thousand times. If the picture were photographed down to ordinary motion picture frame size, the resolving power of the film would, without going into figures, have to be far better than anything now available; and, if the number of panoramic strips were increased from 200 to 500 ($^1/_4$-inch strips on a 10-foot screen), the resolving power necessary to present individual views to 100 eyes in a row at a 20-foot distance would simply be impossible of attainment because it would demand film images smaller than the wavelength of light. Much larger film than that now used would then be another special requirement.

Going over now to the projection of the picture so obtained, the problem of the exact registration of the strip images upon the projection screen is made excessively difficult by the motion of the film. Each image must, in turn, be so accurately positioned that no wavering of the picture occurs. This means that the film must not shift laterally by as much as one-hundredth of the width of the strip image or approximately, for the case just considered, $^1/_{50,000}$ part of an inch at the projector. When, in addition to these requirements, we remember that warping, expansion, and contraction of the film material would injuriously affect the registration, it is sufficiently obvious that projection of motion pictures in relief by this method calls for a perfection of apparatus and materials quite beyond anything now in sight. The alternative methods which were noted in the last section, while avoiding the chief difficulties of registration, call, as already noted in the case of still projection, either for a multiplicity of projectors or for high speeds of projection, which in the case of motion pictures would mean some hundreds of times present projection speeds.

CONCLUSION

As we have reviewed the problem of projecting pictures in relief, it appears that there are two clearly differentiated methods:

(1) Involves the distribution of the images to the observers' eyes by means of apparatus individual to each observer.

(2) Calls for means of producing this distribution at the projection screen.

The practical disadvantage of the first scheme is that it involves multiplication of viewing apparatus, and some effort and inconvenience on the part of the observers. The disadvantages of the second method, as they have appeared from this analysis, are the excessive refinement of all the apparatus parts, which could be avoided only in part by having recourse to a multiplicity of projecting units or excessive speeds of projection. In their present experimental state of development, the special screens and other devices called for by the second method of projection are too crude for projecting pictures visible to audiences of any great size, and the relief images can be produced with any satisfactory degree of definition only if the objects of interest lie close to the plane of the screen. This latter objection is entirely lacking in the first method of projection. In fact, it may be said that in the present state of art, the only good quality stereoscopic projection which is now possible is accomplished by means of alternate projection, complementary color filters, polarizing devices, or other means operating at the eyes of the observers. The means involving distribution of the images at the screen are of great optical interest, and may be said to be completely postulated theoretically, but their practical realization on anything like a commercial basis appears remote.

It has been tacitly assumed throughout this discussion that, if the various projection schemes were worked out to perfection, the resultant relief motion pictures would possess qualities of naturalness which would add to the appeal of the motion picture. There is, however, one general consideration which must be recognized: namely, that it is not, speaking broadly, possible to project a picture in relief which will be "correct," and at the same time exhibit noteworthy relief to all members of an audience of any size, stationed at greatly different distances from the screen. Striking stereoscopic relief is observed in real life only for relatively close objects, and the amount of relief varies with the distance of the observer from the object. If, therefore, a scene were projected in relief to natural size in the average auditorium using the "parallax panoramagram" method, in which the relief changes as it should with the distance of observers, only those members of the audience who were in the front rows would find the relief quality much of an addition to the picture. If the first method of projection be used, in which only two pictures are taken, it is true that all members of a large audience will perceive striking relief, since the two eyes of each observer will see definitely different pictures; but it is at only one observing distance, namely, that from which the original object was photographed, that the relief will be correct. At other distances, the two pictures will correspond to points of view greater or smaller than the normal distance between the eyes, giving exaggerated or diminished relief.

In ordinary projection, in particular motion picture projection, objects are rarely reproduced in their natural sizes; usually the screen picture is very greatly magnified. In relief projection, magnification presents a difficult problem. In the absence of relief, gigantic close-ups produce little or no impression of unnaturalness. If, however, a typical close-up were presented in relief, the appearance of the picture would inevitably be strange and unnatural to many in the audience. For instance, if the relief picture be produced by one of the first methods, involving the projection of two images to be separated at the eyes of the observers, all the observers, as just noted, will have the same two points of view, which will correspond to eyes separated by various distances, according to the viewing position. The observers from nearby, for whom the pictured object subtends a much larger angle than normal, will be virtually seeing the object as though their eyes were separated by several feet. In the case of the second kind of relief projection, enlarged images are, strictly speaking, ruled out. A magnified image will actually appear magnified; a face, for instance, will appear as a giant's face, larger than natural, and exhibiting the decreased stereoscopic relief that a large object does as compared with a small one of similar shape. (To put it another way, if the screen image be magnified, the separation of the eyes of the observers should be increased in the same proportion.) Close-ups for this kind of projection should be shown in natural size, but should be so photographed as to appear located in space in front of the screen at such a distance from the observer as to give the desired degree of intimacy. This introduces the interesting complication in this kind of projection that observers nearer than the point where the image is formed in space will be between the image and the screen, and will get no picture. Practically, it means that no image in space should be very far in front of the screen.

I do not purpose at this time to enter into a detailed discussion of these complications, but merely to draw attention to the fact that the attainment of entirely correct relief projection would carry with it an inevitable restriction in the size of the audience which would get much benefit from the added factor of relief. If the relief effects are to be entirely natural, the motion picture would have to return to a close simulation of the dimensions of the regular stage, abandoning one of its unique advances over the stage, namely, the "close-up." Doubtless, were relief projection to become feasible and commonplace, a special art would be developed, which would strike some workable compromise between the appealing qualities of relief and the unnatural distortions which great magnification would introduce.

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DISCUSSION

MR. KELLOGG: When the two views of the Capitol at Washington were shown, I wondered how far to the side one could go before the actual difference in the size of the pictures makes it practically impossible to merge them.

MR. IVES: I do not know. Stereoscopic relief can be obtained with one of the two images in very poor shape. I imagine one could tolerate a lot of distortion and yet get the effect.

MR. GAGE: These parallax panoramagrams, particularly those that are colored, are very pleasing. However, I wonder, although they may be interesting as novelties, whether they would be desirable as a regular thing in the theater. This is a question that ought to be considered here.

PAST-PRESIDENT CRABTREE: I believe that the mind can imagine a lot of things.

If the necessary willingness to believe is created in the observers, they will undoubtedly imagine a certain amount of relief, both in the sound and in the picture.

MR. KURLANDER: In view of the many difficulties in getting true stereoscopic effects, is there not a simpler method of creating a pseudo effect that would be better than the present flat effect?

MR. IVES: A great deal can be done by lighting, and by poor depth of focus. And where the nature of the subject will permit, the relative motion of the camera and object provides a beautiful relief. But this is a subject to which I have not given much attention. I was talking about binocular or stereoscopic relief.

MR. VICTOR: May I offer, as my personal belief, that we will eventually find the solution to stereoscopic relief in colors? Every artist knows the value of color perspective, and I think that some day we shall have a color projection system that will give us very nearly the effect of stereoscopic pictures.

MR. IVES: There is a beautiful painting in the Gardiner Museum, in Boston, which I would cordially recommend to every one interested in this line of speculation. It is a picture by Sargent—a group of dancers with musicians in the background. It is lighted with spotlights, in a rather long room, and as one enters through a door at the back, he obtains a remarkable illusion of relief.

MR. KELLOGG: Concerning the true stereoscopic effect, when two pictures are merged, there is only one plane in registration. Everything else is out of registration, and in so far as the images of the two observing eyes fuse in the consciousness, there must be a blur. Now, a number of efforts have been made to produce three dimensional pictures, I believe, by printing two photographs or otherwise combining them into a single picture which both eyes see, and in which everything in one plane is sharp and everything in any other plane is double. I should like to know whether, as long as one is willing to center his attention on that one plane, it provides any better sense of depth than can be gotten from any ordinary sharp picture.

MR. IVES: My comment on that would simply be that it does not conform to the second of my series of points—that appropriate images are not distributed to the appropriate eyes.

MR. GREGORY: Has cylindrically lenticulated film been used for the taking of parallax panoramagrams?

MR. IVES: Yes, it has. It is more efficient in utilizing the light.

MR. MAXFIELD: There is an effect I have noticed quite frequently on entering a motion picture theater; someone coming out swings the door open, and I see a close-up on the screen standing out in beautiful third dimension. On measuring approximately the distance from the place where I had noticed that effect, to the screen, it looked as though the close-ups had been taken with approximately a four-inch lens. I was viewing the picture from my position, at the same angle subtended by the lens when the scene was photographed, assuming that a long focus lens had been used on the close-up. I should like to ask Mr. Ives if he has any information regarding the relative importance of really correct perspective *versus* binocular, where one views the picture from a relatively long distance.

MR. IVES: I do not know anything about viewing from a long distance. It is well known in ordinary photography that for a picture to present correct perspective it should be viewed from the distance which held between the lens and the plate. And by looking at such a picture at that distance with one eye, I have heard that one gets a sensation of relief. What happens is, that he does not miss the other eye so much. Personally I do not get a sensation of relief by looking at a picture with one eye at that distance. But people tell me they do.

MR. MAXFIELD: I do.

THE EUROPEAN FILM MARKET—THEN AND NOW*

C. J. NORTH AND N. D. GOLDEN**

Summary.—*European producers will offer some 450 feature pictures during 1931. Leading producing countries are Germany, offering over 150 German dialog pictures, England some 140 sound features, and France over 100 Frenchdia log films for the year 1931. Europe is rapidly wiring its theaters, as indicated in the 10,400 wired theaters during 1931 as compared with the 4950 theaters wired during 1930, over a 100 per cent increase in the short space of one year.*

Elimination of legislation detrimental to American interests occurred in France during 1931, and a tightening up of quota legislation was continued in Germany. Agitation to increase the quota percentage to 50 per cent in the United Kingdom gained very little headway, while other countries that have become picture conscious are trying to encourage their own production through subsidies, contingents, or taxes, as the case may be. Coupled with the problem of European production competition and the artificial trade barriers set up by European governments, is that of supplying European countries with dialog pictures in their native tongue.

While the above obstacles appear difficult to surmount at the present time, the ingenuity of American technicians and producers will find a way to solve these problems to the extent of producing a sufficient quantity of foreign dialog films at a cost that will bring a fair return on their investment.

The financial destinies of most of our film companies—certainly all the leading ones—come unpleasantly close to depending on the state of our film revenues from abroad, of which Europe supplies nearly 70 per cent. Back in the days of the silent film, approximately 30 or 40 per cent of our entire rentals came from overseas. After foreign audiences stopped going to see pictures merely because they had sound—in other words, in 1930—our foreign revenues dropped to about 25 per cent. As of today, many authorities consider that they have fallen below 20 per cent. Obviously the slack must be taken up somewhere, and it is therefore no coincidence that the economies forced on the various motion picture companies this year have occurred just at the time of the curtailment of our foreign revenues.

Perhaps the most effective way in which to apprehend the condi-

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Chief and Assistant Chief, Motion Picture Division, Bureau Foreign and Domestic Commerce, Washington, D. C.

tion in Europe, and the changes that have taken place, is to consider briefly the situation that exists in a few of our major European markets, after which we can possibly reconstruct a picture of the scene as a whole.

The United Kingdom—our most important customer, not only in Europe but in the world—began to find itself film-minded during 1930, and by the end of that year was quite strongly entrenched as a competitive factor in its own market. Prior to that time, it suffered an overwhelming dependence on American pictures to the extent of about 80 per cent, even as late as 1929. However, the final establishment of talking pictures gave Great Britain a medium for the exploitation of its fine stage traditions, and although slow to realize how quickly sound films would dominate the scene, once under way the momentum acquired was fairly great. Thus, British production that accounted for less than 90 films in 1929, increased to a total of 135 in 1930, and will reach better than 140 by the close of this year. It should be noted that of this 140, about 108 are the products of six companies, led by British International and Gaumont-British with 35 each, all of which companies have well equipped plants, extensive distribution facilities, and theater outlets aggregating a capital investment according to unofficial estimates of not far from two hundred millions of dollars.

TABLE I

Production Schedules of Foreign Producers

Germany			France			England		
	1930	*1931*		*1930*	*1931*		*1930*	*1931*
Ufa	18	25	X-Y-Z*	9	11	British Int. Pictures	34	35
Suedfilm		12	Gaumont-Franco Film-Aubert	11	10	Gaumont-British Corp.	9	35
D. L. S.	5	19	Pathé-Natan	11	16	Gainsborough	25	12
Emelka	6	10	Jacques Haik	10	7	British & Dominion	16	12
Terra	9	10	Braunberger-Richebé	4	8	British Lion Associated	5	86
Others	136	88	Others	31	55	X-Y-Z*		
						Miscellaneous	46	26
Total	174	164	Total	76	107	Total	135	134

* American Producing Co.

In spite of England's financial difficulties, the past year has been relatively prosperous so far as motion picture receipts are concerned. For, while theater attendance has declined considerably from the novelty days of 1929, the outlets for sound film showings are much greater. For instance, at the end of 1930, about 2600 houses were wired. As of today's date, this number has increased to about 4100 out of less than 5000 theaters, a gain of nearly 65 per cent. The only difficulty here from the American point of view is that, even though the quantity of films imported from the United States is still decidedly in the majority and may amount to as much as 70 per cent of the total for the year, British films are gradually getting more advantageous play dates, and in a striking number of cases are grossing up to 50 per cent higher. In other words, the British public is at last getting something that pleases them, out of their own studios, and even though there is no language barrier as in Continental Europe, many of the present run of the British-made product have local features, whether of voice, setting, plot, theme, or the like, from which they acquire greater audience value than those imported from the United States.

This is a new situation, and is one that supplies food for thought. For now that the snowball has gathered momentum, there is no knowing how great it may become. We may see the time when England will produce not only enough for the greater proportion of its own needs, but will also supply the bulk of the pictures shown in its dominions. This is probably a pessimistic outlook for us, but undoubtedly revenues from this market are due for a steady decline.

The recent recommendation of the Federation of British Industries and of the Trades Union Council, to increase the quota to 50 per cent, made little headway. The English government decreed, in 1927, that a certain proportion of all the films distributed and shown in England must be British made. This proportion last year was 10 per cent for the distributor and 7.5 per cent for the exhibitor; and this year is 12.5 and 10 per cent, respectively. That the advantages of the quota outweigh its initial disadvantages through the organization of mushroom companies offering quota films is a question. In any event, it now seems to be recognized that nature should be allowed to take its own course, and that no further attempt should be made to legislate an increase in film output.

When we come to Continental Europe, the language factor immediately appears, and must constantly be borne in mind in any consideration of France and Germany. In the former country great strides have been made in production. In 1929, about 52 films were produced (mostly silent); in 1930 this was increased to 76 films in sound alone, as well as 18 silent films and a number in foreign dialog. This number will be further increased this year to 107 sound and dialog pictures, exclusive of foreign versions. Of those pictures produced, Pathé-Natan and Gaumont-Franco-Film Aubert are the leaders; but in France production in general is considerably more

TABLE II

EUROPE

Increase in Number of Wired Theaters, 1930–1931

	October, 1930	October, 1931
United Kingdom	2600	4100
Germany	940	2000
France	350	850
Sweden	90	550
Italy	120	450
Czechoslovakia	75	300
Spain	145	290
Austria	55	295
Denmark	45	200
Netherlands	95	180
Hungary	70	175
Switzerland	65	140
Rumania	50	135
Belgium	30	125
Yugoslavia	35	110
Poland	60	105
Finland	15	70
Greece	20	70
Norway	30	60
Turkey	10	40
Bulgaria	10	35
Portugal	15	30
Other European countries	25	90
TOTAL	4950	10,400

decentralized than in this country, no less than 42 companies engaging in the production of pictures in 1930, of which 27 produced only 1 film each.

French films have in general great popularity, some indeed such as Rene Clair's *Sous les Toite de Paris* and *Le Million* grossing sums beyond what all but a very few American films have grossed in the most prosperous era of silent pictures. Here again, French stage tradition and the opportunity of hearing the French language spoken by French actors has brought about a strongly nationalistic attitude on the part of French audiences, with the result that American companies must supply French language pictures in order to do business in France.

And yet the French have to contend with one of the most difficult of film problems, namely, product shortage and an insufficiency of play dates to enable them to secure sufficient revenue on the average run films to expand their production to any marked degree. Obviously, their own production is insufficient to meet their demands. And outside of that, they have only the French versions of American made films and an additional few supplied by Germany. Of the former, only about 25 were made in Hollywood so far this year, with possibly an equal number in Germany. The result was that at the end of last June the French abolished their quota system in favor of limitations against only those countries which themselves have restrictions. Thus, free entry of American product into France is assured. And there is no question that the French market can absorb as many films from the United States as our companies are likely to put out, the understanding being that these must be in the French language.

I referred a moment or two ago to France's insufficiency of play dates. There are about 3000 theaters in France. At the end of 1930 some 350 theaters were wired, and even now the number is only 850. With less than one-third of the theaters in France adapted to sound reproduction it can readily be seen how far the French market is from realizing its true potentialities. Obviously, the silent exhibitors must wire or go to the wall.

When we turn to Germany we find that the film business is at an exceedingly low ebb. The economic depression is having a retarding influence on theater attendance; and many exhibitors are on the verge of bankruptcy which has its painful repercussion on both distribution and production. In addition, high taxes threaten to take what small profits the few exhibitors are making. This situation incidentally is a hold-over, more or less, from last year. Germany has, furthermore, continued her rigid policy of import restriction against foreign sound pictures, only 105 of these being permitted entrance between July 1, 1931, and June 30, 1932. Incidentally, this official trade barrier has so far been more or less meaningless to the American trade, which has not produced German dialog films in quantity beyond what they could get permits for—and it must be remembered that German audiences insist on German dialog—but it definitely limits our future chances of deriving much revenue from Germany in the near future.

In spite of the rather pessimistic picture just drawn of German film conditions, it must not be understood that no money at all is being made in Germany. As a matter of fact, the bankruptcies are most numerous among the smaller and weaker elements in the industry. Ufa and Emelka, the latter now being reorganized, are the two largest producer-distributor-exhibitors in Germany. The former produces approximately 25 features a year and spends upward of $80,000 on each of them. In addition, it controls 170 theaters, including many of the best locations in Germany. The Emelka chain consists of 50 first-run houses, and produces 10 to 15 films a year. These and two or three other companies are said to be making money—Ufa just declared a six per cent dividend—and taken together, they will account for a large proportion of the 164 films to be produced in Germany during 1931. This, with such foreign versions as may be secured from French and American sources, will come fairly close to filling the needs of the German market though there is the possibility of a product shortage. It is to be noted that German films are designed not only for the needs of the domestic market but to compete actively throughout all Central Europe where German, even if not the primary language, is generally understood. Special agreements have been made with Austria, Czechoslovakia, and other countries, by which German pictures gain easy entrance. Germany is also concentrating on foreign versions, particularly French, and may soon have as many as 40 films for that market. The intensity of this competition and the headway it has made must be considered by American film interests as at least a subsidiary factor in our diminishing film revenues from Europe.

As to German exhibition outlets, at the end of 1930 about 940 German theaters were wired. This number has now increased to about 2000. The equipment used is German made, mostly Tobis-Klang film. There still remain more than 3000 theaters not wired which exhibit only old silent films and which must be wired or pass out of existence.

The rest of Europe can be covered in a few words. Little is to be expected from Italy, where the ban on all foreign dialog films has created such an acute product shortage that fewer than 50 features are available for a market that requires over 250 a year. Nearly half of these are being produced by Pittaluga, also one of the largest exhibitors, but the product is not sufficient even for his own houses. Obviously, American features in Italian dialog must be very cheap to show a profit, and with English dialog banned, even when explained by Italian sub-titles, there will be very little of the film product of this country seen on Italian screens. I might add that the Italian situation is merely an intensification of what has been going on since the early days of talking pictures.

Central Europe, meaning Austria, Hungary, Czechoslovakia, Poland, and the Baltic States, as implied above, is being drawn somewhat into the German sphere of picture influence. They have become picture conscious, however, and are trying to encourage their own production through subsidies, contingents, or taxes, as the case may be. The Scandinavian states, and especially Sweden, are also trying production in their own language. American films are, of course, being shown in all these countries, but the language obstacle is difficult to overcome. The outlet for sound pictures is gradually

TABLE III

FOREIGN THEATERS

	Approximate Number of Theaters		Approximate Number of Theaters Wired	
	1930	*1931*	*1930*	*1931*
Europe	27,000	29,535	4,950	10,400
Far East	4,000	5,350	900	1,900
Latin America	4,000	4,700	450	1,575
Canada	1,100	1,100	450	700
Africa	750	770	40	116
Near East	50	85	10	25
TOTAL	36,900	41,540	6,800	14,716

being extended in all of them through increased wirings, with the result that Europe is far more overwhelmingly committed to sound pictures than even figures would seem to indicate.

As a summary, the charts show, on the one hand, European production, and, on the other, the expansion in European play dates through increases in wiring. They provide an illuminating picture, especially on the production side, with well over 400 films offered in competition to our own.

All told, one must remember that the American trade is faced with two important obstacles in Europe. The first is the language question and its subsidiary competition, the latter being almost the direct result of the former. The various European countries must have films they can understand, and until we can devise a method economically profitable to give them such films, with the additional factor that they must be of a quality to compete with locally produced films molded on native stage traditions, this problem will not be solved. In fact, it is doubtful whether the correct solution to this has been given either by that school of thought which advocates production of foreign versions abroad, or those that believe production can best be done at home. Perhaps the newest types of dubbing, if not too costly, will come closest of all to the solution, particularly when applied to films in which action predominates. In addition, and this is the second obstacle, we have to run the gauntlet of contingents, subsidies, and other forms of government protection designed to foster the development of the home product. These may tend to decrease when it is comprehended that an industry cannot be legislated into existence; but at present they, in combination with high taxes, are doing much to make the European film field a series of pit-falls for the unwary.

In order to brighten the picture, it may be well to state that these somewhat pessimistic observations on the decline of our European revenues do not necessarily imply that these revenues will reach the vanishing point. Far from it. This is a period of adjustment. If competition is increasing, so also are film outlets through an increase in the number of wired theaters. Europe is going through a profound depression which is keeping many people out of the theaters, and is impeding theater construction. When things pick up, and with better theaters, the chance of increased revenue from an individual picture will be greater. In other words, we can make more money on fewer pictures. And finally it might not be presumptuous to believe that the ingenuity of our producers will find a way to solve the language difficulty to the extent that we shall be able to turn out foreign language films in sufficient quantity and quality, at a cost that will bring us a fair return on the investment. The easy-money Europe of silent picture days is gone, but as a market offering better returns than now, it holds possibilities.

DISCUSSION

MR. RICHARDSON: My reports from France indicate that the projection of pictures in France, both as regards sound and the picture itself, is nothing less than terrible as compared with our own. The same is largely true in Germany. And there is no question, gentlemen, but what that very largely decreases the revenue of theaters. I believe that the reason why the photoplay theaters in North America are so well patronized is that the picture and sound are reproduced by expert men.

I believe that the producers might well call the attention of European exhibitors to the fact that they cannot possibly obtain the requisite revenue if they put on the screen a very poor picture, and radiate from the horns sound of very unsatisfactory quality.

MR. MCGUIRE: While Mr. Rubin, chairman of the Projection Practice Committee, was in France about a year ago, he reorganized the entire projection staff of Publix Theaters in that country. That program included raising the compensation of the men and improving their standing. If these methods were more generally adopted in foreign countries much better projection would be secured. The importance of projection and of the projectionist is now fully realized in the United States, and other countries would do well to follow our example along these lines.

PAST-PRESIDENT CRABTREE: In connection with the matter of producing films with foreign dialog, in Hollywood I saw a synchronization of the dialog of a foreign actress with the lip movements of an American actress. When the picture was projected on the screen, Italian actors and actresses equipped with ear-phones, were arranged in front of the screen before a number of music stands. By watching the screen and listening to the sound coming from the horn, remarkable synchronization was effected. This method of synchronizing is beyond the experimental stage now, and the films are now being supplied to the trade.

MR. GOLDEN: It is true that our technicians at the studio have been able to produce a fine result by synchronizing the foreign language and the lip motions of our American actors. However, there is one obstacle that they have not yet been able to overcome, and that is the question of the proper language as used in the country for which the version is made.

In New York the other day I had the pleasure of talking with a man connected with the foreign department of one of our large producing units, and his complaint was that regardless of how short a time a foreigner has been in this country, even as short as a six months' period, there is something that creeps into his language that is offensive to the native foreigner in his own country. The producer, to secure the true speaking language of a given country, must bring the cast from their native country and use them for a certain number of pictures, release them and send them back to the country from which they came, and then bring over other native actors. The synchronization part of it is all right, but idioms of expression, and a certain amount of slang, get into the foreigner's speech that are not acceptable abroad.

MR. KELLOGG: How nearly universal is the standard film track location and offset?

MR. GOLDEN: It is practically the same as used in this country. From reports, and samples of film we receive from foreign countries, it is practically the same. I am quite sure that Klangfilm-Tobis is about the same as Western Electric or any one of our recording systems.

MR. MONOSSON: Does Europe include the U. S. S. R.?

MR. GOLDEN: No. In Table II Soviet Russia is excluded because this country does not maintain diplomatic relations with Russia, and we are in no position to receive authentic information from our own offices. Foreign audiences insist on our American stars. It is going to be some years before the foreign producer can establish his stars to the point where our American stars will be rivaled, and since the foreigner likes our American stars, he must like our technic in the production of motion pictures. And as long as the foreign producer, therefore, puts out pictures of the type that he is putting out today, he is not going to get very far.

True, most of this production abroad, as a matter of fact, has been sponsored, not by the movie goer, but by the business man of the country in question, and even reaches so far as the governmental heads. You have the finest example in the British quota system. The British quota system was not instituted by the producers or exhibitors of the country. It was originally pushed forward by the manufacturing interests of England. They felt our American pictures were carrying a propaganda into England which resulted in the sale of our American goods in England and its dominions.

The revenues received by the exhibitor abroad are much smaller than those received by the exhibitor in this country. He does not get the patronage at the box-office that we do. Therefore, he cannot pay the salaries that our American projectionists get. He must accept inferior workmanship.

But, with many of the theaters having an average seating capacity of two hundred, passing out of the picture and being supplanted by the *de luxe* houses, I am sure that projection, theater construction, and entertainment values will be improved and placed upon a higher plane.

VICTROLAC MOTION PICTURE RECORDS*

F. C. BARTON**

Summary.—*A new type of disk record, known as the Victrolac record, is described. The material of which it is made is a thermoplastic resin, which must be cooled before being removed from the mold. The paper discusses briefly the characteristics of this material, the time of playing of records made of it, operating features of the tone arm and pick-up system, resonance characteristics of the tone arm, and the characteristics of the chromium needle.*

A new type of disk record has recently been made available to the motion picture industry, which record presents a number of advantages over previous types in that it has better reproducing qualities, better wearing properties, is non-inflammable, practically unbreakable, water resistant, smaller for equivalent playing time, has much lower surface noise, is lighter and flexible.

The development of the new record has come about through the constant search being made by research engineers for new materials which would advance the art of record making and would bring about an improvement in an art that has remained almost stationary, except for minor changes, for a period of twenty years. In the last few years, chemical engineers have given a great deal of time and attention to the development of synthetic resins, and the outcome of this work has resulted in the production of a great many variations of two general groups of these resins. The groups comprise those resins which polymerize or cure and become infusible and insoluble after the application of heat, and those which are thermoplastic but non-curing; in other words, which will flow and mold under heat but which must be cooled before removal from the mold.

A great number from each group have been used experimentally in the hope of finding a material which would be modified to give the looked-for improvement in record quality and an almost equal number of disappointments have been encountered. Approximately

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* Presented at the Spring, 1931, Meeting at Swampscott, Mass

** RCA Victor Co., Camden, N. J.

a year ago, however, a resin of the second group, that seemed to hold promise of having the desired characteristics was found. The chemical engineers responsible for the development of this resin were called into conference with the engineers of the record manufacturers and a coöperative program was laid out in which the technics of the two groups were combined to further the development of the resin and to combine it successfully with other materials, to the end that a satisfactory record material might be evolved. A number of months of concentrated effort on the part of these two groups of engineers resulted in the production of the compound now known as *Victrolac*. This compounded resin has very remarkable properties, and the records made from it have many points of superiority over former products.

Among the principal advantages is the greatly reduced inherent background or surface noise as compared with former types of record material. In the past it has been found necessary to use a large groove and to record sounds of great amplitude so that the recorded amplitude would be large compared with the amplitude of the surface or scratch noise; and that by this means the music would mask the surface noise, or at least make it less noticeable. Advantage has been taken of the improved surface conditions of the new material by employing a lower amplitude of recording, smaller grooves, and by placing the grooves closer together, thus increasing the playing time per inch of recorded radius of the record in direct proportion to the increased number of grooves per inch, which in this case is from 90 lines per inch on the old records to 120 or 130 lines per inch on the new records. This represents an increase of from 2.7 minutes per inch of recorded radius on the old records to 3.9 minutes per inch on the new, and since a film 1000 feet long projected at 24 frames per second requires about 11 minutes to run, the recorded radius of one of the new records corresponding to 1000 feet of film will be 2.82 inches. Allowing $^1/_4$ inch of radius or $^1/_2$ inch of diameter for margin and 2.82 inches of radius or 5.64 inches of diameter for recording, we have left 5.86 inches as the center diameter for a 12-inch record which is satisfactory as regards frequency response for the width of groove used. The decrease in the amplitude of the recording for the case of the smaller groove is about the difference between +9 db. for the old records and +5 db. for the new records, or the new recording amplitude is about 60 per cent of the old. The decrease of surface noise is proportionately much greater than the decrease of recording level. The surface of the new material is only about 43 per cent of the old, which leaves a net gain of approximately 1.4 to 1 in apparent surface noise-to-signal ratio in favor of the new material. In other words, if the scratch and the recording noises were reduced by equal percentages there would be no change in the noise-to-signal ratio, but in this case the surface noise level has been reduced much more than the signal level; therefore, there is a net gain in performance.

Fig. 1 illustrates the relative size of the standard groove on the 16-inch record as compared with the new groove on the 12-inch record. It will be noted that the curvature in the bottom of the groove is the same in each case, and that the groove of the new record is merely a little narrower and shallower.

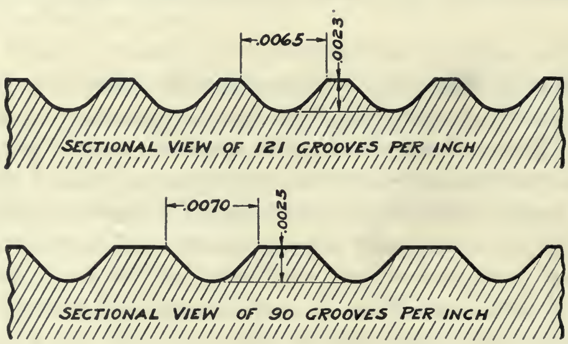
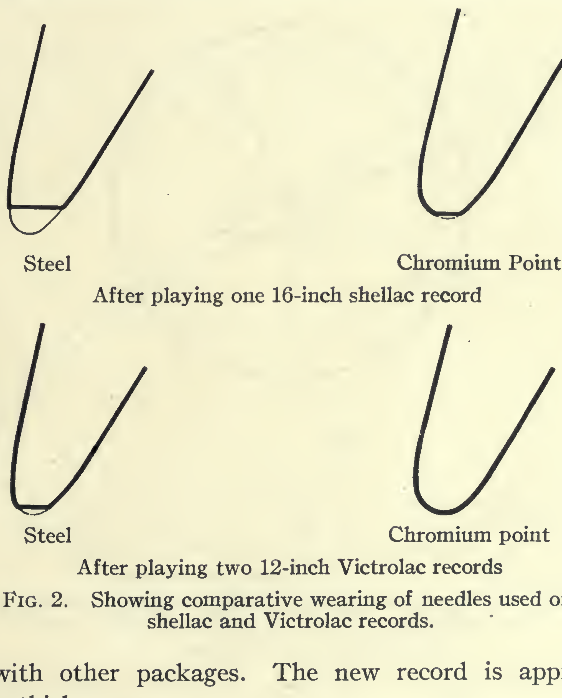


FIG. 1. Relative size of standard groove on 16-inch record, as compared with the new groove on the 12-inch record.

It is well known that the response characteristic, or the ability to reproduce from the record certain frequencies, is directly associated with both the linear speed and the width of the groove. In other words, the higher the linear speed or the narrower the groove, the greater is the possibility of reproducing from the record the higher frequencies. The narrowing of the groove on the new record accounts for the fact that smaller center diameters down to $5^1/_2$ inches may be used in the new records, while still maintaining a frequency response characteristic equal or superior to that obtained from the 16-inch records with the larger center diameter.

Another advantage of the material used for these records lies in its strength and flexibility. On account of these features it has been found possible to produce a 12-inch record for motion picture work weighing approximately 4 ounces, as compared with 24 ounces for the 16-inch record. In addition to the reduction in weight, the record is practically unbreakable.

These two features make possible a very considerable saving for the producer or distributor in shipping the records. Extremely careful and cumbersome packing of records is no longer necessary, and shipments may be made by mail or express without other protection than a couple of sheets of corrugated board on either side of the record so as to prevent damaging the record surface by allowing it to come into



Steel Chromium Point

After playing one 16-inch shellac record

Steel Chromium point

After playing two 12-inch Victrolac records

FIG. 2. Showing comparative wearing of needles used on shellac and Victrolac records.

contact with other packages. The new record is approximately 0.040 inch thick.

Another but possibly less important advantage lies in the decrease of abrasion of the needle. An ordinary full-tone steel needle will show much less wear after playing one of the new records than after an equivalent amount of playing one of the old. (Fig. 2.)

It would now be of interest to present a few points in which the manufacturers of reproducing equipment, and operators of the equipment, can assist in the full realization of these advantages. The inherent strength of the resin itself is relied upon to give the record the required solidity. This permits using a soft filler which assists in reducing the surface noise. None of the hard, highly abrasive fillers commonly used in manufacturing records are used. But the strength of the material and its ability to withstand abuse do not necessarily go hand in hand, and it may therefore be stated that the new material is susceptible to injury through improper use. The records have been designed to be operated under the same average conditions as the old records; that is, a standard full-tone needle with a pick-up pressure of approximately 5 ounces and a needle placement which will bring the

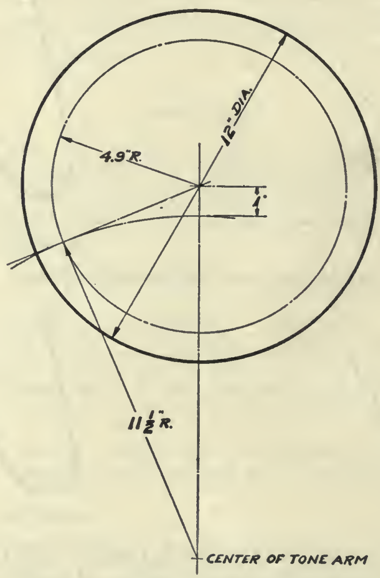


FIG. 3. Illustrating proper adjustment of needle on arc tangent to tone arm radius 1 inch from center.

needle within $1^1/_4$ inches of the center of the turntable when the tone arm is swung to position directly in line with the center. This placement will make the needle tangent to a circle approximately 11 inches in diameter when using a tone arm $11^1/_2$ inches long. (Fig. 3.)

A more desirable set of conditions, with particular reference to the new record, would first require a pressure on the needle of 3 ounces, a pressure which can be maintained by additional counterweighing of the reproducing tone arm. Such a simple correction can be made by the operator by allowing the pick-up to rest upon the platform of a small postal scale, placing the tone arm in a horizontal position and adjusting or adding to the counterweight to get a reading of 3 ounces.

Second, a displacement of the needle from the center equal to 1 inch would be required, making it tangent to a circle approximately $9^3/_4$ inches in diameter, which would lie approximately at the middle of the recorded area of a 12-inch record. (Fig. 3.) A change of this nature may be difficult to make in existing equipment, but if the distance between the needle and the center of the turntable is not more than $1^1/_4$ inches, no difficulty will be experienced. In designing new

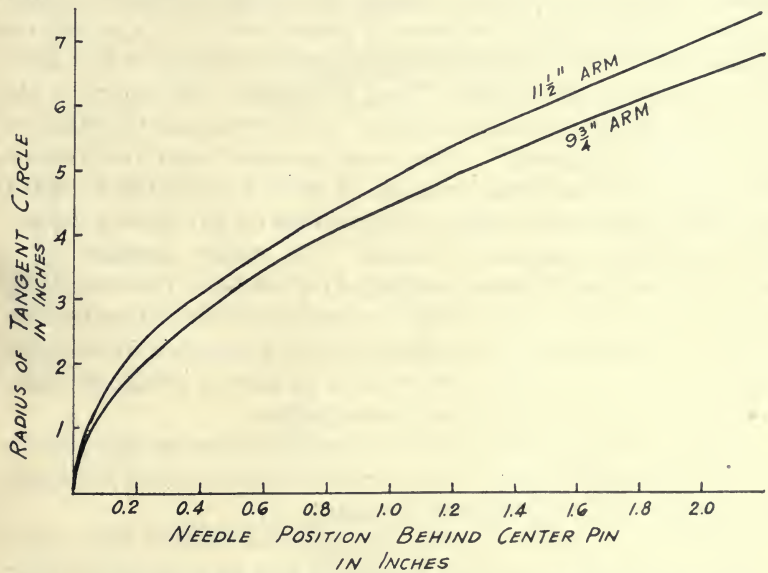


FIG. 4. Relation between needle position and circle of tangency for a tone arm $11^1/_2$ inches long and a tone arm $9^3/_4$ inches long.

equipment, however, this point should be considered, and the placement should be made so as to get the best results out of the 12-inch record. (Fig. 4.)

The decreased level of the recording which, as I have said, is about 4 db. below that of the 16-inch record, will make it necessary for the operator to increase the gain by a point or two in order to raise the volume in the theater up to the level formerly obtained with the 16-inch disk. No change will be necessary in the needle, provided a normal full-tone needle that is not excessively sharp is used.

Relatively little consideration has been given in the past to the shape of the needle point. Although the record material itself has been sufficiently abrasive to wear down the needle point rather quickly to fit the groove, with the new material this process takes place much more slowly; and with the slightly softer record stock, cutting of the record may result from either too fine a point or too high a pressure. Assume that the combined weight of the pick-up and the tone arm is 5 ounces, or roughly $^1/_3$ of a pound, and that the area of the point in contact with the record is 0.003 inch in each direction, or approximately 9 square mils. Under such conditions, if the pick-up weighs 1 pound, the pressure under the needle would be 110,000 pounds per square inch; but since it weighs only $^1/_3$ of a pound, the pressure will be of the order of 37,000 pounds per square inch, a fairly high stress even for metals. When we consider the nature of the record compounds it is remarkable that such a stress can be withstood even for a single playing. A reduction in weight from 5 to 3 ounces will cause a corresponding reduction of stress from 37,000 to 22,000 pounds per square inch, a value still quite high for an ordinary thermoplastic molding compound to stand. The existing standard of 5 ounces was selected to insure tracking of the needle, or following of the sound wave, on the very heavily recorded 16-inch picture records; but since the amplitude of recording of the new records is considerably reduced, there is no longer the need for so great a weight to insure tracking, and 3 ounces have been found ample.

The new records, if used under the conditions recommended above, will have a life much longer than any records that have been previously produced for the motion picture industry.

Needle development has been carried on in parallel with record development, and there is now available a new type of needle admirably adapted to the new record, although its use is in no way restricted to this record. It is a full-tone steel needle having a chromium tip. When used under a 3-ounce load this needle will successfully play at least twenty-five of these 12-inch records. A number of playings greatly exceeding twenty-five have been successfully made in the laboratory, but this number is recommended as representing good practice. Assume a 12-reel feature motion picture show running four times a day. Twenty-four records would be played on each projector each day, requiring a change of needle only once a day per projector.

Before closing, a short statement referring particularly to the design of tone arms and their effect on the performance of a record might be appropriate. Judging from the characteristics shown by some of the tone arms that have been tested, their designers apparently have considered them as merely means for holding the pick-up in its proper position on the record. True, this is one of its functions, but another and equally important function is that of controlling the tendency of the pick-up as a whole to rotate around the natural longitudinal axes of the arm, the impulse causing this tendency being furnished by the lateral motion of the needle during the recording. Some tone arms, instead of exerting a corrective influence against this tendency, by their construction actually tend to aggravate the tendency to rotate. The increase of this tendency will, of course, occur at or near

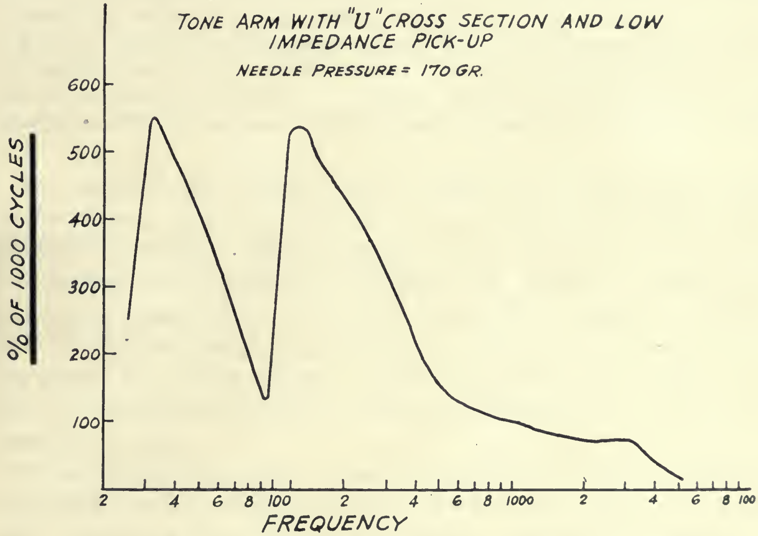


FIG. 5. Resonance characteristic of an undesirable tone arm.

the frequency at which the tone arm and pick-up would vibrate if they were placed under torsional stress and suddenly released; in other words, at the period of natural resonance. If this resonance frequency occurs, as it frequently does, in the lower musical register, then a severe load will be imposed on the record; and the needle will tend to leave the groove each time the arm is shocked into vibration by a passage in the record of a frequency corresponding to the natural period of the tone arm system. A curve plotted from data obtained from a particularly bad tone arm is here shown in Fig. 5. The conclusion reached from this is that, if it were not possible to design an arm free of natural periods, the arm should be designed so that the period will occur at a frequency well below 100 cycles, or when the recording has been so attenuated that the shocks produced will not be large. In general, long straight *U*-section channels should be avoided.

In reviewing the performance possibilities of this record it is the firm opinion of the developers and manufacturers of the record that an outstanding advance has been made and that with a small amount of coöperation by designers and operators of the equipment, the full advantages of the new development may be realized.

OPTICS OF PROJECTORS FOR 16 MM. FILM*

A. A. COOK**

Summary.—*The limits of illumination available in a projector are fixed by three factors: the size and brilliance of the light source, the effective aperture of the optical system and the design of the condensing lenses. In modern 16 mm. machines of the standard type, about 100 to 120 lumens are available through an f/2 optical system; these values, which are not corrected for shutter and film losses, mean that 1.6 to 2.0 per cent of the total radiation is being used. The use of low voltage lamps has not changed this ratio to any extent. The effect of varying each of the above factors is discussed, and the increase in screen brightness that is likely to be obtained is estimated.*

The fundamental requirements of apparatus designed to project motion pictures from 16 mm. film are too well known to need any detailed description. The apparatus must be compact and light, and the number of adjustments necessary to operate it should be reduced to a minimum. As an optical instrument it ought to produce a clearly defined image on the screen. It is also obvious that the location of the optical elements and their relation to the light source must be exactly maintained if maximum illumination is to be consistently secured.

Projection optical systems consist of a source of light, a collective system for directing the light through the film gate, and an objective lens for imaging the film upon the screen. Let us first consider the light source. The advantages of tungsten lamps are evident from the requirements already outlined. They are small in size, easily located in a fixed position, and require a minimum of adjustment during operation. Several filament designs of high efficiency have been developed with parallel coils arranged to fill a rectangular space about two-thirds the size of the film gate opening. The spaces between the coils are of approximately the same width as the coil, this arrangement permitting the use of a spherical mirror behind the lamp to image each coil in the adjacent space. This adds to the efficiency by heating the filament and gives the unit nearly the appearance of a solid

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Bausch & Lomb Optical Co., Rochester, N. Y.

source. By doubling the useful angle of radiation in this way an increase in illumination of 50 to 75 per cent is obtained. The exact amount depends on the quality of the mirror and the position of the filament supporting wires.

The filament housing is a tubular bulb $1^1/_4$ inches in diameter. This size has been adopted as standard for 16 mm. equipment, although it may not prove sufficient for the continual demands for higher wattage.[1] Bulb diameter is an important dimension from the optical point of view. The efficiency of the condenser and reflector depend on the angular size of the cone of light that they can take in from the source and transmit through the system. A shorter distance between filament and condenser would be helpful, therefore, in that it would permit a larger angle to be used by a condenser of given diameter. Lamp manufacturers have been working on this problem, as is shown by the fact that in some of their recent designs the filament has been offset to a position well forward of the center of the bulb. This change provides a mechanical advantage which can be especially useful in the 16 mm. projector. Condenser design has often been handicapped here by the limited space available. An increase in the diameter of the mirror will be necessary, of course, for its distance from the filament has been increased. There is more room behind the lamp, however, and this slight change can be easily made.

The collective system may be either a condenser or a reflector. Both methods have been applied to the illumination problem in projection, but more space is required by a reflector, for the same useful angle of radiation, than by a condenser with rear mirror. Therefore, the condenser has been the preferred form in 16 mm. machines.

The function of the condenser is a subject that has been thoroughly analyzed and presented before this Society.[2] Only an outline will be given here of the working of this element of the optical system as it applies in this special case. If a solid source of light of sufficient size and uniform distribution could be placed at the film gate, no condenser would be needed. A tungsten filament is not solid, however, nor can a lamp bulb be placed at that point. By using a condenser a source image is substituted for the source itself; by locating the image in front of the film plane the unevenness of the source can be equalized. Fig. 1 is a sketch showing the condenser in its relation to the other parts of the system. The condenser, L_1, produces a magnified image of the filament of such size as to fill the projection lens, L_2. In doing this it takes in the large angle of radiation marked a, and forms the image at a smaller angle a'. The radiation can now be transmitted through the projection lens L_2, as a result of this change in its direction. In this way the condenser makes useful the radiation from a small source through a large solid angle in space. Otherwise, a very large source would be needed to produce the same effect.

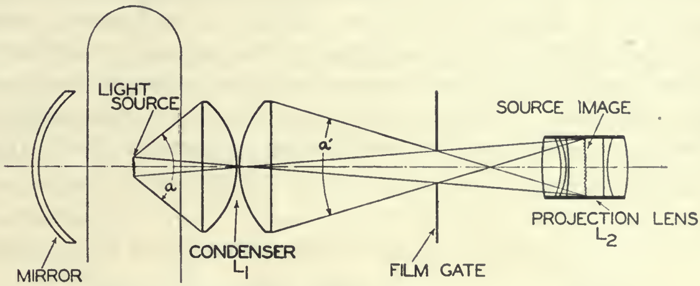


FIG. 1. Projection optical system for 16 mm. film.

There is a very definite relation here between the size of the source, the size of the projection lens, and the focal length of the condenser. All the parts of the optical system are interdependent in this way, and proper proportions must be maintained to obtain maximum efficiency

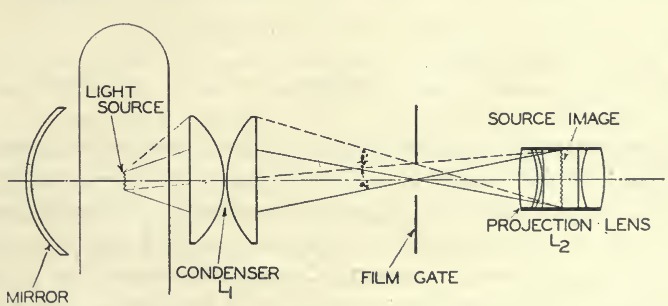


FIG. 1a. 16 Mm. optical system, showing illumination at margin of film.

of the whole unit. The conditions determining the diameter of the condensing lenses are shown in Fig. 1a. Two solid lines drawn from the extreme edge of the effective lens opening to the center of the film aperture form an angle a'. The broken lines in the same way determine angle b' at the margin of the picture. These two solid angles, a' and b', must be equal in size and must be filled with light in order to get the best possible illumination at the corners of the screen. This means that the condenser should be large enough to furnish light through all of the angle b'. This condition is usually not perfectly fulfilled in practice. A 15 per cent decrease of illumination at the margin is commonly accepted as satisfactory.

Condensers constructed according to these specifications are still found to differ considerably in efficiency, due to differences in their correction for spherical aberration. This is a well-known defect, found in all simple lenses, that causes in this instance a loss from the marginal portion of the light beam as it is converged to the image point by the condenser. The loss is not so serious in 16 mm. projection systems as in cases where the source image is located at the film gate. It can be corrected to a large extent by proper condenser design. The

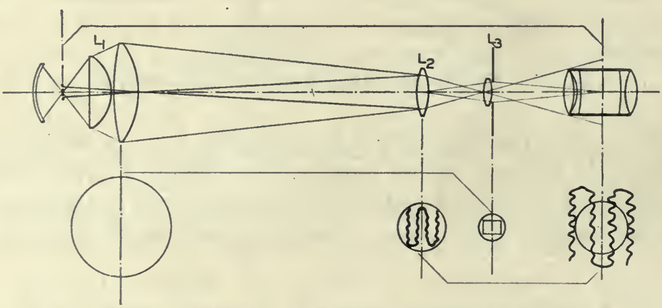


Fig. 2. Relay condenser. Conjugate images are connected by brackets.

use of aspheric surfaces is one effective method, this kind of correction having been found to result in screen illumination 15 per cent greater than that obtained with the ordinary plano-convex condenser lenses.

The relay condenser is a more complex device that may prove useful with 16 mm. equipment. Its use in motion picture work is not new.[3] But it produces uniform illumination from a tungsten source with so little loss that it ought to be included in any discussion that deals with projection from filament lamps. As shown in Fig. 2, it is a compound lens system composed of three units. There is a condenser system, L_1, of large angular aperture to image the source upon a relay lens, L_2, placed a short distance in back of the film gate. The third element, L_3, serves to form a second image of the source in the projection lens. The relay lens must be large enough to receive all of the source image, and of such focal length as to form a reduced image of the condenser at the film gate. Note that it is the evenly illuminated condenser surface, not the source, that is imaged on the film. This accounts for the uniform screen illumination produced by the system. It is 40 per cent more efficient than plano-convex condensers. The extra length of the unit, amounting to six inches over all for a 16 mm. outfit, is a decided disadvantage. But if it ever becomes necessary to build a special type of projector for school or auditorium use, this method of illumination should be of great service. It can be constructed to work with a small source, and provide sufficient magnification to fill larger projection lenses than any that are now used in 16 mm. work.

The projection objective is the third important part of the optical system. Two-inch focus lenses of *f*/2.0 are standard equipment at the present time on practically all projectors except those designed for use in cabinets. They must be well corrected for this large aperture, but the field to be covered is so small that the requirements can be met

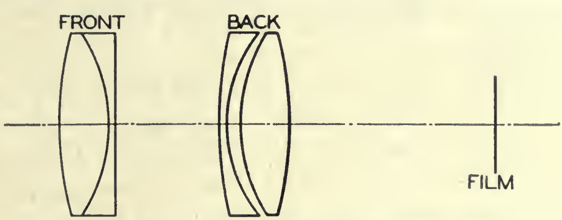


FIG. 3. Projection objective of Petzval type.

without difficulty. There are many types of lenses that could be used. In any such situation the cost element is bound to be a decisive factor, and it has operated in this case to select the least expensive lens that can be made to do the work. Before discussing the details of this particular lens construction, it would be well to consider the original from which it was derived. This lens form, shown in Fig. 3, is Petzval's portrait objective. It has undergone modification many times, but is still the formula most often used for projection work. It can be very precisely corrected for the small field required, and has a light transmission, in short focal lengths, of 73 per cent.

Fig. 4 shows the modified form that is now used in so many 16 mm. projectors. Note that the two rear elements have been cemented, and that the spacing between front and back has been increased to nearly twice the length of the original construction. The first change, by eliminating two air-glass surfaces, increases the light transmission to 81 per cent; the increase in length has the effect of shortening the back-focus of the objective. This means that the rear element can be made smaller in diameter without sacrificing in light transmission, and that it has more space in which to converge the beam of light from the film gate. The rear element thus acts as a collective lens for the system, which results in the practical advantage that objectives of this construction, of any focal length, can be used interchangeably on a projector without alteration or adjustment of the condensing system. The only disadvantage of this short back-focus objective is that it has a slightly curved field. This defect is noticeable only in critical tests, however, and would be difficult to detect in practical use on a projector, with moving film as a test object.

The final screen illumination produced by a 16 mm. projection system depends on the effectiveness of the four elements that have been described: the light source, the rear mirror, the condenser

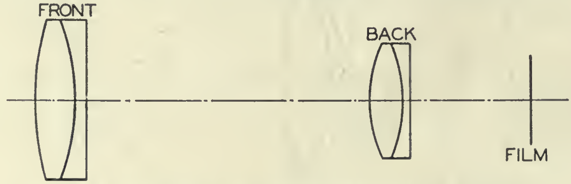


FIG. 4. Projection objective with short back focus.

system, and the projection objective. Increases can be obtained by using a brighter source, by improving the condenser correction, and by increasing the aperture ratio of the entire optical unit. Recent attempts at improvement in the 16 mm. field have been mainly directed toward the light source, and this choice is a logical one for the equipment manufacturer because it involves the least amount of redesign on his part. To meet this demand lamps of greater brightness have been developed, the increase being due to the use of larger wire size in the filaments operated at a lower voltage than previously used.[1] The possibilities here are beyond the field of optics, and must be left to the electrical engineer.

There are two points about lamp filaments, however, which are of optical interest. One is the fact that filament supporting wires cause illumination losses unless they are placed outside the angular field of both the condenser and the rear mirror. The second concerns the filament itself. The aperture of a projection system must be filled with light if it is to work at its best efficiency. With a filament lamp, the source acts as a discontinuous surface, and the openings in its area cause a real loss of light. This effect is shown in Fig. 5, which is a photograph of a 4-coil tungsten filament and its mirror image, as they appear at the aperture of a projection lens. Any change that would help fill up these spaces and thus make the source more solid would mean an increase in illumination.

Improved condenser design offers a small field for improvement which is applicable, perhaps, to many of the commercial machines. Even with a perfect condenser, however, one can do no more than to fill the projections lens with an image of the light source. The brightness of the source and the effective aperture of the system then determine the illumination. Increasing the aperture offers interesting possibilities that are yet to be considered. An $f/1.5$ optical system should give 75 per cent more light on the screen than the $f/2.0$ lenses now used; experience indicates that these theoretical increases are seldom attained, however, and that a figure of 50 per cent is much nearer the probable increase. The cost element enters into this situation to such an extent that an increase in aperture is not likely to be attempted in commercial practice until all possibilities of the light source have been realized.

FIG. 5. The filament image as it appears in the projection lens.

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[2] KELLNER, HERMANN: "The Function of the Condenser in the Projection Apparatus," *Trans. Soc. Mot. Pict. Eng.* (Nov., 1918), No. 7, p. 44.

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DISCUSSION

MR. PALMER: It has seemed to me, from casual observation, that the proportions of the filament should be one to three-quarters—three-quarters as high as it is wide, in order to conform to the dimensions of the picture aperture. Am I correct in assuming that?

MR. COOK: In the case of 16 mm. projectors, we can not get uniform illumination when the filament is imaged on the aperture itself. For that reason the image of the filament is moved forward enough to produce the desired effect of a uniformly illuminated screen. It actually amounts to imaging the source between the projection lens and the aperture. The projection lens is round, and it seems to me that a nearly square source would be as valuable as one that is oblong. The effect of the aperture in stopping down the light is, of course, noticeable as soon as we get the image in front of the aperture. But in order to follow out that line of reasoning we should use square condensers and a square projection lens. It seems to me that a round source would be more nearly the ideal, from the present set-up we are using in sixteen millimeter work. There is no doubt that if we image a square source to fill a round projection lens, we waste the light coming from the corners of the filament. But the illumination obtained depends on the brightness of the source and the effective aperture of the system.

MR. HICKMAN: It seems to me that it makes no difference how much light is spilled over the edge, provided a little more can be obtained in the center. No one is really concerned with what is lost around the side.

MR. KURLANDER: The shape and size of the filament are also governed by the desire of the projector manufacturer. Of course, the projector manufacturer is susceptible to some influence by the lamp manufacturer, but sometimes he is not, and he has his own ideas. I believe that the present trend is toward the square shape, the size being dependent upon the inscribed circle determined by the back element of the projection lens. Also, with some special forms of optical systems, special shapes and sources are required, and those special shapes immediately give rise to new lamps. Sometimes the new lamps are placed on the schedules and are available to other manufacturers who do not know the history of their development, and choose from them at random to meet their conditions.

So there are a number of reasons for the different shapes of light sources, and while theoretically, a solid source should be in the proportion of three to four, a square source is easier to construct mechanically and does the same work.

MR. GAGE: The last picture that Mr. Cook showed was a photograph of the projection objective filled with the filament. That is the way it looks when you stand at the screen and look at the projection objective through a dark glass, while the picture is being projected. If you find that the entire surface of the projection objective appears filled with light, when observing the projection lens from all points of the screen, the optical system is delivering all the light it is capable of delivering. If, on the other hand, you find it is not filled with light, perhaps you can tell by simple inspection where the defect lies. Perhaps the filament is askew, perhaps the image of the filament in the mirror does not fill the space between the filament legs with light, or perhaps the filament is not big enough to fill the aperture. If you find a small image of the filament filling only a part of the area, a larger filament is required, or perhaps a shorter focus condenser, to magnify the filament image to a greater extent.

If, now, we go through the back-focusing process, setting up the whole projection system with the aperture, the objective and so on, and put a light in front of the objective, with a card at the focus of the condenser, it can readily be seen that there is no use in having a filament any larger than the spot of light received on the card.

One thing Mr. Cook did not explain: if the condenser is brought close to the filament, while, at the same time, the surface of the condenser is bent, as can be done theoretically, a larger amount of the light will impinge on the first surface of the condenser brought into the optical system by simply bringing the same diameter condenser close to the filament. The acceptance angle becomes greater, and the filament image becomes larger, until the surface of the condenser comes into contact with the glass bulb surrounding the filament.

With the present sized filaments, the filament image is sprawled over a larger area of the objective than can be used.

The greatest possibility of improving the system is to increase the intrinsic brilliancy of the filament. By using a more efficient condenser it is possible to use a smaller filament area. Nothing is gained unless the intrinsic brilliancy of the light source is increased. At the same time its area can be reduced by a more efficient condenser.

MR. RAYTON: There is one point that Mr. Cook and Mr. Gage have not touched on, that might be worth mentioning since so much attention has been paid to the appearance of the front of the objective. If we are to judge whether the relative aperture of the optical system is completely filled with light, we will have to do something more than look at the front of the objective under normal condistions: namely, we will have to insert a pinhole aperture at the center of the film gate. We may find, by so doing—and we probably will find—that the front of the objective is filled with light. We will most certainly find, if we move the pinhole to the corner of the film gate, that the objective is no longer filled with the image of the filament. We may also find cases in which, with the full film gate exposed, the front of the objective appears to be filled with the image; but that when we introduce the pinhole aperture at the center of the film gate the lens aperture is no longer so filled. If it is not, then under those circumstances the condenser design is not the most efficient that could be used.

This point ought not to be overlooked, and I want to emphasize it, that we do not get full information about how an optical system is working without an exploration carried out with a pinhole aperture at the film gate.

MR. KURLANDER: I should like to ask if it is not true that the objective lens is seldom filled by each individual point of the aperture.

MR. RAYTON: It is generally true.

MR. KURLANDER: Then I wonder why so much light is spilled over the aperture plate to get uniform screen illumination when it would be cheaper to use a cheap lens and a diffusing element in front of the condenser lens.

MR. RAYTON: Usually because the condenser is not large enough. The relative aperture of the projection lens required in order to get center brightness is one thing Mr. Cook mentioned the fact that a decrease of brightness of fifteen per cent or more at the margin will pass unnoticed. To get uniform quality of illumination all over the screen, we have to use condenser lenses possibly somewhat larger than are ordinarily used.

MR. KURLANDER: Do you have to go to such extremes to get evenness?

MR. RAYTON: You do with the set-up for motion picture illumination.

MR. KURLANDER: I have obtained uniform screen illumination of equal intensity by focusing the filament at the aperture plane, and then smoothing out the light by placing a diffusing element in front of the condenser lens.

MR. RAYTON: It is quite unreasonable that you should.

Mr. Kurlander: It seems unreasonable, but I hope some time to be able to show it.

Mr. Cook: Will back-testing according to Mr. Gage's method in this way show that the filament should be round rather than square?

Mr. Gage: When I tried back-testing the condenser system with the aperture in place, I obtained, at the position of the filament, not an exact image of the aperture, but approximately that. It is wider than it is high and is rectangular, with rounded corners.

Mr. Farnham: There is an eternal demand for more and more light from projection optical systems. There are three ways of obtaining it: greater source brightness, greater efficiency in controlling the light through the optical system, and utilizing greater source area without reduction of efficiency. I do not see how we can expect an increase of source brightness of a very high order, that is, two- or three-fold, as we are now operating the tungsten filaments at 3400°K., and the melting point of tungsten is 3650°, the highest of any metal we know. The wire has been so disposed in making a concentrated source as to secure an optimum effect of black body radiation and a high order of average source brightness to maximum brightness. Further increases will be a few per cent at a time. It would appear that the greatest development lies in the direction of improved optical efficiency and of utilizing greater source areas. This is particularly emphasized when it is realized that the over-all efficiency of the best projection optical systems is approximately five per cent.

SILICA GEL AIR CONDITIONING FOR FILM PROCESSING*

E. C. HOLDEN**

Summary.—*The need of properly conditioning air in motion picture film processing plants is pointed out and the values of temperature and relative humidity in current use in such plants are indicated. In particular, the process of humidifying, in which pure silica which has passed through the sol and gel stages of manufacture, commonly called silica gel, is used, is described. The principles involved in the process and the efficiency of the method in controlling the condition of air are explained, and curves are given showing the efficiency of adsorption.*

The most obvious application of air conditioning in the motion picture industry, aside from the comfort conditioning of theaters, is in film processing. This seems a relatively simple operation, more or less satisfactorily performed at a large number of places; nevertheless, a reactionary attitude of secrecy still prevails, even as to this detail, resulting in wide variations in local practice.

There is probably an ideal set of conditions for film processing, the determination of which would be hastened, to the benefit of all, if a more enlightened policy of exchange of experience were practiced, such as is fostered by this and other technical societies. Cases where secrecy in the arts is justified and desirable are the exception rather than the rule.

AIR CONDITIONING REQUIREMENTS

The usual requirements to be met by air conditioning for health and comfort purposes are that:

(1) The air must have the approximate chemical composition of fresh air.
(2) It must be free from odors.
(3) It must be clean.
(4) It must have an effective temperature within the comfort zone.

In the case of film processing, the important factors are as given under (3) and (4). Processed air should be super-cleaned, as nearly free from suspended solids as is possible, and its effective temperature

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.
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must be within the "comfort zone" for films instead of for people. It must be remembered that the effective temperature with relation to a moist surface is determined by the dry-bulb temperature, the relative humidity, and the velocity of the contacting air; and that the requisite "comfort zone for films" is such that they may be dried rapidly without suffering distortion or becoming brittle.

All are agreed as to the desirability of having the air perfectly clean, a requirement which has become all the more important with sound recording. The standard oil-surfaced baffle and the felt filter types of air cleaners are not adequate for this purpose, as the former puts oil into the air and the latter lint, both of which may adhere to the film and produce highly objectionable effects.

There is considerable difference of opinion as to the optimum film speed, the volume, temperature, and the relative humidity of the air to be circulated through the drying cabinets. In practice, temperatures from 50° to 110°F., relative humidities varying from 20 to 80 per cent, and film speeds ranging from 15 to 130 feet per minute are variously used. Even allowing for the difference between positive and negative film requirements, such extremes cannot all be right. The ideal conditions can be determined only by making systematic tests. For this purpose adsorption conditioning units can supply clean air at any desired temperature and humidity.

SILICA GEL

Silica gel is chemically pure silica, which has passed through the sol and gel stages in manufacture, and which is therefore amorphous and highly porous in structure. The granular silica gel used in air conditioning units is equivalent in texture to 6 to 14 mesh, and has the appearance of colorless, semi-transparent sand, although its specific gravity is less than that of crystalline quartz because of its porosity. The pores represent the water of hydration which was removed when the material was converted from a gel to a solid. They are smaller than the wavelength of light, and are invisible under the ultra-microscope.

This structure gives silica gel remarkable properties. The intense force of the resultant capillarity enables the granules to adsorb vapors within the gel granules, thus making it possible to separate vapors and imperfect gases from air and other perfect gases. The granules will take up from 30 to 50 per cent of their own weight of water vapor depending upon the conditions, without swelling or becoming externally moist. One must think in molecular dimensions to realize that one cubic inch of the material has an internal surface of over one acre, and that when ground to the fineness of flour, only two per cent of its internal structure is destroyed, absorption tests proving that it retains 98 per cent of its original adsorptive capacity.

When the gel has taken up its useful load of vapor, it is readily reactivated by heat, which drives off the adsorbed vapors; after reactivation it is ready to be used again. The action in both cases is the purely mechanical action of capillarity working against vapor

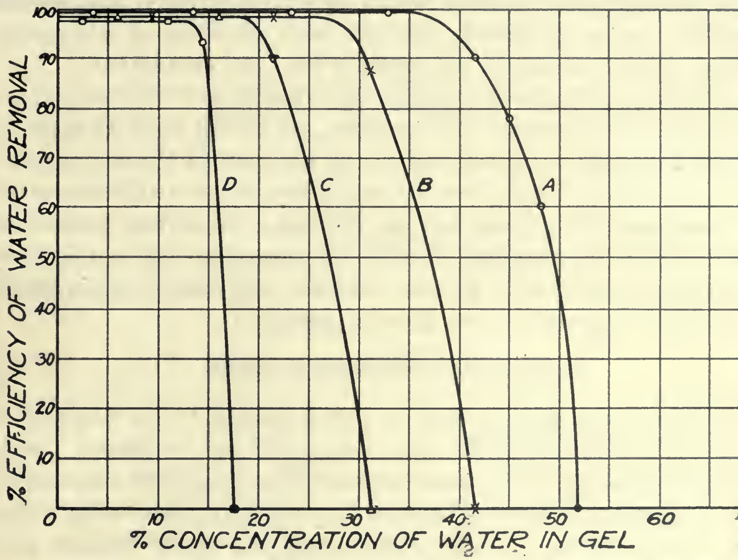


FIG. 1. Curves showing performance of silica gel in dehydrating air of various initial saturations at 25°C. and at atmospheric pressure. *A*, air at 100 per cent saturation; *B*, 60 per cent; *C*, 40 per cent; *D*, 20 per cent.

tension. No chemical reaction is involved, so that there is no deterioration of the gel; and the cycle of operations can be indefinitely repeated.

The capacity and efficiency of silica gel as an adsorbent is dependent on a number of factors: the composition, the temperature, and the pressure of the gas-vapor mixture, the partial pressure of the vapor to be treated, the rate of flow per unit weight of gel, and whether the treatment is single or multi-stage, approaching adiabetic or isothermal operation.

It is impossible in the limits of this paper to give exhaustive data for all conditions. Fig. 1 shows its performance when dehydrating air of various initial saturations at 25°C. and at atmospheric pressure. To determine the useful gel saturation in operation, the residual saturation of the gel of from 4 to 7 per cent should be deducted from the total saturations shown.

In practice the efficiency of adsorption may be made to exceed 99 per cent, depending on the type and size of the unit used, by keeping the operating cycle within the "break-point" limit. Some installations are guaranteed to deliver air at −30°F. dewpoint. By treating a regulated fraction of a total flow of gas-vapor mixture, any desired saturation can be produced; and the high efficiency of adsorption makes it possible to treat a minimum of the total circulation.

It is because of the power of silica gel to maintain a vacuum greater than 29 inches of mercury in a vapor system that it finds its application in refrigeration, the adsorber taking the place of the compressor.

Silica gel shows a similar selectivity for liquids, due to the character of the internal gel surfaces and the differences in surface tension of various liquids, thus making possible the separation and purification of hydrocarbons and other liquids; however, this class of applications is not of direct interest in the present paper.

CONDITIONING AIR FOR FILM DRYING

There are two practical stages in drying film, first: the removal of the excess surface water by the compressed air "squeegee," and, second, the removal of the water contained in the swollen films down to approximately 15 per cent residual hydration, required to keep film flexible and durable. These requirements are quite distinct and should be considered separately.

In the preliminary stage, blowing off the moisture on the wet film by compressed air at the squeegee, the air should be clean, oil-free, and anhydrous, but the treatment actually used to condition the compressed air, so far as the writer knows, is to pass it through the usual compressed air receiver followed by some form of strainer; or at best, a simple type of air filter, as described by Crabtree and Ives,[1] for removing the condensate of compression and entrained compressor cylinder oil. No practical mechanical filter is 100 per cent efficient, and as it cannot remove vapor, a decrease of temperature between the separators and the squeegee causes further condensation of water and oil vapor; and finally, as the air expands at the nozzle and thus becomes chilled, more vapor will condense.

CONDITIONING COMPRESSED AIR

When air is compressed, some of the compressor lubricant is mechanically entrained in the air flow as a fine mist, and some of it, even though the highest test oil be used, is partially cracked and vaporized by the heat of compression. If efficient separating receivers and mechanical filters be used after the compression, a large part, but not all, of the liquid oil-mist and water-condensate of compression settles out, although none of the true vapor of the oil or water is removed, these vapors passing on and condensing later in the line, especially at the discharge, due to cooling on re-expansion.

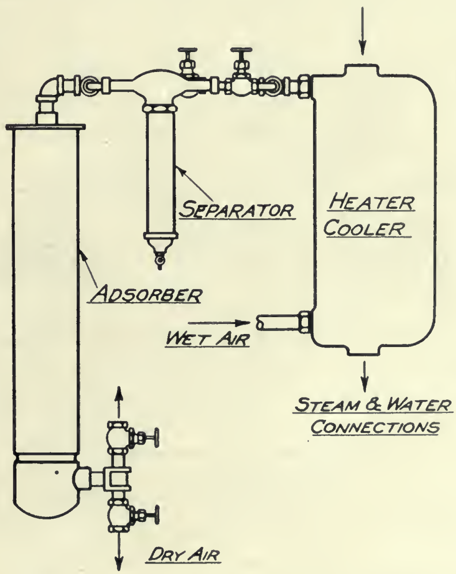


FIG. 2. Compressed gas dehydration unit.

This can be entirely prevented and the air can be dried to a dew-point below any possible expansion temperature, and all oil vapor as well as oil-mist will be removed by inserting a silica gel pressure type adsorbing unit anywhere in the compressed air line following the receiver. The air passes through a bed of silica gel which adsorbs both the oil and water vapors and returns practically anhydrous, clean air to the line. Such air delivered at an effective pressure through the nozzle at the "squeegee" should do more than merely blow off the excess water; it should deliver uniformly clean film and appreciably reduce the duty required of the drying cabinets.

Fig. 2 shows one type of small compressed air or gas silica gel dehydrator.

CONDITIONING AIR FOR FILM DRYING CABINETS

Inasmuch as films are made of permeable organic material, they will distort and lose their durability just as timber warps when improperly seasoned, and drying requirements cannot be figured *a*

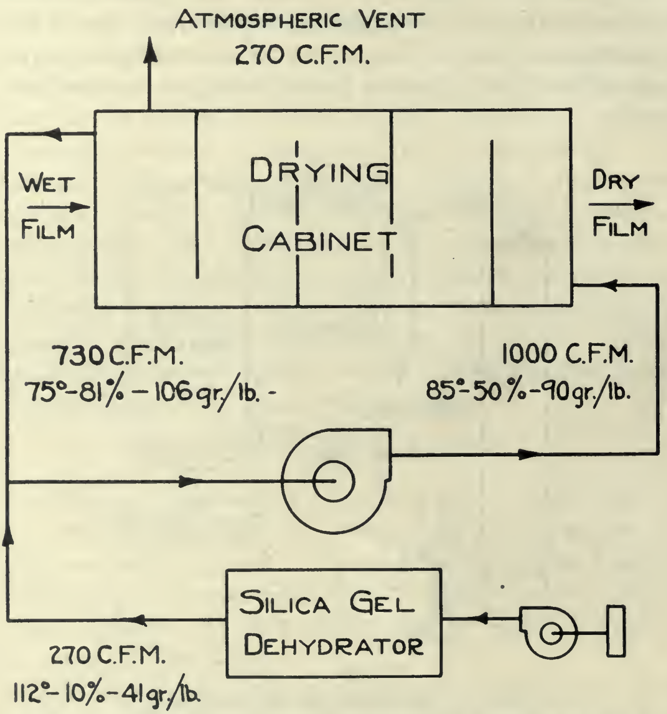


Fig. 3. Silica gel film drying; schematic diagram—1000 cu. ft. per minute circulated; 10 pounds of water per hour evaporated; volumes not corrected for temperature.

priori as can evaporation from metal surfaces, but must be determined by experience.

It is not, therefore, in the province of this paper to decide, or even to offer, an opinion as to what are the ideal conditions for treating either positive or negative films, or how much an anhydrous squeegee that has not heretofore been available to the industry, may hasten and simplify the subsequent drying. This can so easily be done, however, that it would seem worth proving.

The air conditioning system, now in common use in processing film, of spray cooling or refrigerating to remove some of the water vapor, or in winter, of spray humidifying followed by reheating, treats the whole air stream, the used wet air being blown to waste.

The silica gel adsorption system, owing to its ability to deliver practically anhydrous air, treats only a fraction of the air circulated, this fraction having an excess moisture capacity corresponding to the quantity of water being removed from the film. The whole air

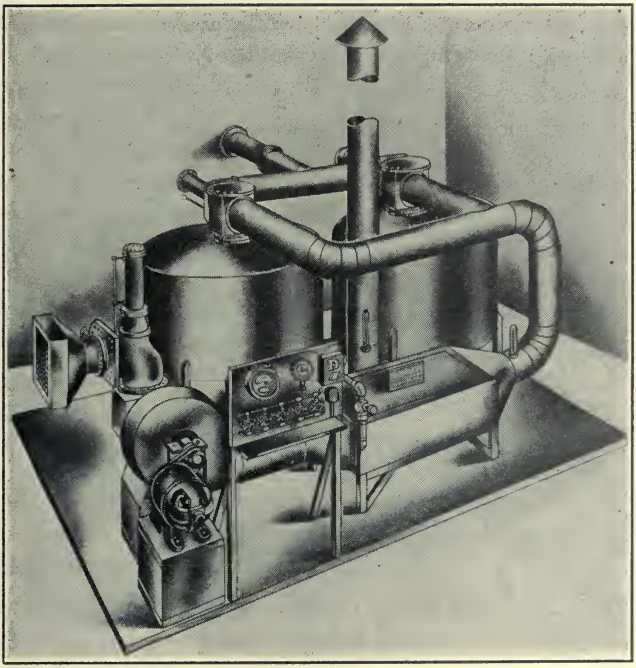


FIG. 4. Unit for treating air or other gases continuously at low pressure.

stream with its dried fraction can then be returned to the cabinets in a closed circuit. The absorbing operation releases the heat of adsorption, which varies up to one-third more than the latent heat of the water removed, so that any additional heat requirement is reduced or eliminated, and the closed circuit and special filters and the gel bed assure perfectly clean air and a complete control of temperature and relative humidity.

It does not seem logical to have to add water to a drying unit With the adsorption system, if it be required to increase the humidity, the hydrometric control automatically slows or stops the adsorber operation and throttles the waste blow-off, so that the moisture taken from the film itself quickly builds up the humidity to the desired point, when the control again automatically regulates the adsorber to maintain it, and the necessary output of wet air is discharged through the relief valve.

As an example of how this works quantitatively, the flow-sheet, Fig. 3, is given, based for convenience on the circulation of 1000 cubic feet per minute, assuming that 10 pounds of water per hour are to be removed. It is to be noted that the dehydrator would operate only when the atmosphere contains more than 90 grains of water vapor per pound of dry air, if that is the desired entering humidity.

It is apparent from the practice followed in many film laboratories that the desired absolute humidity of the air entering the cabinets is higher than the average absolute humidity of the atmosphere, and that, therefore, the normal pretreatment required for fresh air entering the drying cabinets is humidification rather than dehumidification. Whenever the atmospheric humidity exceeds the allowable humidity of the air entering the cabinet, a drying unit will be useful for maintaining the drying capacity without increasing the temperature of operation. This means, however, that predrying is necessary only in humid summer weather when the drying unit would be a convenient auxiliary for maintaining production regardless of the weather.

The type of unit required is shown in Fig. 4, and consists of an air filter with two single-stage bed adsorbers operating alternately, adsorbing and activating, thus being capable of continuous 24-hour production.

REFERENCE

[1] Crabtree, J. I., and Ives, C.E.: "A Pneumatic Film Squeegee." *Trans. Soc. Mot. Pict. Eng.*, XI (Aug., 1927), No. 30, p. 270.

MEASUREMENTS WITH A REVERBERATION METER*

V. L. CHRISLER AND W. F. SNYDER**

Summary.—*A description is given of apparatus with which the rate of decay of sound energy in a room may be measured. A loud speaker is used as a source of sound. When the sound reaches a steady state the loud speaker circuit is opened and at the same time a timer is started. When the sound energy has decayed to some definite value the timer is automatically stopped. If made in a portable form this equipment may be used to study the acoustical properties of auditoriums. Attention is called to the errors which may occur in these measurements.*

With the advent of the talking picture, the determination of the sound absorption values of various materials has become of considerable importance. The original method of measuring the coefficients of these materials is due to W. C. Sabine, and requires the use of a reverberation room and rather large samples of material. The inconvenience of this led to attempts to find a method which would permit the use of smaller samples.

One of these attempts, known as the tube method, is shown in Fig. 1. A mathematical formula can be derived showing that the sound absorption coefficient of the sample placed at the end of the tube can be computed if the relative values of the amplitude at the maximum and minimum points of the standing wave system in the tube are measured. Unfortunately, the results obtained in this manner are not in agreement with those obtained in actual installations. For this reason the method has been abandoned. At the present time it is necessary to adhere to the original reverberation method to obtain results which can be depended upon in actual installations.

Figs. 2 and 3 show a plan and cross-section of the reverberation room at the Bureau of Standards. To obtain satisfactory measurements it is absolutely essential that all external noise should be eliminated. The outer walls and roof have therefore been con-

* Presented at the Spring, 1931, Meeting at Hollywood, Calif. Publication approved by the Director of the Bureau of Standards.

** Bureau of Standards. U. S. Department of Commerce, Washington, D. C.

structed so that they are unconnected with the inner walls and ceiling. Due to this construction outside noises are seldom heard.

Fig. 4 shows an interior view of the reverberation room with a sample of material laid on the floor, and Fig. 5 shows the position of the observer while measuring the absorption of an audience.

To make measurements in this manner requires a trained observer. The method is very tedious as approximately one thousand observations are required in order to obtain satisfactory values of the absorption coefficients of a sample at six frequencies. To eliminate the personal error of the observer and to make measurements more quickly

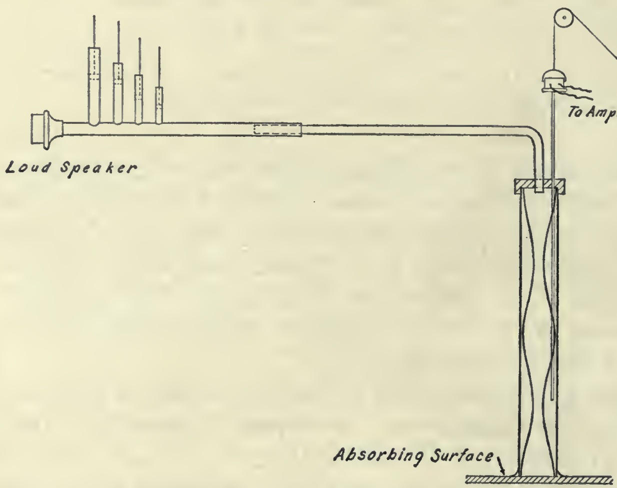


FIG. 1. Diagrammatic scheme of the tube method of measuring sound absorption coefficients.

and more accurately, considerable work has been done at the Bureau of Standards, as well as at other laboratories, to develop a method in which all measurements are made with some instrument.

The first attempt was by use of an oscillograph.[1] As the sound waves decay in a very irregular manner in most cases, it is desirable to take the average of a number of measurements in computing the results. Figs. 6 and 7 show the irregular way in which the sound may decay after the source has been cut off. Fig. 6 is for a frequency of 128 cycles and Fig. 7 for a frequency of 512 cycles. If enough records are taken at each frequency and the measurements averaged, satisfactory results can be obtained, but this requires too much work.

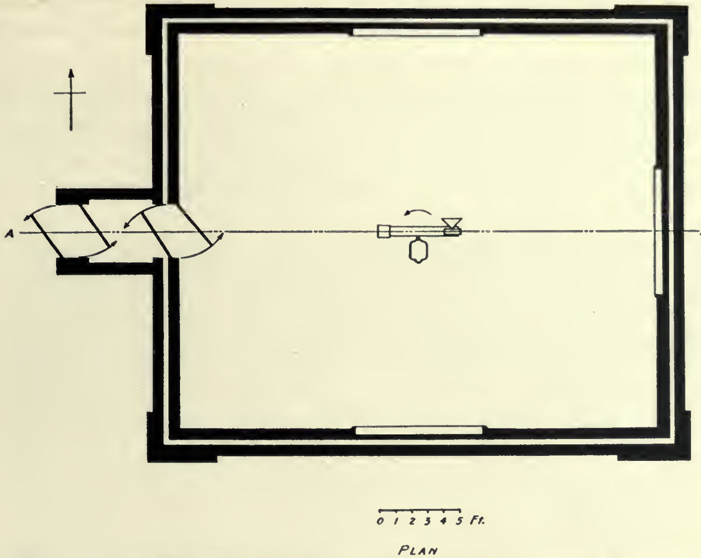
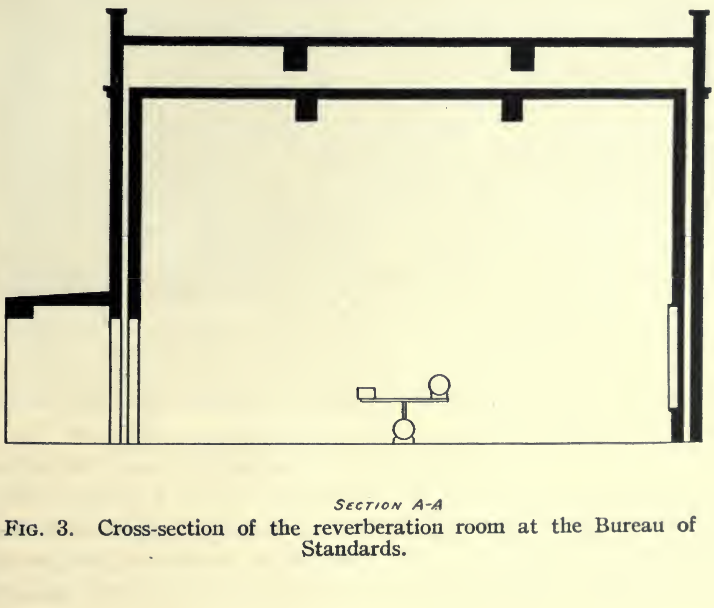


FIG. 2. Plan view of the reverberation room at the Bureau of Standards.



SECTION A-A

FIG. 3. Cross-section of the reverberation room at the Bureau of Standards.

The most satisfactory arrangement[2] that has been tried is represented schematically in Fig. 8. The source of sound is a loud speaker supplied with an alternating current of the desired frequency from a suitable oscillator and amplifier. The sound is picked up by a condenser microphone, and is then amplified. The purpose of the attenuator will appear from the following text. It is desired to call attention to the section of the circuit following the amplifier marked

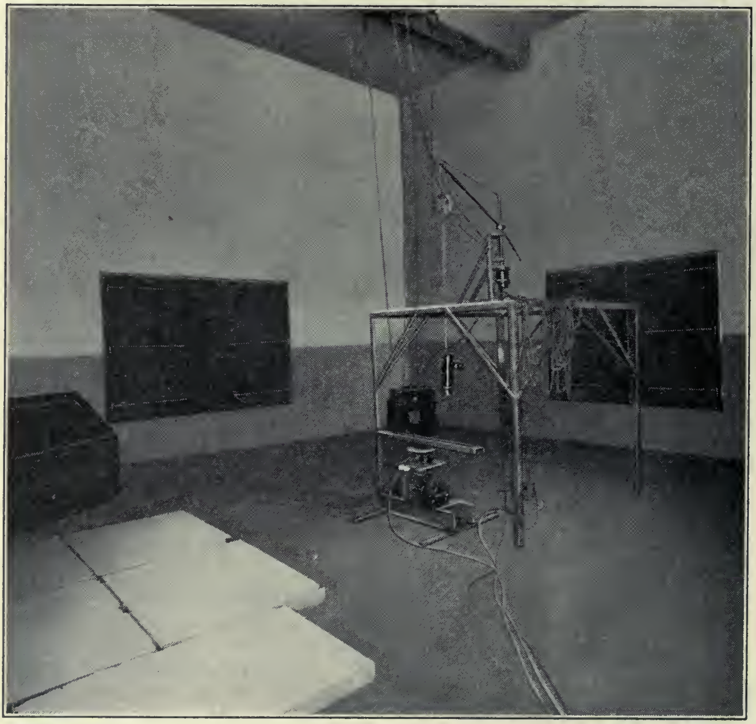


FIG. 4. Interior view of the reverberation room at the Bureau of Standards, showing a sample of acoustical material on the floor.

"tube relay," which consists of a rectifier tube followed by a stage of direct current amplification. The circuit is shown in Fig. 9.

These tubes are connected in such a manner that, after the alternating potential applied to the first tube decreases to a definite value, a very small additional decrease causes a relatively large increase of the plate current of the last tube. This has been accomplished by utilizing a "freak" characteristic of the first tube. Fig. 10 shows the static characteristic of this tube and gives the variation of the screen-grid current and the plate current with the grid potential when a

FIG. 5. View showing the position of the observer while measuring the acoustical absorption of an audience.

definite screen-grid potential is used. To produce such a characteristic only a limited range of screen-grid potentials can be used. If the tube

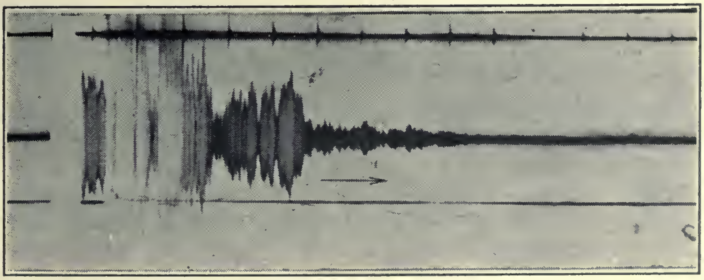


FIG. 6. Oscillogram showing the decay of sound after the source has been cut off; 128 cycles.

is biased so as to obtain rectification at the upper end of the curve, advantage can be taken of the abrupt change in plate current with a very small change in grid voltage.

Fig. 11 shows the modified plate current when an alternating voltage is applied to the grid of this tube, and the corresponding change in plate current in the last tube.

The sudden increase of the plate current of the last tube operates a relay which stops the timer. As the timer is started automatically when the loud speaker current is broken, this device gives the time required for the sound to decay to some level determined by the amount of amplification used.

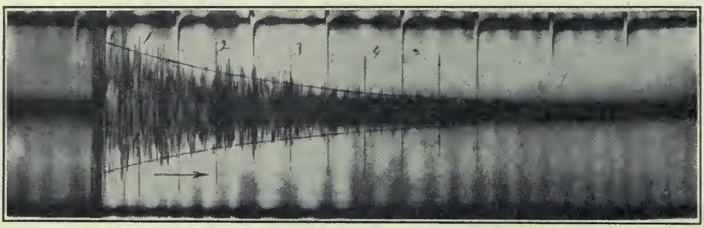


FIG. 7. Oscillogram showing the decay of sound after the source has been cut off; 512 cycles.

By using an attenuator in the amplifier circuit the time required for the sound to decay to different levels can be determined. In this way a decay curve can be obtained similar to that obtained in calibrating a room by the ear method, which uses different intensities, the ratios of which are known.

There is one marked difference between these two methods. In

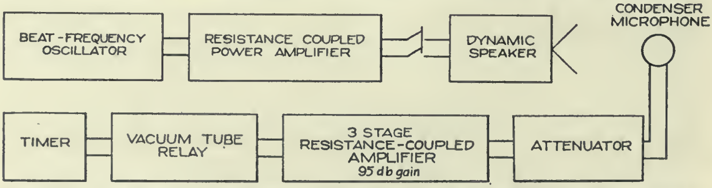


FIG. 8. Schematic arrangement used at the Bureau of Standards for making acoustical measurements.

the ear method we start at different intensity levels and end always at the same lower level, which is the threshold for the ear of the observer. In the instrumental method we always start at the same intensity level and end at arbitrary thresholds whose ratios are known. Fig. 12 shows a curve thus obtained. It will be observed that the points fit a straight line very closely. The points on the curve are not the results of single measurements but are each the average of ten measurements. With a timer which adds, several measurements can be taken rapidly and the average obtained, thus eliminating the uncertainties of a single measurement.

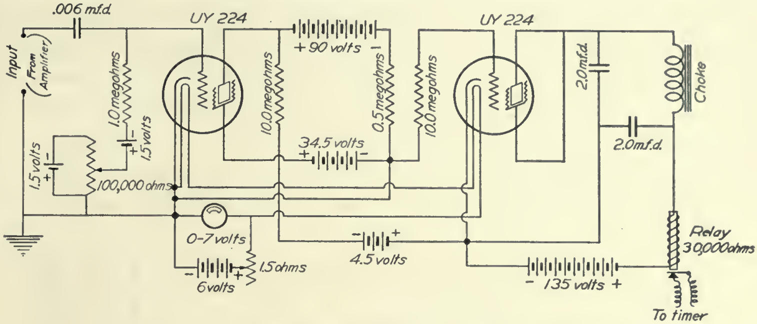


FIG. 9. Circuit diagram of the vacuum tube relay.

The slope of this line gives the rate of decay of the sound energy. From this slope the reverberation time may be computed, as reverberation time has been defined as the time required for sound to decay

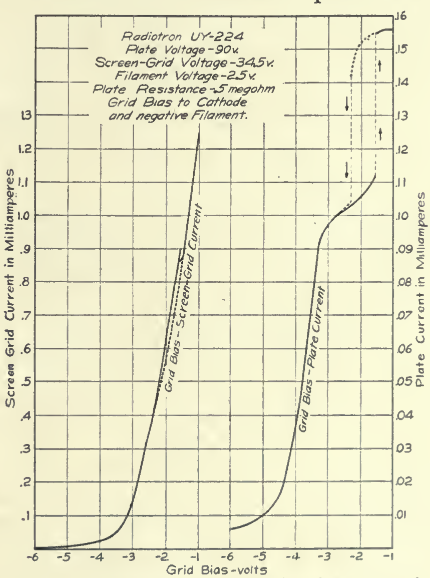


FIG. 10. Static characteristic of the rectifier tube of Fig. 9.

sixty decibels. Knowing the reverberation time, the total absorption of a room can be computed either by Sabine's formula or Eyring's general reverberation equation, as may be desired.

This arrangement gives a satisfactory instrumental method of measuring sound absorption, and also a method of determining the reverberation time of any room.

Satisfactory equipment for making these measurements does not solve all the difficulties of making such measurements. If an accuracy of not greater than ten per cent is desired in the total absorption, most of the difficulties vanish; but when greater accuracy is desired several precautions must be taken to obtain a uniform distribution of sound energy in the room where the measurements are made.

To obtain such a distribution a band of frequencies was used at

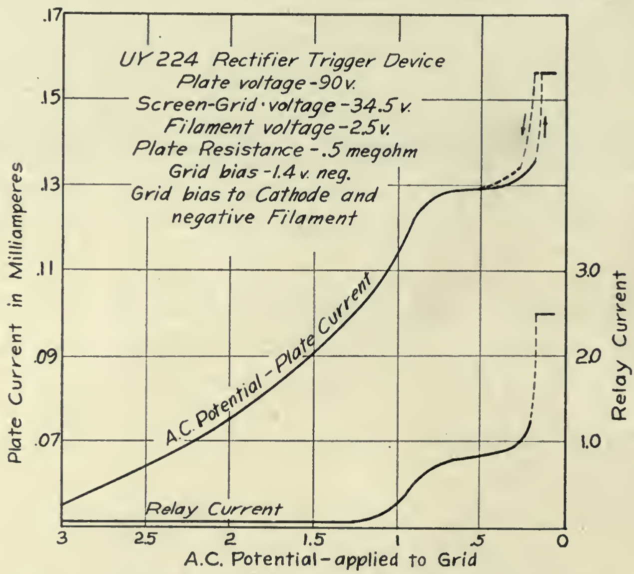


FIG. 11. Response characteristic of the rectifier tube of Fig. 9.

first; but later work has shown that this is undesirable, as beat notes may occur, which appreciably alter the result. The source of sound is in constant motion, this motion aiding materially in producing a uniform distribution. At the higher frequencies it was thought that this motion would be unnecessary, but it was found that the apparent rate of decay of a sound might vary ten per cent when both the source of sound and the microphone were stationary. This random variation rarely exceeds two per cent when the source is in motion.

When making measurements in a reverberation room it is possible to take these precautions, but in studying the rate of decay in a theater or auditorium, it becomes more difficult.

To make an intelligent application of acoustical material in a theater it is believed that equipment such as described here, or the reverberation meter as developed by the Bell Telephone Laboratories, should be used to study typical auditoriums and to learn more about sound distribution and rates of decay in different portions of the room.

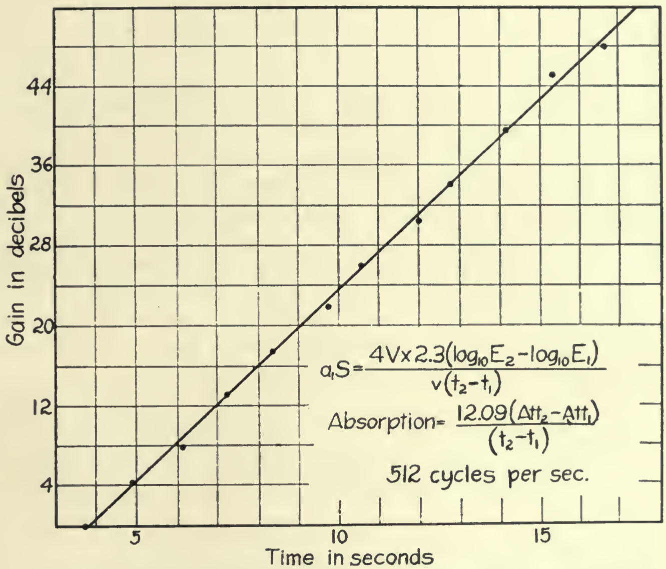


FIG. 12. Decay curve obtained by making measurements of a room, starting at the same intensity level and ending at arbitrary thresholds whose ratios are known. Each point represents the average of 10 measurements.

This study should be made at all frequencies so as to aid in determining the most desirable characteristics of a sound absorbing material and the locations in which such material should be applied.

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[2] MEYER, E.: "Automatic Reverberation Measurement," *Zeit. f. Tech. Physik.*, II (1930), No. 7, p. 253. STRUTT, M. J. O.: "Automatic Reverberation Measuring Instrument," *Elek. Nach. Tech.*, 7 (July, 1930), p. 280. WENTE, E. C., AND BEDELL, E. H.: "A Chronographic Method of Measuring Reverberation Time," *J. Acoust. Soc. of Amer.*, I (April, 1930), No. 3, p. 422.

16 MM. SOUND FILM DIMENSIONS*

RUSSELL P. MAY**

Summary.—*A method is set forth for the derivation of dimensions and locations of the final projection print and all camera, printer, and recording apertures, consideration being made for film weave, shrinkage, and mechanical tolerances in the apparatus involved in producing and projecting the film.*

Two methods of producing films are considered: (*a*) *Projection positive print made from a 16 mm. dupe negative by continuous contact printing, where the dupe negative is made by optical reduction of the 35 mm. picture from a master positive and the sound re-recorded from a 35 mm. sound track, and* (*b*) *production of the projection positive print from a 35 mm. picture negative by optical reduction and re-recording of the sound from the 35 mm. sound film directly to the final 16 mm. positive. The method provides for modification of these processes so that any combination can be used.*

Motion pictures in the home have in the past three or four years enjoyed a slow but steadily increasing popularity and utility. One witnesses frequently at the beaches and other resorts, amateur cinematographers with their cameras making pictorial records of their children's and friends' animations. Each year these experiences have become more frequent and now it is not unusual to be entertained, during an evening's visit, with motion pictures whose principals are your own friends and acquaintances. At the motion picture counters of photographic supply houses we see interested people discussing cameras, projectors, lenses, *etc.*, or leaving ciné-films to be developed. By these activities it is not difficult to conclude that the public is, in part at least, cinette-minded.

Development of motion picture equipment in all its branches has advanced in amazing strides since the introduction of sound, and paralleling this, the home sound movie has likewise been developed. Numerous devices have already made their appearance on the market. Thus far, they all employ disk type sound records driven synchronously with the film, but sound projectors utilizing sound on film are soon to make their début.

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** RCA Victor Co., Camden, N. J.

In order to present this subject clearly, it is desirable to review the difficulties encountered in the early attempts at interchangeability of films made by the various producers of sound films of the variable width and variable density types. Innumerable cases of variations of locations of sound track, recorder, and reproducer optical systems contributed to endless difficulties in attempts to arrive at universal operation and satisfactory performance of reproducing equipments. Augmenting these difficulties another source of trouble arose due to inherent requirements of the variable width and variable density type sound records, the former requiring that the scanning slit fully cover the record at all times, allowance being made for variations that might be introduced during the production of the projection print or in the projector. Should the end of the scanning slit fall within the boundaries of the record, the peaks would be "chopped off," thereby introducing distortion in the reproduced sound. It is therefore evident that the sound track width should be somewhat less than the length of the scanning slit.

In the case of the variable density type record, the opposite requirement, that the scanning slit should at no time fall outside the boundaries of the sound track, applies. Should this occur, noise might be introduced by either the sprocket holes or the picture.

Thus we see that if a universal scanning slit is to be used in projectors, the first-mentioned record must be narrower than the latter and the locations of the records and the scanning slit must be held to close limits.

It is needless to dwell on the desirability of preventing a recurrence of past difficulties with the advent of home sound motion pictures. Surely no word of explanation is needed to point out the importance of standardized film, recording and reproducing slit dimensions, when considering the potential home and industrial fields for this class of equipment and the production of apparatus and films, the success of which depends wholly upon interchangeability of films in the projection equipment.

With this point in view, this paper sets forth a method for the determination of film dimensions taking into account the variations experienced by the films from the making of the original 16 mm. negative to the projection of the positive print. This method has been followed in arriving at the projection print dimensions, as well as the projector sound and picture aperture dimensions.

The diagram in Fig. 1 shows all the probable steps in the production of the positive film from a "dupe" sound and picture negative and the extreme variations considered. It may be advantageous for

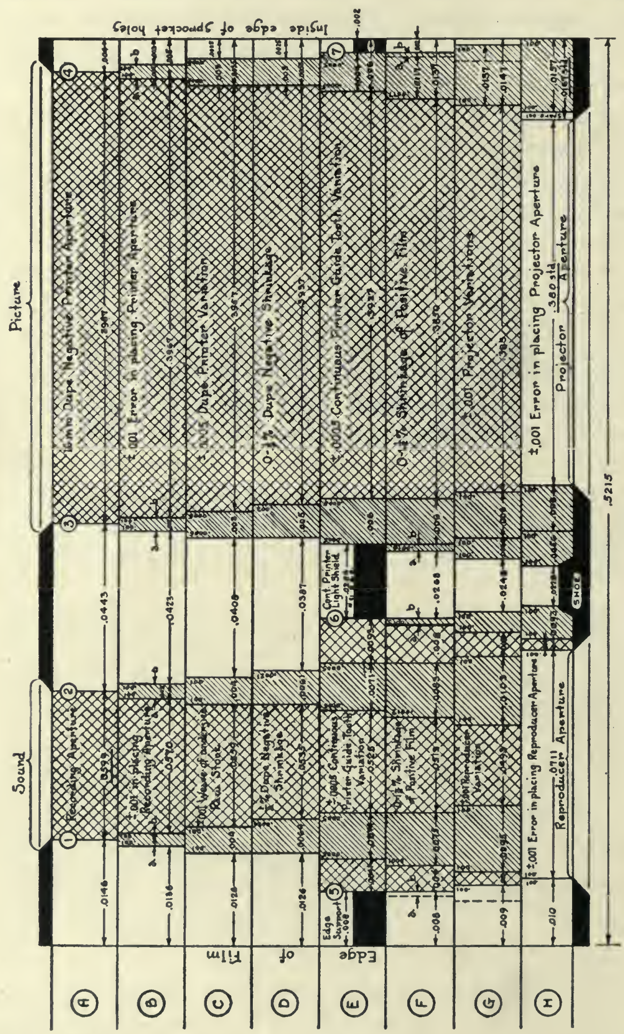

FIG. 1. Sixteen mm. film and apertures; dimensions and locations. Diagrammatic layout showing variations, tolerances, and shrinkages of positive film made by contact printing from dupe negative.

various reasons to produce projection prints by direct reduction of the picture from a 35 mm. negative and re-recording of the sound from the 35 mm. film direct to the projection positive. Fig. 2 shows the various steps involved in this procedure. It will be noted that

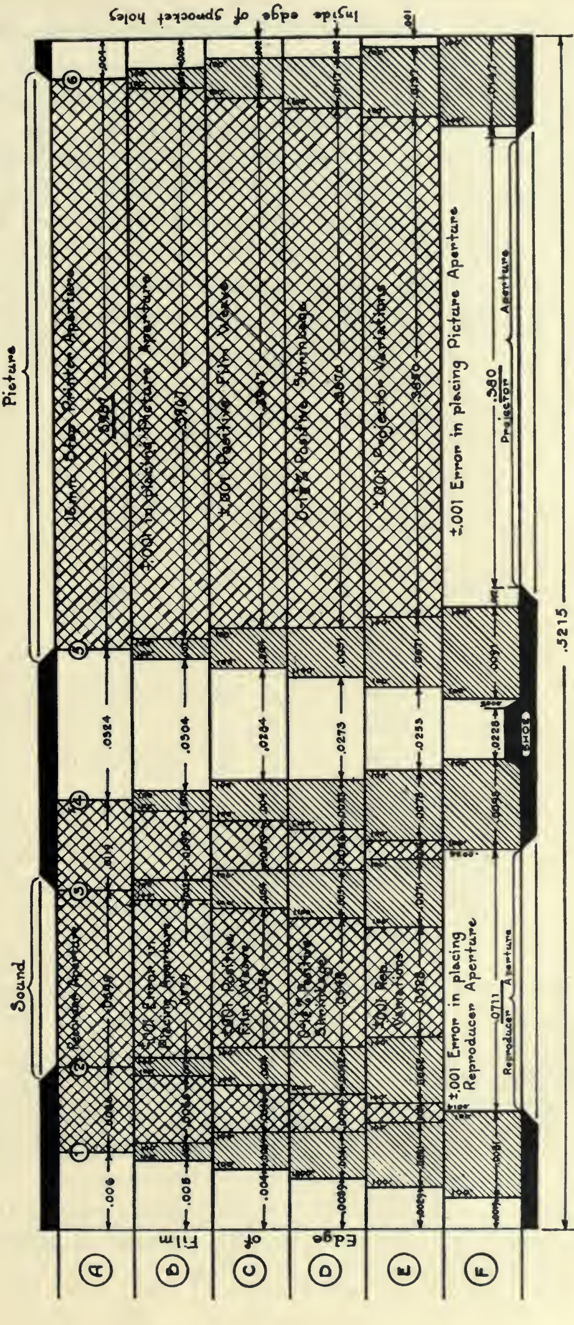

FIG. 2. Sixteen mm. film and apertures; dimensions and locations. Diagrammatic layout showing variations, tolerances, and shrinkages for positive film made by direct sound re-recording and picture reduction.

the sound and picture apertures in both diagrams are the same. This was done in order that the processing equipment might be universally adaptable to both methods. The latter method involves fewer steps, which will increase the margin of safety.

The variations used in the original calculations were twice those shown in the diagrams and were based on the practical limits of the machines to which they apply. A film 0.660 inch wide resulted, which did not meet the requirement that the sound and picture be adapted to a 16 mm. film. Examination of the various steps shown in Fig. 1 discloses that each factor varies, within certain limits, in-

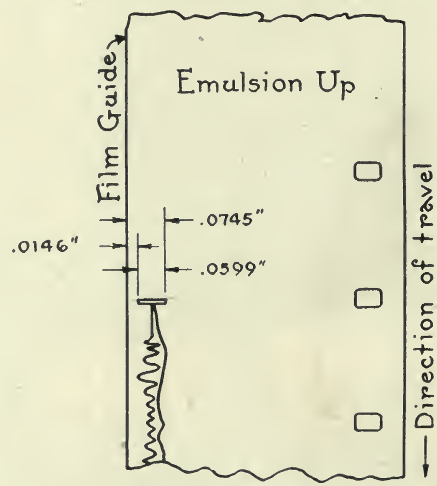

FIG. 3. Light slit dimensions and location for making dupe negatives on 16 mm. sound recorder. The diagram shows the film in the recording position with the emulsion facing the recording light.

dependently of any other. By applying the principle of probability to the distribution between these limits, the likelihood that all the variations will simultaneously occur in the same direction is so remote that it falls within the bounds of safety to reduce the original limits to one-half those shown in the diagram. By so doing, we are enabled to use standard 16 mm. film to carry the sound track in addition to facilitating the projection of present amateur films.

The projection print will be a 16 mm. film having standard perforations along one edge only. Eliminating the perforations along the opposite edge provides space for the sound track.

The requirements to be fulfilled are as follows:

(1) 16 Mm. film having one row of sprocket holes.
(2) Standard projector picture aperture.
(3) Projector picture aperture within the film image at all times.
(4) Clear space between picture and sound for a film supporting shoe in recording, printing, and reproducing equipment.

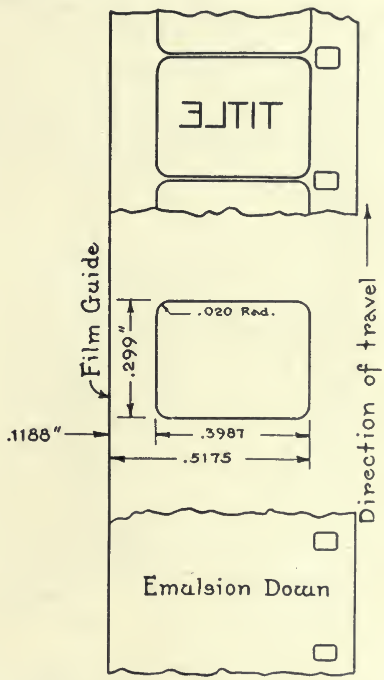

FIG. 4. Printing aperture dimensions and locations for making direct reductions to 16 mm. dupe negatives on optical reduction printer. Diagram shows film in printing position with the emulsion facing the printing light.

(5) 60-Mil recording slit.
(6) Sound reproducing slit to cover track at all times with ends riding in opaque stripes adjacent to the track.
(7) Transparent space at sound edge of film to prevent peeling off of emulsion.

Starting at the top of the diagram, Fig. 1, the solid areas represent aperture plates and the clear spaces the apertures through which the sound recording and picture printing lights pass as indicated at

1, *2*, *3*, and *4*. The lines thus numbered will be referred to as the "principal lines." The departure of latent or developed images from these starting points is shown by the parallel lines, diverging at each step, for the reasons indicated. Lines diverging to the left have been designated *a* and those to the right *b*, in each instance. These lines denote extreme limits only, and when considering picture or

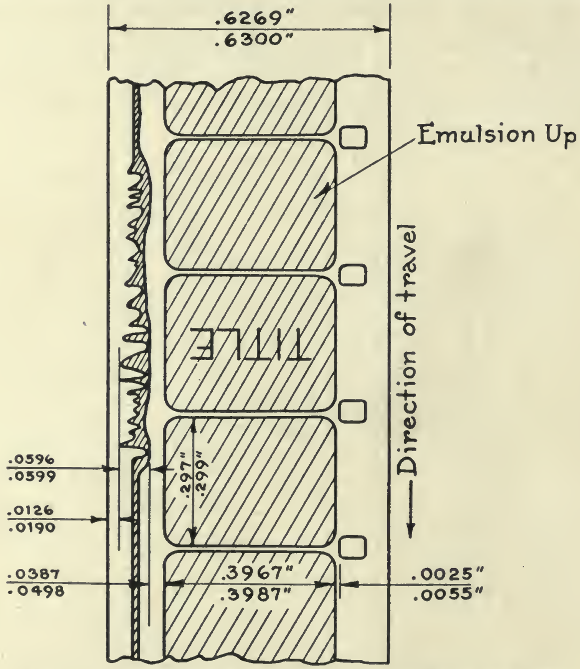

FIG. 5. Sound track and printer dimensions and locations; 16 mm. dupe negative (developed, 0 to 0.5 per cent shrunk). The sound record leads the picture by twenty-one frames or 6.3 inches.

sound track widths, the total distance between lines having similar designations is determined by addition.

The divergence continues in a regular manner in both directions down through steps *A*, *B*, and *C*. Variations shown in step *D* deal with dupe negative shrinkage and therefore are in one direction only, and since shrinkage of the dupe negative can result only in displacement to the right, the *a* lines continue down from *C* to *D* without change. The dupe negative is guided in the continuous printer by the sprocket holes, which in the diagram are represented by the vertical line at the right-hand edge, and causes the shifting of the film image, due to the shrinkage, to occur in the direction shown. The line, *4b*, in this step does not show a shrinkage offset This was purposely omitted as it only amounts to 0.00001 inch and can be neglected.

Step *E* shows the film image positions after printing the dupe negative in the continuous printer, whose variations are as indicated. The solid areas indicate light-shields built in the printer. The solid area near the center is a light-shield and film support to hold the dupe negative and positive films in contact. The space between this and the shield on the left represents the opening of the sound printing light aperture. It will be noted that a space exists between the

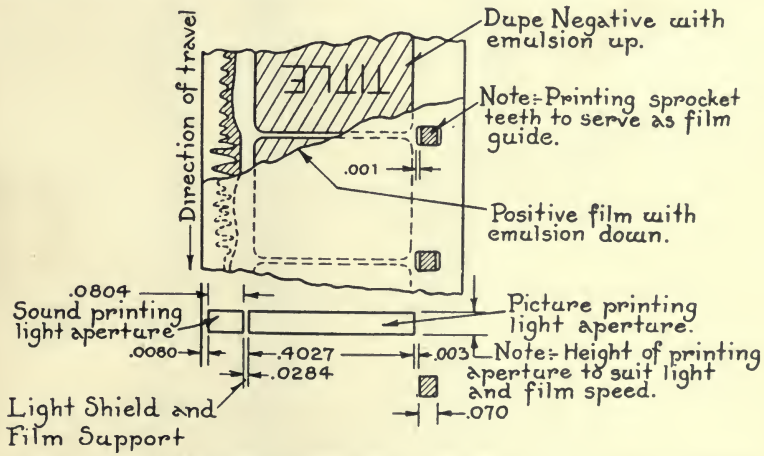

FIG. 6. Printing apertures, dimensions and locations; 16 mm. continuous contact printer. Diagram shows negative and positive films in printing position, emulsion facing printing lights.

maximum sound track limits and the ends of this aperture. It is through these clear spaces that the light of the sound printer passes to print the black stripes at either side of the sound track. The space occupied by the light-shields will receive no light, and therefore will result in transparent stripes on the developed positive film. The right-hand edge of the center light-shield coincides with the projected line *3a*, and represents the left end of the picture printing light aperture and, as shown, coincides with the picture negative in its extreme left position. When the picture negative assumes an extreme right position a clear space of 0.006 inch will occur between it and the end of the aperture, and will show up as a black stripe on the positive. The opposite end of this aperture is located at the projection of line *4b* at step *E*. Addition of the dimensions involved results in an aperture 0.4027 inch long, the end of which is located 0.002 inch from the sprocket holes. Under these conditions we may be sure that the picture will never be cut off in the printer, and the sound track will at all times be bordered with black stripes.

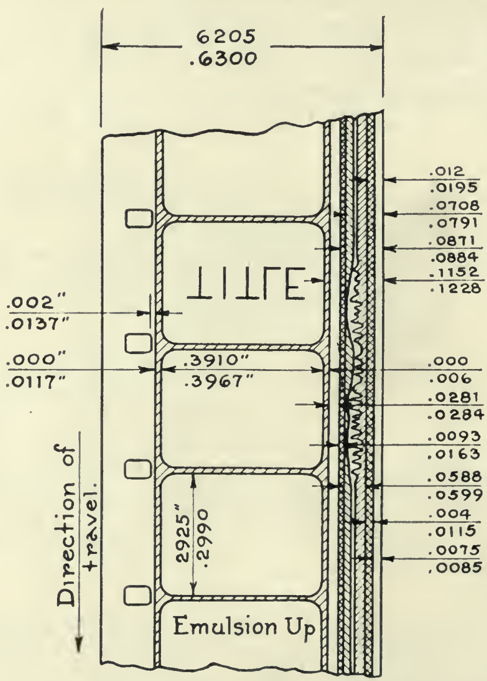

FIG. 7. Sound track and picture dimensions and locations; 16 mm. positive (developed, 0 to 1.5 per cent shrunk) made from dupe negative.

Step *F* deals with shrinkage of the positive film, and shows that the image shifts to the left. This is due to the fact that during projection the film is guided by the edge of the film adjacent to the sound track and, therefore, any motion of the film image due to shrinkage will be in this direction.

The opaque light-shields shown in step *E* introduce a new set of secondary lines, *5*, *6*, and *7*, which must be considered in all subsequent steps. It will be noted that these lines undergo the same divergence as the principal lines. Line *5a* is shown dotted, as it falls without the boundaries of the reproducer aperture and is unimportant; the same holds true for line *7a*. Line *5b*, however, converges toward principal line *1a*, and *6a* toward principal line *2b*, at each succeeding step. The divergence of the principal lines continues through steps *G* and *H* for the reason noted, finally meeting the secondary converging lines. Attention is directed to the fact that lines *2b* and *6a* do not actually intersect at step *H*. This would ordinarily occur, but in this particular case a modification was necessary to

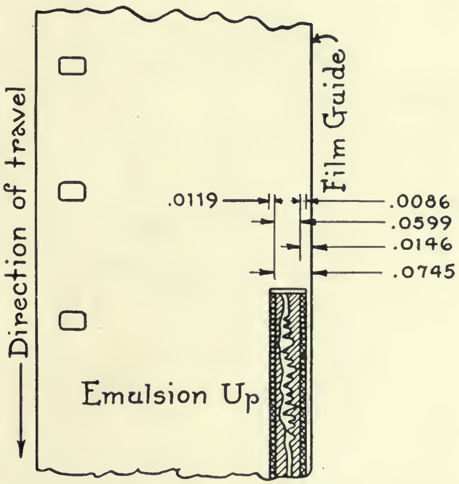

FIG. 8. Light slit dimensions and location for making direct re-recordings on 16 mm. sound recorder; diagram shows film in recording position with emulsion facing the recording light.

adapt the reproducing aperture to film made either by printing or by direct re-recording. These points of intersection define the limits of the projector sound and picture apertures. The shoe shown between the two apertures serves as a support for the film and rides in the clear space indicated by the lines converging from the center printer shield. The dimension 0.0228 inch defines the limits to which the edges of the clear space can move toward each other and not its actual width, thus assuring that the shoe in the position shown will at all times ride on an emulsionless surface. By using the intersections of the progressive variations as locating points for the aperture, we are assured of proper registration with the film images.

In the construction of the diagram, the width of the film from the inside edge of the sprocket holes to the opposite edge of the film, 0.5215 inch, is used as the working basis, and satisfies requirement No. 1.

Having predetermined all the factors which should be satisfied,

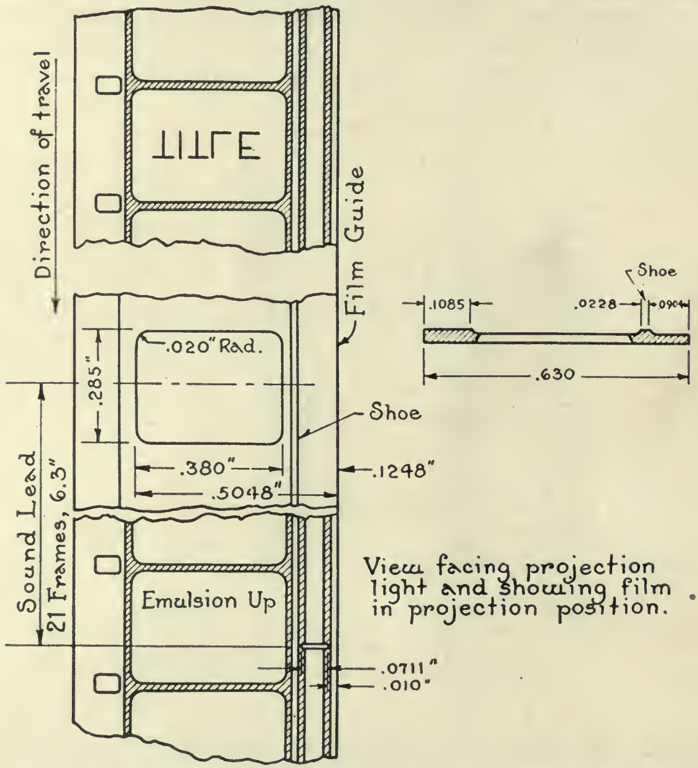

FIG. 9. Picture aperture and scanning line dimensions and locations; 16 mm. projector. Diagram shows film in projection position facing projection light.

the diagram was laid out completely as shown, minus the dimensions. Requirement No. 2 was met by locating the 0.380 inch projector picture aperture at the center of the film, having the 0.0167 inch distance to the sprocket holes. By constructing lines *4a* and *4b* so that they are located between the picture apertures and sprocket holes, requirement No. 3 is fulfilled. The dimensions shown are derived from the 0.0167 inch spacing and the predetermined variations indicated by the vertical figures. The point of coincidence at *4* determines the right-hand edge of the printer aperture. Point *3* is located by similar treatment.

A shoe width of not less than 0.020 inch was considered desirable, and after an initial calculation 0.0228 inch was chosen as it facilitated the use of standard gauge sheet metal for the light-shield. Requirement No. 4 is thereby satisfied.

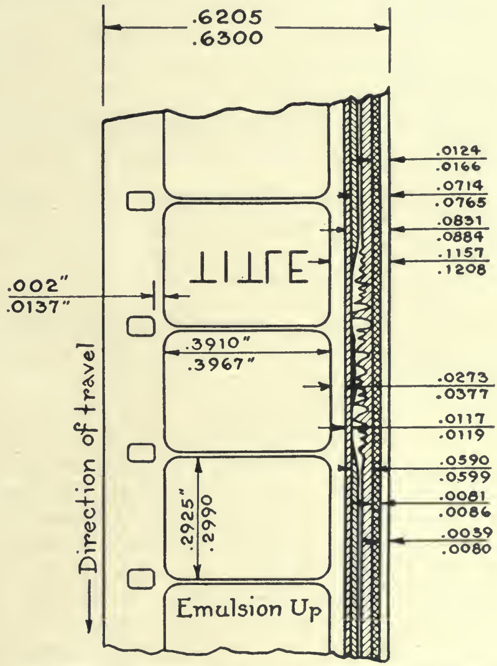

FIG. 10. Sound track and picture dimensions and locations for 16 mm. positive (developed, 0 to 1.5 per cent shrunk) made by direct picture reduction and sound re-recording.

The position of *2b* at step *H* locates the right-hand end of the sound reproducing aperture or slit. Requirement No. 5 is met by making the distance between lines *1* and *2* at step *A* 0.060 inch and the position of *1a* at step *H* satisfies requirement No. 6; working up from this point to secondary line *5* results in a distance from the edge of the film of 0.008 inch, which satisfies requirement No. 7. Fig. 2 shows the method as applied to 16 mm. sound films made by direct re-recording of sound and reduction of picture from 35 mm.

dupe negative. The aperture dimensions and location are identical to those shown in Fig. 1.

The two methods shown in the diagrams provide a flexible arrangement whereby 16 mm. projection prints may be made using either method or any combination thereof. In other words, in addition to the methods shown in the diagrams the sound may be re-recorded and the picture printed from a 16 mm. dupe negative, or the sound may be printed from a 16 mm. dupe negative and the picture printed by optical reduction from a 35 mm. dupe negative. In any case, we may be assured, however they are made, that they will always register properly in the projector.

With regard to sound tracks of the variable density type, it will be observed that adequate provision has been made to permit the scanning slit to fall within the track area if the methods set forth are followed, the additional width being provided by utilizing the space occupied by the black stripes in the variable width type of record.

The accompanying drawings show in detail all aperture dimensions and locations, and maximum and minimum film dimensions as derived by the foregoing methods.

DISCUSSION

MR. MITCHELL: Judging from our experience on 35 mm. film, we ought to consider maximum shrinkage. The fact that 16 mm. film is made of safety stock, which shrinks more than standard stock, should also be considered.

The elimination of one row of perforations will tend to obsolete a lot of 16 mm. film already in use both here and abroad.

MR. MAY: We have considered the matter of obsolescence of the existing 16 mm. equipment, and feel that it is not as important as it may seem, due to the fact that a picture made for sound requires sound with it in order to afford a satisfactory performance.

We do not think it important to be able to show sound films on existing 16 mm. projectors, but we do feel that the projection of existing 16 mm. films made with amateur cameras should be capable of being projected in our new sound equipment. That is possible. As to shrinkages, we have allowed somewhat more than what we encounter in practice. One and one-half per cent is ample for the positive.

MR. VICTOR: Is this paper intended as a proposal for a standard?

MR. MAY: Yes.

MR. VICTOR: Have you experimented with contact printing from 16 mm. negatives to positives, with the sound track?

MR. MAY: We have, and are satisfied that it can be done commercially.

MR. VICTOR: Is the emulsion fine enough?

MR. MAY: I might add that it is not as good as we would like it to be. But it is our opinion that the projected picture and the sound quality are commercially satisfactory.

MR. SPONABLE: I note that the distance between the sound records of the corresponding pictures is 6.3 inches. That is not a straight reduction from thirty-five to sixteen, is it?

MR. MAY: No. The two distances that are used are for theater use. The distance used by RCA Photophone, Inc., is somewhat different from that used in the Movietone. If I am not mistaken, it is on the opposite side, too, is it not?

MR. SPONABLE: It is my impression that the separation is fifteen and a half inches, for theater use. It seems to me that if the 16 mm. machine were properly designed, we could use a straight reduction from 35 mm. film.

MR. MAY: That would be true if we were making it from a sound negative of which the dupe is already made. It might be more practicable to print first the sound and then the picture, in which case the dupe negative could be run through the two printers one after the other, in which case the sound lead would not be important.

MR. SPONABLE: I wondered whether it was a case of not being able to design a projector that would give a displacement of four and three-quarter inches?

MR. MAY: There would result little less than the present length of six inches. This is as short as we can make it and still get the various mechanisms in place. We have been using a single row of perforations for probably two and a half years in our development work, and have found that the wearing qualities of the film show no appreciable difference, whether one or two rows of perforations are used. In fact, we have run films to destruction, and in most cases cannot keep the splices in long enough to finish a film. I might add that twelve or fifteen hundred trips to the gate are not uncommon. And usually the emulsion and the surface of the film are damaged, rather than the sprocket holes.

MR. RICHARDSON: How is it proposed to adapt the sound to the relatively tiny figures in the 16 mm. screen image?

Using the relatively narrow 16 mm. sound track, is it possible to obtain the same quality of the sound that may be had from the wider track?

MR. MAY: The picture can be made about as wide as five feet. When sitting in a small room, the angle at which the eye subtends the screen is not greatly different from the similar angle in the theater. In other words, sitting in a living room and watching a picture as large as can be projected from a 16 mm. film, one obtains the same illusion of size as he does in the theater. As to the sound, the sound track is only ten mils narrower than that used on 35 mm. film. The latter has a seventy-mil track, and we have used a sixty-mil track in our small film. The difference in size of track is only about sixteen per cent. The sound output is about the same as that obtained from a radio set—comfortable room volume.

MR. HICKMAN: This is not an attempt to form standards at any immature stage in the development of the art. The complaint has been made, in previous developments of motion picture engineering, that dimensional coöperation is absent at the start; after the job is done the manufacturers try to get together and find out how they can simplify matters. Now we have the advantage here of someone's thinking out clearly and carefully, at the very beginning, the factors that underly the situation; presenting them quite openly, so that what is being thought by one powerful group will be known by all. I do not think that there is any question of establishing these standards at this time.

Mr. Hardy asked me to announce that this paper was presented under full cognizance of the Standards Committee and is being considered by them.

MR. EVANS: One of the reasons why the Standards Committee wanted to have this paper presented before the Society at this time was to discover what, if any, objections to it might be raised, so that the Committee would have as many facts before it as possible when it attempts to standardize 16 mm. pictures.

To the Committee were presented several communications indicating quite different viewpoints on the subject. One communication advised that although we were going to have a 16 mm. sound track, it ought to be 20 mm. Another one stated that if we were going to have a 16 mm. sound track, two rows of perforation should be used. Those were important differences. The Committee welcomes free discussion of all such important factors, so that it will have all the various viewpoints before it.

MR. COOK: After an experience of eight years in the Kodascope Libraries, I can assure you that a single row of perforations is ample to secure a much greater projection life of the film than is likely to be consistent with the obsolescence of the subject. The Bell and Howell machine has only one claw on one side; test strips have been run in this machine many hundreds of times without apparent deterioration of the edges of the perforations.

MR. RICHARDSON: With a single line of perforation, would it not be necessary to adjust the tension carefully?

MR. COOK: In the 16 mm. film a more accurate registration is possible with a single row of perforations than is likely in the 35 mm. film with two rows of perforations. There is no difference that the unaided eye is able to discover in the image projected from a film with a single row of perforations than from one with two rows.

PROPOSED CHANGE IN THE PRESENT STANDARDS OF 35 MM. FILM PERFORATIONS*

A. S. HOWELL AND J. A. DUBRAY**

Summary.—*There are at the present time two standards of 35 mm. film perforation, one known as the Bell & Howell perforation for negative films and the other the rectangular perforation for positive films, both of which have been approved and adopted by the Society of Motion Picture Engineers. Unfortunately, the use of these two standards introduces complications found detrimental in certain types of work, which indicate the advisability of having a single standard.*

It is felt that the rectangular style of perforation has advantages that it is desirable to retain. An alternative standard is proposed that will combine the advantages of both the present styles, and which, at the same time, can be used on practically all existing equipment without alteration of that equipment. Means are also suggested for shortening the transitional period of such a change-over.

There are at the present time two standards of 35 mm. film perforation, one known as the Bell & Howell perforation for negative films and the other the rectangular perforation for positive films. Both standards have been approved and adopted by the Society of Motion Picture Engineers, for reasons which are well known.

It appears that while the decision to adopt two perforation standards was originally taken with a view of reconciling commercial requirements and economic dictates, the adoption of a double standard has now created an undesirable condition, especially in contact printing, process work, *etc.*, involving exact superimposed registration.

While it is true that until now the motion picture industry has been able to get along with the two standards of perforation, it is equally true that this double standard creates a serious barrier to further technical advances of motion pictures. This barrier is perhaps only important at the present time to a limited number of motion picture technicians, but it is a barrier which will rapidly and seriously hamper the efforts of the industry toward further achievements.

In this connection, it is interesting to review the discussion that

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Bell & Howell Co., Chicago, Ill.

occurred on the rectangular perforation at the time it was proposed by the Standards Committee.[1] At that time, the difficulties arising from the use of two standards of perforations were pointed out, and the situation today, with respect to the impossibility of securing satisfactory registration when the two sizes of perforations had to be used together, was forecast.

In present practice where superimposed registration is required, as in composite photography; dupe negatives for lap dissolves; step printing with pilot control; color photography, in which two negatives are exposed simultaneously in contact or in superimposed relation, or two frames exposed in accurate relation to one another,

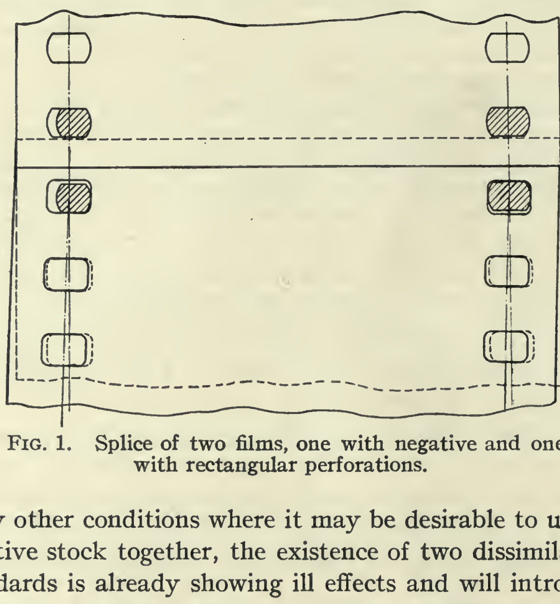

FIG. 1. Splice of two films, one with negative and one with rectangular perforations.

and many other conditions where it may be desirable to use positive and negative stock together, the existence of two dissimilar perforation standards is already showing ill effects and will introduce even more serious obstacles in the near future. Furthermore, the dual perforation standard may eventually become a cause of trouble in theater projection, with the practice of indiscriminately using both positive and negative perforations in release prints. When both types of film perforation are used indiscriminately in this manner, it is impracticable, if not impossible, to maintain good splice registration even with the best facilities available.

For instance, Fig. 1 shows a splice of two films, one with negative and one with rectangular perforations. In the shaded outlines, two conditions of the positioning of the splicing machine pilot pins, with respect to the perforations, are shown, the pilot being of the same size and shape for both conditions. In the upper part of the drawing, the pilot pins are assumed to fit the negative perforation perfectly. These same pilot pins cannot, however, fill the rectangular perforation, and the drawing plainly shows what the maximum error in registration may be.

When two sizes of perforation are used, as it is quite impracticable to provide two sizes of registering pins in the same splicing machine, the only alternative is, of course, to use the smaller or negative size pins, with the resultant probable error as illustrated. The dotted line portion shows the correct alignment when the splice is made in correct registration. The possibilities of errors occurring in splicing under present conditions have been presented here as being perhaps the most tangible and most easily illustrated.

Such errors of registration, however, assume a much greater importance in special process cinematography and in general studio and laboratory processing practice. For instance, in sprocket control printing machines in which the sprocket design is correct for obtaining both longitudinal and side control for the negative form of perforation, there is an essential lack of side control of the positive film having the rectangular perforation. This amounts to approximately 0.0045 inch in excess of that existing between sprocket tooth and negative perforation.

An additional tolerance allowance has to be made on the sound track to take care of this. In order fully to satisfy this control condition, it would be necessary to use the negative form of perforation for both positive and negative film.

We are therefore faced with two alternatives: either to eliminate one of the two standards now in use or to adopt a perforation that will combine the advantages of the two present types in such a manner as to provide the facilities mandatory to good registration in processing as well as adequate control in projection.

The rectangular form of positive perforation has some advantages; for instance, it provides for equal longitudinal compensation, while providing better means for the transverse control with sprockets as well as with pilot-pin means of registration. It would not be practicable to eliminate the present negative perforation in favor of the present positive rectangular perforation; but it would be entirely possible to eliminate the present positive perforation without affecting any of the present processing equipment. However, it may be considered desirable to retain the advantages of the rectangular form of the positive perforation.

It is therefore here proposed, that a dimensional change be made

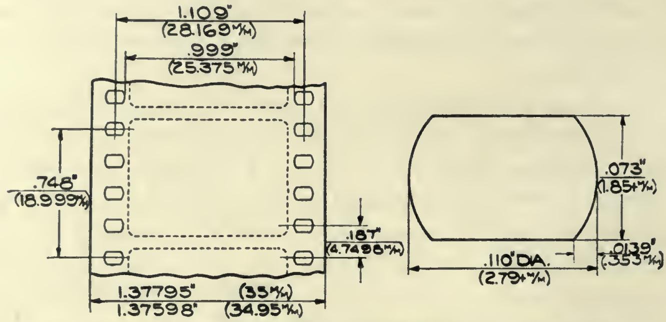

FIG. 2. Bell & Howell negative perforation; standard 35 mm. negative film.

in the present positive standard of perforation which will permit using positive or negative films interchangeably or indiscriminately, and with equal facility in nearly all existing processing equipment.

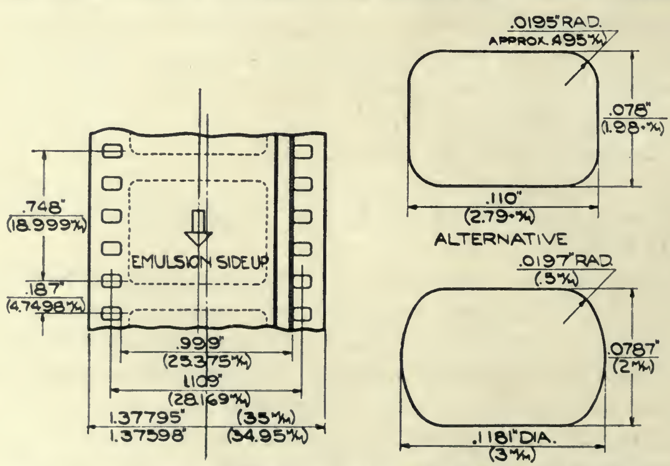

FIG. 3. Standard 35 mm. positive perforation and alternative approved by the S. M. P. E.

The dimensional characteristics of the two standards now in use will be reviewed and the advantages of the proposed change explained.

Fig. 2 gives the dimensions of the Bell & Howell negative perforation, which is bounded by two straight parallel faces 0.073 inch apart and by two curved faces corresponding to two arcs of a circle having a diameter of 0.110 inch, the height of the chord of the radial

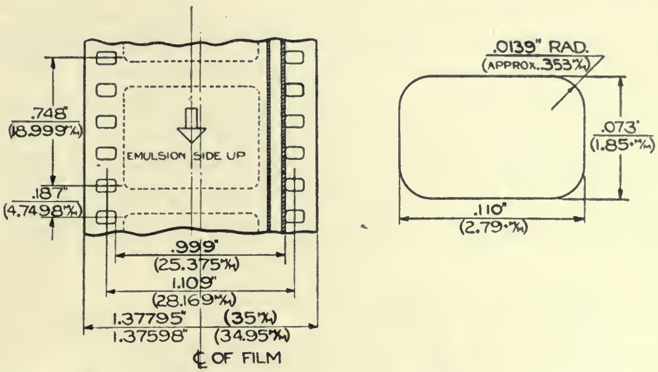

FIG. 4. Perforation dimensions proposed for 35 mm. positive film.

portion being 0.0139 inch. The pitch of this perforation is 0.187 inch.

Fig. 3 shows the dimension of the standard 35 mm. positive perforation and an alternative approved by the Society of Motion

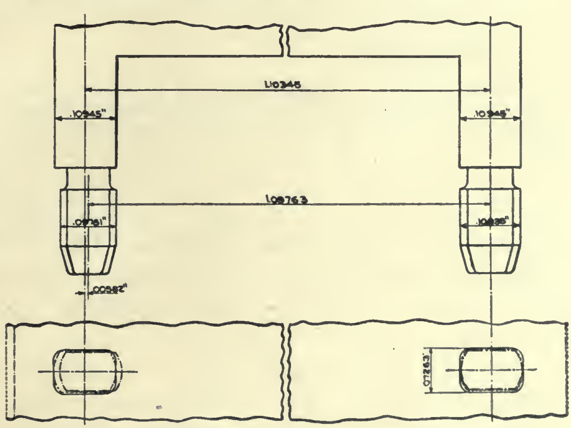

FIG. 5. Punches for re-perforating old negatives.

Picture Engineers. It will be necessary to consider only the rectangular perforation with rounded corners of the shorter radius, since it is fortunately the only one in common use; if both were in use, the situation would be still more complicated.

As shown in the figure, the width of the perforation is 0.110 inch, as in the negative perforation, while its height is 0.078 instead of 0.073 inch. The radius of the rounded corners of the rectangular perforation is 0.0195 inch.

Fig. 4 shows the perforation dimensions which are suggested for consideration as a proposed standard for both negative and positive film, with certain restrictions imposed with respect to sprocket controlled processing mechanisms. These restrictions consist in retaining the present shape of sprocket tooth until the obsolescence of the present form of negative perforation, which could be safely anticipated to require a period of about 15 to 20 years. This

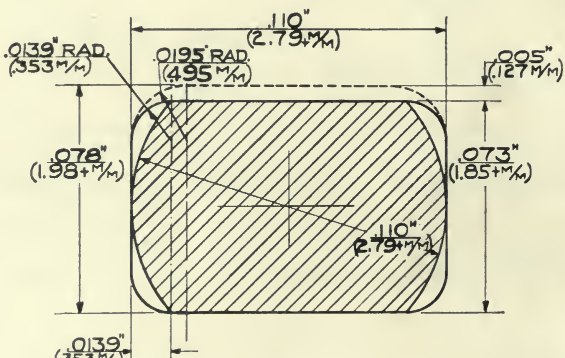

FIG. 6. Composite drawing showing present standard negative film perforations, proposed rectangular form of perforation, and present positive film perforation, superimposed.

period could be shortened if, say, after a definite lapse of time, whatever old negatives were to be printed could be re-perforated. This re-perforating has been done in the past with perfect satisfaction, and would be entirely practical should this proposal be acceptable.

Fig. 5 shows how this is accomplished. A rectangular punch is made with the lower end ground to fit the present negative perforation. The end is pointed to facilitate entry and positioning.

Only one pair of holes is perforated at a time. The sprocket hole on the control side is perforated to cut out the corners only, while the opposite perforation would be cut more on one side than the other, depending on the shrinkage. This assures perfect control and yet takes care of shrinkage.

The dimensions suggested for the modified perforation are as follows:

Perforation width	0.110 inch
Perforation height	0.073 inch
Rounded corners of a radius of	0.0139 inch
Pitch	0.187 inch

It will be noticed that the shape of the proposed perforation is rectangular with rounded corners. Its width remains 0.110 inch, as in both of the present perforations.

Its height is that of the present "negative" perforation and the radius dimension of corners is changed from 0.0195 to 0.0139 inch,

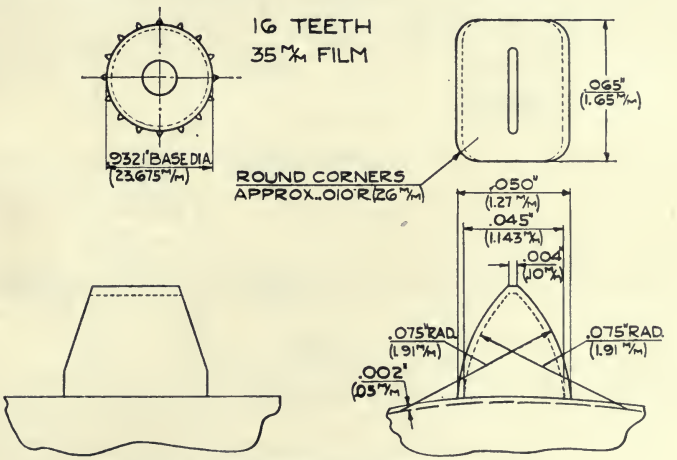

FIG. 7. Intermittent and feed sprockets.

in order to coincide with the chord height of the radial portions of the present 35 mm. negative standard perforation, as shown in Fig. 6.

Fig. 6 is an enlarged composite outline drawing in which the lined portion represents the present standard negative film perforation, with its major and minor dimensional extremities shown in coincidence with those of the proposed rectangular form of perforation.

The dotted line portion of this figure represents the outline of the present positive film perforation with relation to the proposed standard perforation showing the differences in the minor dimensions, amounting to 0.005 inch.

Since the pitch and height of the proposed perforation are identical to those of the present negative perforation, no alteration is necessary in camera or laboratory apparatus as used today for which the size, shape, and pitch of the sprocket teeth have been carefully calculated with regard to the relation of the arc of contact of the film with the periphery of the sprocket, and to the extent of film shrinkage that is to be accommodated.

For projection machines, which must accommodate a greater film shrinkage than cameras and laboratory apparatus, it may or may not be found advisable to modify the height of the sprocket tooth and its width at the base, as illustrated in Figs. 7 and 8. These

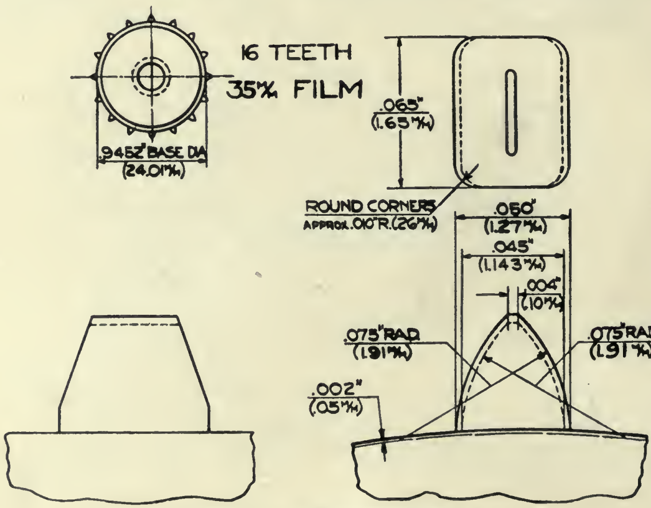

FIG. 8. Take-up sprocket.

illustrations show: first, the dimensions of an intermittent and feed sprocket, and second, those of a take-up sprocket. The diameter of the take-up sprocket is less than that of the others, resulting in a reduction of effective tooth pitch for the former, the size and shape of the teeth being the same for all sprockets. Here again, it is interesting to refer to the original discussion on the rectangular perforation,[1] when it was seriously debated whether it would not be advisable to standardize the sprocket rather than to change the film.

The figures show that the proposed alteration consists in a reduction of the width of the tooth base from the present standard of 0.050 to 0.045 inch.

After considering the improved means now available to exchanges and theaters for handling positive films, and the decreased possibility of using film that is excessively shrunken, the writers do not feel that the slight difference between existing sprockets and the proposed alteration would be of any serious consequence, even though the present standard tooth width of 0.050 inch is retained.

Incidentally, if such a change in the sprocket should be considered desirable, it might be pointed out that most of the sprockets in use on projection machines are probably so worn that they would not have to be touched; it would be a comparatively simple matter to have new projector sprockets made to the new proposed dimensions. If the Society of Motion Picture Engineers, however, considers it advisable to maintain the same amount of relative clearance as is now provided in the present positive standard perforation, the suggested alteration of projector sprockets would not present any serious difficulties.

REFERENCE

[1] Report of Film Perforations Committee, *Trans. Soc. Mot. Pict. Eng.*, **16** (May, 1922–23), p. 303.

DISCUSSION

MR. COX: Are the conditions of the raw stock, or use of it in the machine, such that the objections originally raised, in 1923, have been obviated in the present system?

MR. DUBRAY: I believe that they have. Although little official data are available on the subject, reports from consumers of film indicate that these objections are overruled sufficiently at least to make possible the proposed change in perforation size and shape.

MR. COX: Have you found any difference in the negative shrinkage or positive shrinkage in the present process over what it was five years ago?

MR. DUBRAY: With regard to negative films, we would say yes. Films manufactured now, experimentation shows, shrink less than the films of five years ago, due, probably, to two main factors: improvement in the manufacture of the film base, and more careful and adequate treatment of the film before and after processing. With regard to positive film, shrinkage accommodation was extended to as much as 2.5 to 3 per cent five years ago, while today film manufacturers seem to be in accord in considering 1.5 per cent the maximum shrinkage that must be accommodated. Again, no official data is available, but practice seems to be in accordance with these data.

PAST-PRESIDENT CRABTREE: For what percentage shrinkage are these teeth calculated?

MR. DUBRAY: If I remember correctly, projector sprockets are designed to accommodate a 2.5 per cent shrinkage, while the sprockets of the Bell and Howell continuous printer accommodate a shrinkage of 1.5 per cent.

THE ANIMATOPHONE
A NEW TYPE 16 MM. SYNCHRONOUS DISK REPRODUCER*

A. F. VICTOR**

Summary.—*A new reproducer employing a vertical turntable and floating pick-up is described. The reasons for the radical departure from conventional design and the advantages resulting from this departure are briefly referred to. The reproducer is of the portable type, being housed in a compact lightweight carrying case.*

Two years ago the Victor Animatograph Corporation made a decidedly original contribution in reproducer design by introducing the vertical turntable. For the first time in the history of reproduction of sound from disks the conventional horizontal turntable had been abandoned, the vertical turntable making possible a more compact design than is practicable with the horizontal turntable, and also makes possible a rigid direct drive that is absolutely positive.

The close coupling of the turntable and the projection mechanism in turn made imperative a positive speed control. No mechanical control could supply the necessary smoothness and uniformity of drive for perfect sound reproduction. This necessity was supplied by a new electro-pneumatic control. A current of air originating in a rotary blower is made to fall upon a thin membrane which carries an electrical contact. The counteracting force is gravity, hence the governor is not dependent upon the action of springs.

When the blast is increased to a certain intensity, the contact opens, causing the current supply of the motor to flow through a resistance, immediately causing the motor to run more slowly. When the projector is operating at the correct speed the contact is made and broken at a rapid rate, thus always maintaining the proper speed within close limits.

The vertical turntable design, revolutionary as it was, proved to be a decided advantage. The quality of the sound produced was distinctly better than had before been obtained from synchronous

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Victor Animatograph Corp., New York, N. Y.

disk equipment. But the mechanical ground noise, so common in all such equipment was present in slight, although appreciable, degree. Experiment showed that ground noise is inevitable in every case where the support of the pick-up is rigidly secured to the base of the mechanism proper.

As insulation and damping did not properly overcome this difficulty, the floating pick-up was designed to do so.

This consists of a support standing beside the reproducer but mechanically isolated from it. The support carries a rocking arm, to the upper end of which the pick-up arm is pivoted. Again the

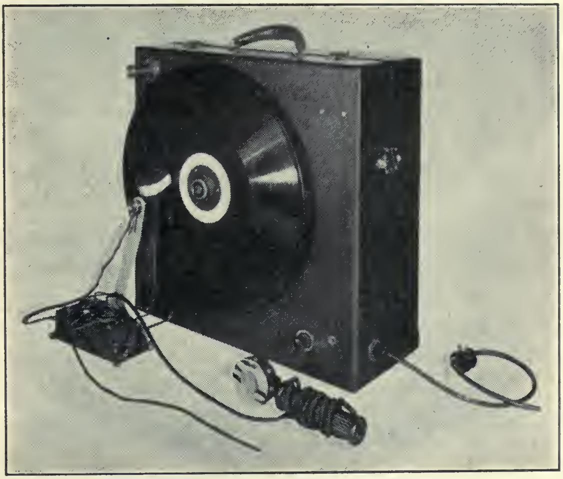

FIG. 1. View of the disk, floating pick-up, and microphone attachment of the Animatophone.

force of gravity is called into play to keep the pick-up arm in a vertical position, regardless of the lateral position of the rocker arm. As a result the reproducing needle is maintained at all times in perfectly tangential relation to the groove, a condition common in recording and the only position which can provide the satisfactory kind of reproduction that attends the utter absence of needle drag against the side of the groove.

The floating pick-up may be used with any needle pressure desired, as merely increasing the distance between the pick-up base and the projector increases the pressure of the needle upon the record. Pressures suitable for both lateral cut and hill-and-dale records may be easily secured.

These three features, the vertical turntable, the electro-pneumatic speed control, and the floating pick-up, have made possible a quality of reproduction by portable apparatus comparable with the best theatrical reproduction.

The projector has incorporated in it a safety throw-off which makes breakage of film impossible. This is a convenience in silent projection, but is vitally essential in film-disk synchronization for obvious reasons. By thus eliminating film breakage, the principal objection to the use of disks is overcome. The compact design of

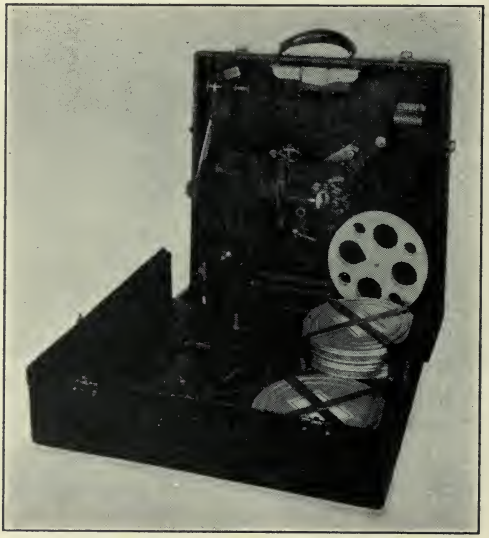

FIG. 2. Interior view of the case showing the projector and the pick-up and film reels in position.

the vertical turntable eliminates the sole remaining objection to the use of disks, so that in the new Animatophone, the disk system is placed upon a par with film recording, while retaining the low cost and simplicity of the disk.

The latest model of the Animatophone is enclosed in a carrying case which also serves as a "blimp," reducing the projector noise to an unobjectionable level. A small disk in the upper front corner of the case is pulled out to reveal the pilot lamp for the turntable. This lamp is connected in the circuit of the speed control so that it permits direct visual observation of the oscillations of the control circuit, a constant check of speed that cannot be overlooked but which is apparent only to the operator.

The Animatophone may be used with standard theatrical disks, or with the home type of disk designed to rotate at approximately eighty revolutions per minute. The change may be effected in a minute, making it possible to project all synchronous films which have been placed upon the market.

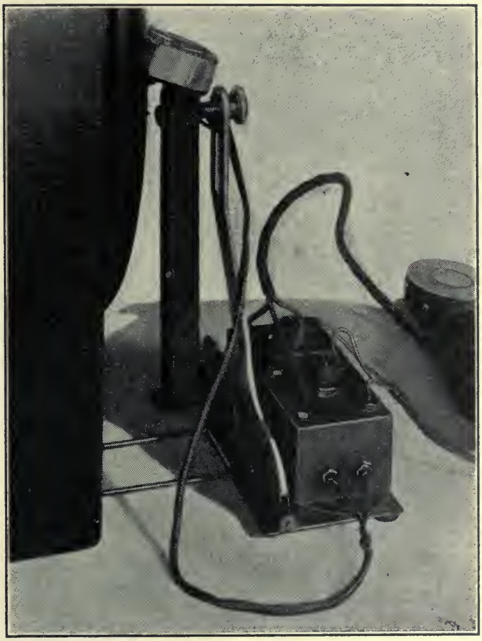

FIG. 3. Close-up of the turntable and pendulum type pick-up.

The light used is the 250-watt, 20-volt lamp, energized by a transformer concealed within the base of the projector.

The projector may be transported threaded, and ready for immediate operation, and four extra films may be carried within the case.

When in operation the projector requires a table space eight by eighteen inches, with nine square inches additional for supporting the pick-up base.

During transportation all items of the equipment, such as the pick-up, the control, and the microphone, are carried in racks inside the case where they are instantly available, yet held so securely that they cannot move when the case is closed. Packed for transportation, the case measures eight by eighteen inches and weighs thirty-six pounds.

DISCUSSION

MR. PALMER: Has Mr. Victor any data as to the mechanical accuracy of the speed control? As in sound recording work it is constantly becoming more necessary to control the speed of the recorder very accurately, I should like to know whether this control offers any possibilities in that direction.

MR. VICTOR: I rather think it does. The trouble with the Animatophone, in the attempt to use it as a recorder, is that the turntable is too light in weight. There is no stabilizing effect as the turntable weighs only four pounds. But I rather think this type of speed control would be very serviceable for more accurate work.

THE ACOUSTICS OF LARGE AUDITORIUMS*

S. K. WOLF**

Summary.—*Extremely large auditoriums present acoustical difficulties which do not readily yield to the customary methods of analysis and correction. This is illustrated by measurements of the time of reverberation, made in the Madison Square Garden, New York, N. Y., which revealed a considerable discrepancy between theoretical expectations and the times actually measured throughout the frequency range. At 500 cycles, for example, analysis of the auditorium indicated a decay period of 35.5 seconds, whereas the time actually measured by the spark chronograph reverberation meter was only 7.6 seconds. On the basis of the measured time, 47,000 square feet of one-inch rock wool were installed. This material was distributed in a manner calculated to suppress undesirable discrete reflections as well as to reduce the general reverberation time. The result was a reduction in the measured time to 3.5 seconds and the complete elimination of acoustic difficulties. Present reverberation formulas do not possess sufficient generality to justify application to enclosures which are extremely atypical in size or shape. Until such formulas are developed, reliance must be placed on actual measurements.*

As has been pointed out so often, the acoustical properties of a theater should satisfy the acoustical requirements of the performance to be held in it. Since types of performance vary, unless variable and controllable conditions are feasible, the selected acoustical condition should conform to a compromise which will most nearly fulfill all demands.

By properly considering the use to which the theater is to be put, prior to constructing it, specifications may be prepared which will assure adequate acoustical control in the new theater. This is naturally more economical than recommending treatment or alterations in existing structures. However, the economies thus effected are not the only reasons which make such scientific acoustical planning desirable. Of equal importance is the assurance that the best conditions will exist after completion.

It is not always possible to determine all acoustic deficiencies by theoretical analyses. Certain types of design and construction may

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Electrical Research Products, Inc., New York, N. Y.

contribute to unusual conditions which are not amenable to exact theoretical analysis. This is particularly true in large auditoriums, since the discrepancies between the actual and the theoretical conditions increase rapidly with size, and in those of very great volume, the theoretical analysis is totally inadequate. In modern scientific design these possible pitfalls may be carefully avoided; in existing theaters their effects can be determined only by instrumental means. We hope that research now in progress will soon yield theoretical methods and formulas capable of diagnosing all acoustic defects.

In the meantime, we must depend on instruments for thoroughly analyzing the acoustical qualities of many auditoriums which have been designed without adequate acoustical study. Instruments are now available which will accurately measure reverberation time, energy distribution, and associated characteristics. Acoustic measurements, although not always necessary, are particularly advisable where peculiar shapes or unusual finishing materials are employed. Unfortunately, this is true of quite a large number of theaters. The guiding factors in the past have been the comfort of the audience, the number of seats in the theater, its beauty, and other practical considerations. The acoustical quality of the theater was often neglected. This neglect was not due primarily to oversight, but rather to a lack of knowledge of acoustical phenomena. As a consequence, the resulting design frequently was acoustically unsatisfactory. We are considering in this paper a rather unusual problem in auditorium acoustics, which, however, will serve to demonstrate the inadequacy of the usually accepted theoretical analysis under certain conditions. We refer to the acoustical problem that existed in New York's Madison Square Garden.

Madison Square Garden was designed primarily as an enclosed sports amphitheater. Acoustics were not seriously considered, since noise and reverberation are expected in an auditorium of this kind. Nevertheless, the size, the shape, and the finishing materials that were used, introduced some very undesirable acoustical effects. When a band selection was played, the tune was scarcely recognizable. When an announcer spoke, his voice could not be heard at distant points. To obviate these deficiencies, a sound reënforcement system was installed. A standard type of public address system was obtained; yet sound in the enclosure was not intelligible. A new system was then built, improving the quality of sound emanating from the system. Still the results were most unsatisfactory. Thus, time and money were wasted before the real cause of the poor grade of intelligibility was fully recognized. The difficulty was caused by the acoustics of the auditorium rather than by any equipment deficiency.

Acoustical correction was not easily achieved, since the condition could not be correctly evaluated solely by theoretical analysis. Such an analysis showed the requisite correction to be unfeasible. Every available surface would have had to be treated and the cost would have been prohibitive. Acoustical measurements of the auditorium, however, showed that correction was not only feasible, but that it could be effected at a relatively small cost. Furthermore, the degree of control would be adequate for both speech and music. This meant that concerts and operatic selections would be rendered under highly acceptable circumstances. The auditorium needs no longer depend

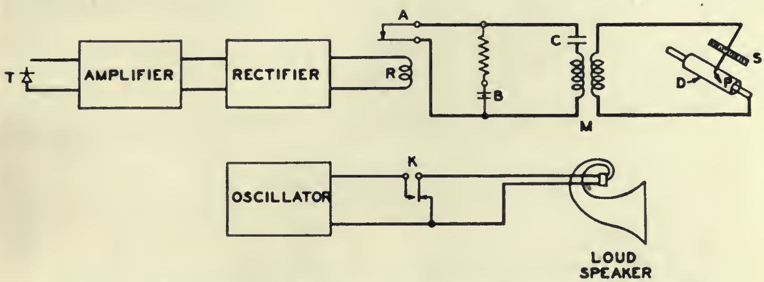

FIG. 1. Schematic diagram of chronograph reverberation meter.

entirely on sports for its economic existence. The method employed in effecting this instrumental analysis, and a comparison of this analysis with theoretical investigations, will be discussed.

The instrumental analysis consisted largely of measurements of reverberation time with the chronograph reverberation meter. This meter was developed by Wente and Bedell of the Bell Telephone Laboratories, and is here shown in a schematic diagram. (Fig. 1.) It consists of a variable gain amplifier, a full-wave rectifier, and a polarized relay with an adjustable bias. This relay is adjusted so that when the rectified current exceeds the biasing current, the relay operates, allowing the condenser to charge. When the current falls below the biasing value, the relay releases, discharging the condenser through the spark coil, causing a spark to pass to the revolving drum. If a special waxed paper is placed on the drum, the spark will produce a spot on its surface. The drum is rotated at a known constant speed.

The operation of this meter is quite simple. A tone of a given frequency is amplified, carried through a switch in the meter, and is then fed to a loud speaker in the room to be measured. With the drum revolving, the sound is switched on, and the amplification is adjusted so that the relay will just operate. At a given position in the rotation of the drum, a trigger arrangement automatically interrupts the source of sound. When this sound has decayed to the level for which the relay has been set, the spark jumps to the recording paper as previously explained. The amplification of the meter is increased 3 decibels, the spark arm is moved a corresponding amount,

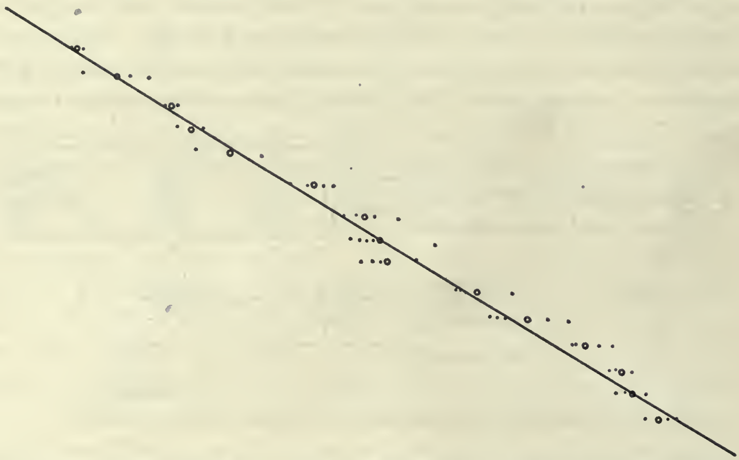

Fig. 2. Reverberation time curve at 1000 cycles, Madison Square Garden.

and the same procedure is repeated. In this way a series of points is obtained, providing an analytical pattern of the decay of the sound. Since the curve is plotted in decibels, assuming a perfectly diffuse sound pattern, a rectilinear graph will be obtained. It is not necessary to measure a complete 60-db. decay, since the line can be extrapolated to any required degree. Knowing the speed of the drum, the time for a 60-db. decay, or the reverberation time, can readily be obtained.

Fig. 2 is a reproduction of an actual curve obtained at a frequency of 1000 cycles in Madison Square Garden. The vertical axis represents the intensity level in 3-db. steps, and the horizontal axis represents time. Note that the points weave slightly about the straight line. This is due to the residual interference pattern in the room.

Fig. 3 shows the reverberation meter.

In making the measurements in Madison Square Garden, specially recorded warble frequency disks were used as a source of sound. The warbling of the frequency helps to break up standing waves. The Madison Square Garden public address system was used to amplify the pick-up from the records, and to reproduce it in the enclosure. Measurements made at intervals of approximately one octave indicated a characteristic as shown in Fig. 4. Attention is here called to the measured time at 500 cycles, 7.65 seconds.

FIG. 3. Photograph of reverberation meter.

Let us now see what theoretical analysis by the classical method would have yielded. (Fig. 5.) The volume of the Madison Square Garden was found to be 6,200,000 cu. ft. The ceiling, walls, and floor were constructed of concrete with a small amount of glass, metal, and wood. These surfaces comprised 342,300 sq. ft. which, for the commonly accepted coefficient of absorption of 0.015, provided 5134 sound absorbing units. The 18,000 wooden seats, which are usually assigned a coefficient of 0.2, provided an additional 3600 units, or a total of 8734 units in the empty auditorium. On this basis Sabine's formula gives 35.5 seconds, and correction to optimum would require the installation of 94,600 units, an obvious impracticability. The use of Eyring's formula offers a refinement which is hardly within the accuracy of the computations, resulting in a period of 35.0 seconds. Comparing these values with the measured time of 7.65 seconds, the inadequacy of the theoretical analysis is readily apparent.

The reason for this marked discrepancy is not fully explained by

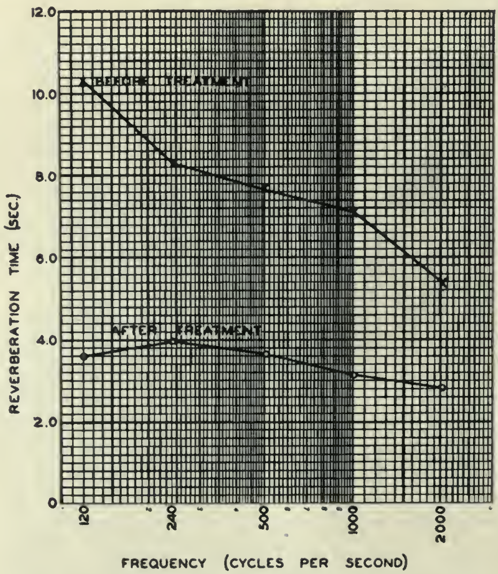

Fig. 4. Measured reverberation characteristics, Madison Square Garden.

existing data. It is fairly certain that it is partially due to the fact that the commonly accepted coefficients are too low. Also, there appears to be a size effect which should be considered in reverberation computations. A contributing factor may be found in an attenuation by the air or in some other acoustical phenomenon not explicitly included in current reverberation formulas. Investigations are being pursued, however, to determine, if possible, the exact reasons for such a large discrepancy.

The acoustical recommendations for treating Madison Square Garden were based on the measured values. Using these true values of reverberation time, and correcting them for the presence of the audience, it was found that with a full attendance of 18,000 people an optimum time of reverberation existed. Under such conditions, however, the acoustics were *yet* remarkably *poor*. This poor acoustical condition was obviously due to the distribution of sound energy. Discrete reflections from the high ceiling eventually reached the seating area as echoes, or with sufficient time lag seriously to impair intelligibility. The problem was, therefore, one of properly locating the absorbing material so as to eliminate these reflections.

By Sabine's formula: $T = \dfrac{0.05V}{A}$

$V = 6{,}200{,}000$ cu. ft.

$0.05V = 310{,}000$

342,300 × 0.015	= 5134	units
18,000 × 0.2	= 3600	"
Total units A	= 8734	

$$T = \frac{310{,}000}{8734} = 35.5 \text{ seconds}$$

By Eyring's formula

$$T = \frac{0.05V}{-S \log_e (1 - a)} = 35.0 \text{ seconds}$$

FIG. 5. Computation of reverberation time at 500 cycles, Madison Square Garden.

The optimum time selected for a volume of 6,200,000 cu. ft. was 3.0 seconds for a frequency of 500 cycles. Since existing optimum curves do not include data for volumes as large as Madison Square Garden, this figure represents the projection of the optimums accepted for smaller volumes, tempered by our experience with the acoustical conditions of large auditoriums and our knowledge of the uses to which the Garden would be put after correction. Adjustment to this optimum value would require 63,800 additional units. Since this would necessitate the installation of a very large amount of material, another plan was considered.

The alternative provided for the construction of a false ceiling made of acoustical material. The ceiling of Madison Square Garden is high and arched, supported by trusses. A false ceiling at the lower line of trusses would reduce the volume by approximately 1,700,000 cu. ft., requiring a correspondingly smaller optimum—2.6 seconds. This volume reduction would, in itself, effect a large improvement in the reverberation time so that a great deal less material would be required.

Fig. 6. Interior of Madison Square Garden after acoustical treatment.

Also the shape of the false ceiling would be greatly superior from an acoustical standpoint. It was therefore decided to proceed according to this plan.

The material selected for the installation was a one-inch rock wool blanket, since this material was found to have nearly the desired characteristic over the frequency range, and satisfied other physical requirements. The trusses were spaced 8 feet apart. Since a standard rock wool blanket is 8 feet long, a rather novel plan was devised.

Angle irons were fastened to the upper faces of the blankets to increase their rigidity, the latter being then laid on the inside of the bottom trusses as these were of the inverted T-beam construction. This method of installation was simple, and reduced the cost of the project. Any section of the ceiling could very conveniently be removed for the purpose of rearranging the drop lights or for fastening various items of circus equipment to the steel work. Roughly, 47,000 sq. ft. of blanket were installed in this manner. (Fig. 6.)

Measurements and observations made since the treatment, indicated a greatly improved condition. The reflections from the ceiling surfaces, which had destroyed intelligibility were eliminated. In addition, measurements show that the reverberation time of the auditorium when empty, has been corrected to 3.5 seconds at a frequency of 500 cycles with a general characteristic as shown. (Fig. 4.) A high degree of intelligibility is now obtained from announcements made on the public address system, and musical selections are heard with remarkable realism and an agreeable blending of tone.

In a situation such as the one that has just been described, there is a considerable discrepancy between the usual theoretical expectations and the actual conditions obtaining. Not all cases are so pronounced. With a certain amount of justification, we can use the theoretical analysis as a sort of projected measurement. However, in acoustics, as in other fields, certain elements are bound to appear which, for various reasons, are difficult to analyze and evaluate. Usually this indicates that the empirical law is being applied to situations beyond the range for which it was intended. It therefore comes about that considerably more weight must be accorded to actual measured results when there is any marked disagreement in the results obtained by the two methods It is hoped, however, that in the near future, a method of computation may be developed which will yield results in close agreement with the true values. In the meantime, the best results are obtained, when measurements are impossible, by a computation, tempered by the experience gained from measurements of similar cases.

COMMITTEE ACTIVITIES

REPORT OF THE SOUND COMMITTEE*

At the Hollywood Convention, a paper was presented by Mr. Ben Schlanger[1] entitled "Reversing the Form and Inclination of the Motion Picture Theater Floor for Improving Vision." As a result of the discussion which followed, it was suggested that the Sound Committee consider what difficulties this type of structure might present from an acoustical standpoint.

The Committee believes that this new design does not present any radically new problems. From the point of view of reverberation, the new design should be slightly better than its predecessor because with a smaller volume of space and equal number of seats, there should be less reverberation. The considerable reduction in the amount of curved surfaces, as shown by the architect's statements and by the proposed plans, will assist in the elimination of undesirable concentrations of sound and is therefore a praiseworthy feature. It seems evident that greater care will be needed from the point of view of distribution of sound from the loud speakers used in a motion picture house. In the new plan, the orchestra space subtends a smaller angle at the center of the screen, which means that the equal distribution of sound from front to back will be somewhat more difficult to obtain. On the other hand, the opening of the space directly underneath the front of the balcony appears to be greater than in the standard designs, so that there would tend to be less diminution of sound intensity in the region back of this location toward the rear of the main floor.

It therefore is evident, with the possible exception that greater care may be required in providing the equal distribution of sound, that the proposed theater design does not present any problem different from that of the present type of theater layout. However, the selection of the proper kind of seat and of the correct type of material for the wall and ceiling surfaces will remain just as important as it is now.

One of the most important problems now confronting the industry is the determination of the proper frequency range for the recording

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

and reproducing systems. It seems to be generally agreed that a frequency range greater than any yet obtained commercially is essential for an absolutely satisfactory reproduction of sound, but the exact limits of this range have so far not been agreed upon by the industry. There are so many unknown or partially known factors involved that to obtain this information economically requires the complete coördination of all phases of the industry.

At the present time it is the general practice, of at least the larger manufacturers of recording and reproducing equipment, to make each individual piece of apparatus as good as is commercially practicable so that it may be a fairly permanent investment and not rapidly become obsolete. For example, practically all the amplifiers used in recording and reproducing are capable of transmitting a much wider frequency band than they have yet been called upon to transmit. Therefore, amplifiers as a rule will not have to be changed when other portions of the circuit, which have heretofore restricted the width of this frequency band, have been improved. This case simply demonstrates the desirability and economy of making each link of the chain of apparatus as good as is commercially practicable so that as the weaker links are made stronger, the effectiveness of the whole system likewise increases.

As a part of this problem, the question of flatness of characteristic within the desirable frequency range must be considered. This Committee believes that while characteristics other than flat must be used at times to counteract certain undesirable conditions, nevertheless, for general application a flat response of each unit, and therefore of the whole system, is the ultimate to be striven for. At the present time there are many restrictions placed upon our obtaining such a characteristic over a wide range, but they should be and are being gradually removed. When temporary expedients have to be applied to overcome such conditions, these expedients should be eliminated as rapidly as possible by alleviating the restricting conditions.

In considering this problem it was fully realized that frequently an improvement in one part of the circuit will make prominent in other portions, undesirable features which were previously unimportant. For example, the introduction of the noiseless recording method has made evident in theater reproducing systems noisy conditions which were previously veiled and therefore unnoticed. Considerable effort and money have, therefore, been spent in improving the condition of the theater equipment.

Taking all these factors into consideration it is the Committee's recommendation that the industry attempt to arrive at a conclusion as to what the ultimate frequency response range should be, and then to attempt to improve the individual pieces of equipment and the technic involved so that the circuits will be competent to transmit this range.

It must not be forgotten that the acoustics of the theater is one of the most important factors involved and might well be placed at the head of the list of individual matters to be improved. No matter how good a recording has been made or how effective the reproducing equipment may be, if the sound is projected into a house having intolerable acoustical properties, the results will likewise be intolerable. Knowledge is available to guide this work and materials for correcting acoustical conditions are at hand. This phase then is not restricted by lack of knowledge or equipment, but rather by the indifference of the theater owners. Other important subjects demanding immediate investigation are loud speaking apparatus in the theaters, film processing methods, and the limitations of the film.

In regard to the last subject, sensitometry presents itself as a matter of first importance. Individual studios are able to maintain certain standards and can meet certain requirements in handling both picture and sound in the negative and also in those positive release prints made in their own laboratories. On the other hand, every studio has its own ideas of film processing, which means that additional prints made by commercial laboratories, either here or in foreign countries, are apt to differ from the original prints made in the studio laboratories. It would seem that the commercial laboratories might well concern themselves with this problem and, together with the producers, insist that an agreement be reached on the proper photographic measuring instruments to be used, as well as to become thoroughly familiar with the correct application of the data obtained from these instruments.

Two steps are necessary: first, standardization of sensitometric measurements so that data obtained in one place may readily be compared with that obtained in another. At the present time such a translation of results from one studio or laboratory into terms which another may understand is almost impossible. Secondly, a better compromise must be found between the requirements proposed by purchasers of processed film and the commercial requirements of the laboratory. A great deal of work in promoting and understanding these needs has been done during the past two or three years; it is important, however, to take immediate steps to bring about a common basis of measurement and understanding as well as to prepare a standard set of specifications to which studios and laboratories may adhere.

While the domestic situation alone is sufficient to warrant action, the added confusion in the foreign situation makes this work all the more imperative. When the release prints are made in a foreign laboratory from a negative produced in an American one, the coördination between the two laboratories involved is practically non-existent.

The Academy of Motion Picture Arts and Sciences is undertaking the problem of correlating information to improve this situation. A duplication of their work is of course unnecessary, but it is recommended that the Society give every assistance possible in this work; first, it should recognize the need for standardization; second, it should coöperate with the Academy should the occasion arise. If the findings of the Academy are acceptable to the Society, the Society should assist in standardizing them.

H. B. SANTEE, *Chairman*

M. C. BATSEL	N. M. LA PORTE	H. C. SILENT
P. H. EVANS	W. C. MILLER	R. V. TERRY
R. C. HUBBARD		S. K. WOLF

REFERENCE

[1] SCHLANGER, B.: "Reversing the Form and Inclination of the Motion Picture Theater Floor for Improving Vision," *J. Soc. Mot. Pict. Eng.*, **XVII** (Aug., 1931), No. 2, p. 161.

ABSTRACTS

The views of the readers of the JOURNAL relative to the usefulness to them af the Abstracts regularly published in the JOURNAL will be appreciated. Favorable views are of particular interest. In the absence of a substantial body of opinion to the effect that these Abstracts are desired by the membership, their discontinuance may be considered.

The Treatment of Auditoriums for Sound Projection. M. SOULIER. *Technique Cinemat.*, **2**, Dec., 1931, p. 35. The steps involved in the preparation of the auditorium for use in sound reproduction are listed, with critical comments on standards of acoustic quality, methods, and materials used. C. E. I.

Architectural Acoustics. Study of a Complex Room. G. LYON. *Technique Cinemat.*, **2**, Dec., 1931, p. 5. Maximum efficiency is obtained in an auditorium when all possible reflected sound reaches the auditor within $^1/_{16}$ second after the direct wave. It is asserted that sound impulses arriving within this interval are integrated in the process of hearing. Certain applications of this principle are treated geometrically. C. E. I.

Ozaphane Sound Film and Sprocketless Projector. *Bull. soc. franç. phot.*, **73**, Aug., 1931, p. 168. Sound prints on Ozaphane film used in conjunction with a scanning device similar to that ordinarily used, have been demonstrated successfully in France. A sprocketless projector was employed. The only new feature of the projector was the take-up mechanism which consisted of a gripping device with an eccentric rubber covered disk which catches a loop of film and carries it away with a uniform speed. Automatic framing is accomplished by means of a photoelectric cell arrangement actuated by the frame lines of the picture.
C. H. S.

Sensitometry at the International Congress for Photography in Dresden. E. LEHMANN. *Kinotechnik*, **13**, Sept. 20, 1931, p. 346. A report is given of the action of the Congress with respect to the proposals of the Optical Society of America for international standards for sensitometry. The Germans proposed to accept the American specifications regarding the color temperature of the light source and the filters for altering the spectral distribution to that of sunlight. They proposed, however, the use of a neutral wedge for determining speeds instead of a time scale, to simplify the procedure for small factories. The matter was finally referred to the sensitometry committees of the different countries for consideration until February 15, 1932, with the recommendation that a final decision be reached in a small commission within a further six months.
M. W. S.

New Lens Eliminates Crane Shots. *Film Daily*, **58**, Jan. 24, 1932, p. 7. This lens, called the "Varo" is set normally to focus on a definite position, whereupon various elements in the lens are moved in synchronism, the focal length changing in smooth progression. Critical definition is claimed to be maintained at all points. The iris diaphragm is operated by a cam at the same time as the lens elements. The focal length can be varied from 40 feet to 120 feet. The normal focus setting is 150 feet to infinity. Supplementary lenses may be screwed into the front for changing the focus to other distances. G. E. M.

Automatic Light Change Key Developed for Printing. *Film Daily*, **58**, Jan. 24, 1932, p. 7. The light change is fitted with 28 keys, of which 24 may be set according to the degree of light intensity. Any single key may be changed quickly without changing the setting of the others. The change from one light intensity to another is instantaneous, and the entire board may be cleared by pressing the clearing key and turning a knob which cuts all exposure values out of register. G. E. M.

New Portable 16 Mm. Sound-on-Film Projector. *Mot. Pict. Herald*, **106**, Jan. 23, 1932, p. 20. The machine consists of a projector amplifier unit and a small loud speaker unit, each operated from any 110-volt, 50- or 60-cycle a-c. circuit. The film used has sprocket holes along one side only, the sound track occupying the other border area. A picture size, 52 inches wide by 39 inches high, is recommended with a projection distance of 23 feet, though a larger picture may be shown if desired. The exciter lamp is a 4-volt, 0.75-ampere lamp and the amplifier contains one UX-868 photoelectric cell and the following tubes: one UY-224, one UY-227, three UX-345, and one UX-280. A dynamic speaker of the flat baffle type is used, having a volume capacity sufficient for a room of 10,000 cubic feet content. The projector amplifier unit is $14^1/_2$ inches long, $13^1/_4$ inches high, $8^1/_4$ inches wide, and weighs 43 pounds. The entire unit remains in the case during use. G. E. M.

Make Talkers for School Use, British Educators Tell Studio. W. H. MOORING. *Mot. Pict. Herald*, **106**, Jan. 9, 1932, p. 22. A series of tests made on the value of sound films for educational use in British schools is reported favorably compared with silent film. Over 3500 students were included, of ages varying from 8 to 18 years, and more than 22,000 examinations were conducted by nearly 200 teachers. Fifteen Middlesex schools, including secondary, junior, and senior institutions, were used for the test, which was under the supervision of the National Union of School Teachers in collaboration with Western Electric, Ltd. A future source of films is not known, however, and the likelihood of one is considered rather uncertain. The detailed report is to appear later.

G. E. M.

Regulating the Acoustics of Large Rooms. E. PETZOLD. *J. Acoust. Soc. of Amer.*, **III**, No. 2, Part I, Oct., 1931, p. 288. A method of control is proposed, whereby the acoustic characteristics of a room may be changed readily. The "controllers" are triangular columns placed in front of the wall (or ceiling). One side of each column is an absorbing surface, another a reflecting surface, and the third a resonating surface, such as wood. Various arrangements of the columns produce the desired effects. W. A. M.

Some Physical Characteristics of Speech and Music. H. FLETCHER. *J. Acoust. Soc. of Amer.*, **III**, No. 2, Part II, Oct. 1931, p. 1. Kinematic and statistical descriptions of the physical aspects of speech and music are given in this paper. As the speech or music proceeds, the kinematic description consists in giving the principal melodic stream, namely, the pitch variation and also the intensity and the quality variations. For speech and song, the quality changes are principally described by giving, besides the main melodic stream, two secondary melodic streams corresponding, respectively, to the resonant pitches of the throat and mouth cavities. To this must also be added the positions of the stops and the high pitched components of the fricative consonant sounds as functions of the time. The statistical description consists in giving the average, the peak, and the probable variations of the power involved as the various kinds of speech and music proceed. These general ideas are illustrated by numerous experimental data taken by various instrumental devices which have been evolved in the Bell Laboratories during the past fifteen years. AUTHOR.

Vitaphone Develops Monitor Used on Set. *Film Daily*, **58**, Jan. 10, 1932, p. 5. An announcement of a new type of monitor desk which can be used directly on the stage near the cameraman and the director. Previously, the monitor desk has been located either in a separate room off the stage, or in a portable soundproof booth, on the stage. Greater flexibility is permitted with the new type of desk. Technical details are not included. G. E. M.

ABSTRACTS OF RECENT U. S. PATENTS

The views of the readers of the JOURNAL relative to the usefulness to them of the Patent Abstracts regularly published in the JOURNAL will be appreciated. Favorable views are of particular interest. In the absence of a substantial body of opinion to the effect that these Patent Abstracts are desired by the membership, their early discontinuance may be considered. If, after two weeks from the date of mailing the April issue of the JOURNAL, no letters concerning the continuance of the department will have been rcceived, the Patent Abstracts will be discontinued.

1,830,173. **Radio Television System.** E. L. NELSON. Assigned to Bell Telephone Laboratories, Inc. Nov. 3, 1931. Circuits for television transmission and reception having a high degree of selectivity with minimum distortion. At the transmitting station the weak photoelectric currents are greatly amplified and used to modulate a carrier current of such high frequency that the distortion of the side band frequencies in the antenna circuit becomes negligible. This frequency may, for example, be 1500 kilocycles. At the receiver initial selectivity is obtained by coupling a local circuit containing resistance to the antenna thereby securing a widened resonance characteristic. The carrier frequency is then combined with a current from a local source of frequency very much higher, so that the resulting "difference frequency" is much higher than the received carrier. This reduces the percentage width of the side band to such an extent that selectivity may be obtained in tuned circuits, without undue distortion and at the same time eliminates interference from the harmonics of the local source, which are of such high frequency as to be harmless. The frequency of the local source may be 6500 kilocycles, for example, in which case the difference frequency is 5000 kilocycles. After passage through highly selective circuits this latter current is combined with current from another local source for producing an intermediate difference frequency, which, after being selectively amplified, is detected to produce the image currents. The frequency of the second local source may be 5120 kilocycles, giving an intermediate frequency of 120 kilocycles.

1,830,231. **Mirror Disk for Television Systems.** A. KAROLUS. Assigned to Radio Corporation of America. Nov. 3, 1931. Scanning system comprising a rotary mirror supporting element, a series of wedge-shaped support members of graduated inclination rigidly secured upon the supporting element, and a reflecting scanning surface rigidly secured to each of said wedge-shaped members. Centrifugal and compressive forces set up upon rotation of the wheel do not effect displacement of the members constituting the mirror.

1,830,239. **Camera.** F. H. OWENS. Assigned to Owens Development Corp. Nov. 3, 1931. Lens turret for cameras, of either the ordinary "view" or "motion picture" type. A fixed lens and a turret carrying a plurality of lenses of different focal lengths are mounted so as to be capable of being selectively brought into operative relation with the camera. The lenses of different focal lengths can be independently brought into picture taking position.

1,830,537. **Lamp Support for Projection Machines.** L. S. FRAPPIER AND E.

BOECKING. Assigned to International Projector Corp. Nov. 3, 1931. An auxiliary light source is mounted in the projector upon a rotatable support which may be turned to bring the auxiliary light source into operative position upon failure of the other light source. The structure is particularly applicable to a mounting for the light source of a sound telescope which is used to pass continuous rays of light through the sound record of a projection film.

1,830,538. **Support for Light Sources.** L. S. FRAPPIER AND E. BOECKING. Assigned to International Projector Corp. Nov. 3, 1931. A plurality of light sources spaced peripherally of a rotatable sleeve which sleeve is adapted to be shifted angularly to bring either light source into position for directing light through the moving film and sound telescope.

1,830,546. **Synchronizing System.** J. HERRMANN. Assigned to Siemens & Halske Aktiengesellschaft. Nov. 3, 1931. A method of synchronizing which utilizes in simple manner the frequency given by the ripple of the armature current as carrier frequency for the transmission of, for instance, a control frequency to a remote station. As the control frequencies in question in this case are frequencies of the order of 50 to 150 cycles, they can no longer be transmitted over telephone lines with intermediate repeaters. The invention is directed to the method for transmitting synchronizing signals which comprises driving a picture telegraph apparatus by a driving motor and producing from the driving motor a slot frequency for use as a carrier frequency for synchronizing signals.

1,830,567. **Safety Shutter for Cinematographs.** A. SHAPIRO. Assigned to Universal Stamping & Mfg. Co. Nov. 3, 1931. The shutter is adapted to move automatically into the path of light to interrupt some of the light rays of the lamp immediately upon the stopping of the light interceptor so as to permit the showing of a "still" picture without injury to the film. A mechanism is provided operable by the light interceptor for quickly moving the safety shutter out of the path of light when the interceptor commences to rotate. The shutter is constructed for dissipating much of the heat in the path of light. A rotatable clutch element is connected to the shutter, and there is a pair of radially movable governor bodies carried directly on the gear which connects to the light interceptor and is movable into frictional engagement with the clutch element for rotating the shutter out of the light path upon the rotation of the interceptor.

1,830,586. **Transmission of Pictures.** E. F. W. ALEXANDERSON. Assigned to General Electric Co. Nov. 3, 1931. The picture receiver has a plurality of channels tuned to respond to a different wavelength with a recorder connected thereto and adapted to respond to all of the transmitted wavelengths. The recorder comprises a vibratory member having means for directing a beam of light on a light-sensitive member, a screen having an opening therein arranged in the path of the beam of light, a source of alternating current connected to the vibratory member, and means for varying the current actuating said vibratory member in accordance with the wavelength of the received signal. The different portions of pictures are transmitted over the different channels and integrated at the receiver.

1,830,596. **Adjustable Mounting for Picture Projection Apparatus.** A. DINA. Assigned to International Projector Corp. Nov. 3, 1931. The plate for supporting the projection head is pivoted to the top of the pedestal. The plate for the lamp house is mounted behind the projection head plate and secured thereto by a pantograph arrangement to insure continuous parallel relation between the axis of the projection head and of the lamp house for both still and motion picture projection. An adjustable bracing device is provided to connect the base of the pedestal and the lamp house plate, which allows lateral shifting of the lamp house as well as adjustment of the angle of projection and also aids in imparting extreme rigidity to the entire mounting structure during operation of the machine.

1,830,601. **Sound Telescope.** L. S. FRAPPIER AND E. BOECKING. Assigned to International Projector Corp. Nov. 3, 1931. The sound telescope is rotatably mounted in a suitable framework and provided with positive means for varying the angular position of the telescope therein. The framework is mounted for movement in a horizontal direction transverse to the axis of the telescope by means of a suitable sliding bracket. The bracket itself may be moved horizontally in a direction parallel to the axis of the telescope. In order to exclude external light from the photographic record, a pair of telescoping members are included between the end of the telescope itself and the sound record and are provided with means for maintaining a positive engagement with both the telescope and the film guide. A special light source is also provided which includes a pair of lights and means for alternatingly bringing said lights into operative position. A second light is accordingly always held in reserve and may be substituted in the system without material interruption of service.

1,830,602. **Distance Releasing Device for Moving Picture Cameras Driven by a Spring Mechanism.** E. GOLDBERG. Nov. 3, 1931. A camera wherein a film driving or feeding mechanism is employed for moving the film strip in the path of the camera lens, means being inserted for controlling the operation of the mechanism as may be required by a user merely by simple adjustment of conveniently arranged control devices and, if desirable, allowing such mechanism to be manually operated both for the photographing of motion and still pictures. The camera is equipped for remote control of the film feeding mechanism whereby the same may be started or stopped by a user in a manner which will permit said user to position himself as a subject to be photographed and when so positioned, effect elective operation of the camera.

1,830,637. **Selector Filter.** P. BROSSE. Assignor, by mesne assignments, to Kislyn Corp. Nov. 3, 1931. A selecting filter for projecting goffered films in colors, having a set of differently colored selector zones occupying its central portion, and differently colored compensator zones at its opposite end portions. The colors of the compensator zones are complements of those of the selector zones which they touch so as to eliminate the noxious colors prevailing.

(Abstracts compiled by John B. Brady, Patent Attorney, Washington, D. C.)

BOOK REVIEWS

Geschichte der Kinematographie. Wilhelm Dost. *W. Knapp,* Halle, a.S., 1925, 51 pages.

This history of motion pictures comprises the following chapters: a brief history of instantaneous photography; the beginning of "living pictures" from series photographs to the projection of "living pictures;" further historical development of motion pictures (1891–1895, approx.); the Kinematograph of the Lumière Bros. (1895–1897); and newer developments and technological improvements (1897–1907). The treatise gives 116 literature references and mentions 151 authors and inventors. Of interest is the reference to the apparent motion of "series" pictures as described by Titus Lucretius Carus, a Latin poet and philosopher who lived 99–55 B.C. The literature references are principally to the European literature, and only brief details of American and English work are given.

L. E. Muehler

Artificial Sunlight. M. Luckiesh. *D. Van Nostrand & Co.,* New York, N. Y., 1930, 264 pp.

The biological effects of radiant energy have been coördinated with the physical principles underlying the study of radiation in an interesting and concise form. Much data, some new and some older, have been assembled in this volume in a manner useful to the engineer, chemist, biologist, or physician.

Application of these data has led to the construction of the G. E. tungsten-mercury arc lamp Sunlamp, the characteristics of which are fully described.

C. Tuttle

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SOCIETY ANNOUNCEMENTS

STANDARDS COMMITTEE

At a meeting of the Standards Committee, held at the General Office of the Society in New York, N. Y., on March 15th, the question of establishing the dimensional standards for projector apertures was again considered, this time in respect to recommendations made recently by the Academy of Motion Picture Arts and Sciences which resulted from the simultaneous study of the problem by that organization and the S. M. P. E. The Standards Committee unanimously agreed to recommend for adoption by the Society the dimensions 0.600 by 0.825 inch as standard dimensions for 35 mm. projector apertures, and the dimensions 0.631 by 0.868 inch for the corresponding camera apertures.

The conclusions arrived at by the subcommittee on 16 mm. sound-on-film, announced briefly in the March issue of the JOURNAL, were accepted and approved, with some modifications. These plans provide two layouts for the film, one involving a single row of perforations, the other, two rows. The former is to be recommended for adoption as a dimensional standard by the Society, with the suggestion that the latter layout, involving two rows of perforations, be also published, but as a non-recommended specification. Both layouts are now being detailed for presentation to the Society at the Washington Convention.

The Committee also agreed to recommend as standard speed for 16 mm. sound-film equipment a speed of 24 frames per second, and for the lead of the sound gate an interval of 25 frames.

PROJECTION SCREENS COMMITTEE

At a meeting of the Committee held on February 18th, definite work was initiated in the various items on the program of the Committee's work for the year, and preliminary reports on some of these items were presented. These items include the following:

(A) New developments in screens: (1) metal screens; (2) screens with embossed surfaces; (3) other types.

(B) Matters for standardization, in collaboration with the Standards Committee: (1) screen sizes; (2) illumination and methods of measuring it; (3) definitions of brightness; (4) acoustic ratings of screens; (5) optimum sizes for theater installation.

(C) Reflection loss data.

(D) Tolerable variation of brightness from point to point of the screen; variation of brightness as a function of the location of the viewer.

(E) Sixteen millimeter projection screens.

Another meeting of the Projection Screens Committee is to be held prior to the Washington Convention for the purpose of drafting the report to be presented at that time.

PROJECTION PRACTICE COMMITTEE

At a meeting held in New York on March 8th, further study was made of the various tolerances, clearances, and tensions, as encountered both in new projectors and in those that have been in service for some time, bringing nearly to its completion the compilation of the table of tolerances, clearances, and tensions that the Committee plans to present at the Washington Convention of the Society. A preliminary draft of a report to be presented by the chairman, Mr. Harry Rubin, at the Washington Convention, dealing with the problems of the release print as they effect the theater, formed the subject of considerable study and discussion. Some of the items involved in this study are: (1) methods of "processing" film; (2) buckling of film in projectors; (3) variations in the density of prints; (4) film cutting for change-overs; (5) inaccuracies in punching release prints.

The Society regrets to announce the death of one of its honorary members,

GEORGE EASTMAN

on March 14, 1932. By action of the Board of Governors, Mr. Eastman's name is hereby added to the

HONOR ROLL

of the Society of Motion Picture Engineers.

ARRANGEMENTS PROGRAM

SPRING MEETING OF THE SOCIETY, WARDMAN PARK HOTEL WASHINGTON, D. C.

MAY 9–12, 1932, INCLUSIVE

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N. C. Haefele
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W. C. KUNZMANN	N. D. GOLDEN	RAYMOND EVANS
P. A. MCGUIRE		T. E. SHEA

NEW APPARATUS EXHIBIT

H. GRIFFIN, *Chairman*

JAMES FRANK, JR.	SYLVAN HARRIS

Note: Manufacturers desiring to exhibit new equipment developed within the past year should communicate with the Editor-Manager of the Society, 33 West 42nd Street, New York, N. Y. The exhibit will be held in the West Lobby of the hotel, near the entrance to the Little Theater, where all technical sessions will be held.

CONVENTION SESSIONS

All technical sessions and film exhibitions will be held in the Little Theater, West Lobby of the Wardman Park Hotel.

BANQUET AND DANCE

The S. M. P. E. semi-annual banquet and dance will be held in the Gold Room of the Wardman Park Hotel, at 7:30 P.M. on Thursday evening, May 12, 1932.

Note: Banquet tickets and table reservations should be procured at the registration desk up to noon of the day of the banquet. Tables will be arranged for six or eight persons.

HOTEL ACCOMMODATIONS

The following special rates have been provided for members of the Society by the Wardman Park Hotel.

Single room with bath	$ 4.00 daily per person
Double room with bath	6.00 daily per person
Parlor and bedroom connecting with bath	10.00 daily and up

Note: Room reservation cards should be returned immediately to the Wardman Park Hotel in order to assure satisfactory reservations.

A modern fire-proof garage is located on the hotel property and a special $1.00 rate per day (24 hour parking) has been arranged.

RECREATION

The Wardman Park Hotel management has arranged for golfing privileges for our members at the Congressional and Indian Springs Country Clubs. The usual course fee will be charged. The S. M. P. E. identification card will entitle you to play at either of the above country clubs during our Convention dates. The weather permitting, the hotel outdoor swimming pool will be available to the members. Regulation tennis courts are located on the hotel property, and riding stables are within a short distance from the hotel. Transportation can be arranged for sight-seeing tours over the new Mt. Vernon highway to various points of interest about Washington. Arrangements for the trip should be made at the registration desk not later than the afternoon of May 10th.

TENTATIVE PROGRAM

WARDMAN PARK HOTEL

MONDAY, MAY 9th

	The morning will be devoted to registration, Committee meetings, *etc.*
11:00 P.M.	*Little Theater:* Convention called to order.
	Address of Welcome.
	Response by the President.
12:00 to 2:00 P.M.	Luncheon.
	Reports of the Convention Committee, the Secretary, and the Treasurer.
	Committee Reports.
	Consideration of Proposed Amendments of Constitution and By-Laws.
	Technical Papers, if time permits.
7:30 P.M.	*Little Theater:* Social gathering and film program of especial interest.

TUESDAY, MAY 10th

9:30 A.M.	*Little Theater:* Papers Program.
12:30 to 2:00 P.M.	Luncheon.

2:00 P.M.	*Little Theater:* Papers Program.
7:30 P.M.	*Little Theater:* Lecture and Film Program.

WEDNESDAY, MAY 11th

9:30 A.M.	*Little Theater:* Papers Program.
11:30 A.M.	*Department of Commerce Building:* Addresses by by heads of government departments.
1:30 to 2:00 P.M.	Luncheon at Department of Commerce Building.
2:00 P.M.	Recreation and Sight-Seeing Trips.
7:30 P.M.	*Little Theater:* Film Program.

THURSDAY, MAY 12th

9:30 A.M.	*Little Theater:* Papers Program.
12:30 to 2:00 P.M.	Luncheon.
2:00 P.M.	*Little Theater:* Papers Program, Open Forum.
7:30 P.M.	*Gold Room,* Wardman Park Hotel: Semi-Annual Banquet and Dance; an evening of frolic. Adjournment of Convention.

Mr. O. M. Glunt, Chairman of the Papers Committee, promises a most interesting program of technical papers, which will be listed in the final issued programs. A reminder for your calendar: S. M. P. E. Spring Meeting dates, May 9th–12th, inclusive; Wardman Park Hotel, Washington, D. C.

Respectfully submitted,

Convention Committee

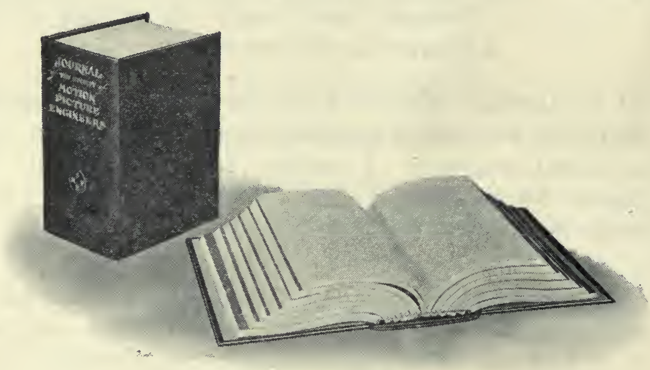
W. C. KUNZMANN, *Chairman*
W. C. HUBBARD
M. W. PALMER

Papers Committee

O. M. GLUNT, *Chairman*

JOURNAL BINDERS

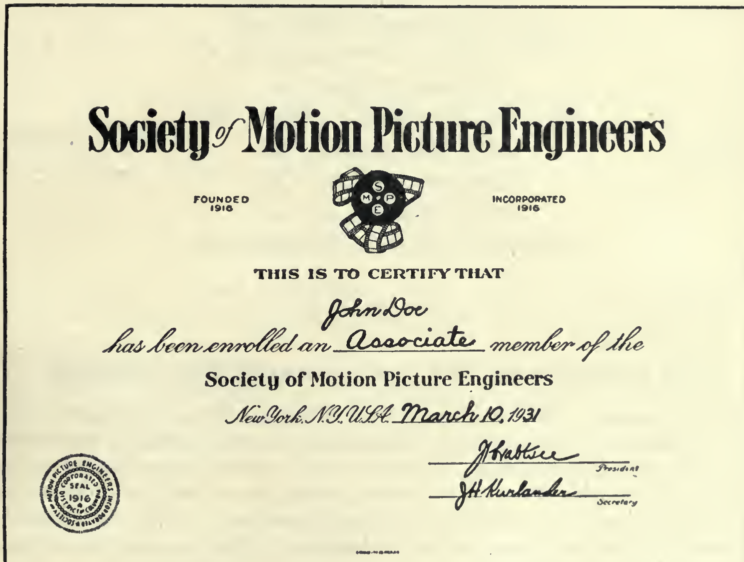
The binder shown in the accompanying illustration serves as a temporary transfer binder or as a permanent cover for a complete year's supply of JOURNALS. It is made of black crush fabrikoid, with lettering in gold. The binder is so constructed that each individual copy of the JOURNAL will lie flat as its pages are turned. The separate copies are held rigidly in place but may be removed or replaced at will in a few seconds.



These binders may be obtained by sending your order to the General Office of the Society, 33 West 42nd Street, New York, N. Y., accompanied by a remittance of two dollars. Your name and the volume number of the JOURNAL may be lettered in gold on embossed bars provided for the purpose at a charge of fifty cents each.

MEMBERSHIP CERTIFICATE

Associate members of the Society may obtain the membership certificate illustrated below by forwarding a request for the same to the General Office of the Society at 33 W. 42nd St., New York, N. Y., accompanied by a remittance of one dollar.



LAPEL BUTTONS

There is mailed to each newly elected member, upon his first payment of dues, a gold membership button which only members of the Society are entitled to wear. This button is shown twice actual diameter in the illustration. The letters are of gold on a white background. Replacements of this button may be obtained from the General Office of the Society at a charge of one dollar.

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BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted. The cost of all the available *Transactions* totals $46.25.

	No.	Price		No.	Price		No.	Price
1917	3	$0.25	1924	18	$2.00	1927	29	$1.25
	4	0.25		19	1.25		30	1.25
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1923	16	2.00		27	1.25		38	3.00
	17	2.00		28	1.25			

Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.50 each, a complete yearly issue totalling $18.00. Single copies of the current issue may be obtained for $1.50 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society, 33 West 42nd Street, New York, N. Y., and should be accompanied by check or money-order.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII **MAY, 1932** **Number 5**

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

WESTERN ELECTRIC NOISELESS RECORDING*

H. C. SILENT AND J. G. FRAYNE**

Summary.—*The Western Electric method of noiseless recording with the light valve is described. The general principles are discussed, the circuit diagram is explained, and the method of adjusting the device for service described. The photographic characteristics of film are considered, and their application in noiseless recording is shown in some detail.*

The realism of the talking picture is materially enhanced if the showing in the theater is free from extraneous sounds that are not a part of the scene shown. The steady grind of surface noise from disk and film records in the past has given a mechanistic feeling to the sound accompanying the pictures. The practical elimination of this noise from film recording has probably contributed more to the convincingness of illusion than any one step of progress that has been made during the past two years. The result is that the finer shadings of sound, whispers, and faint noises, once lost in a background of mechanism, are now elements of reality for facilitating dramatic presentation. The audience listens without effort; the medium by which the sound is brought to them is all but forgotten; the screen is a stage whose illusion of reality finds its chief limitations in those of photography.

Before going into a detailed description of the operation of noiseless recording, the basic principles, according to which the method operates, will be outlined. It is well known that the noise output from a light print is higher than that from a dark print when played on the same fader step. Thus, if an unmodulated sound track be run through a sound projector, the density of the sound track varying from, say, that of clear film to extreme opacity, the greatest amount of noise will be heard when the clear portion of the track is in the sound gate, while the noise will gradually decrease as the dark portions come before the sound gate. However, by merely printing a sound track dark, both the ground noise and the wanted sound are reduced in

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Electrical Research Products, Inc., Los Angeles, Calif.

approximately the same ratio, so that no improvement in the signal-to-noise ratio results. Under former methods of recording, therefore, there appeared to be no way out of the dilemma of effectively increasing the range of sound output above the level of the noise inherent in the film itself. This apparent difficulty has been successfully overcome in the Western Electric system of noiseless recording.

In this system of recording it will be remembered that the exposure on the negative film is made through a light valve whose ribbons are normally spaced 0.001 inch, giving a certain fixed average density of unmodulated track on the negative and, in turn, on the print. It is apparent that this ribbon spacing is necessarily sufficient to permit the movement required by the loudest sounds, and is therefore considerably greater than necessary for the weaker sound. It is entirely permissible to reduce considerably the spacing of the light valve

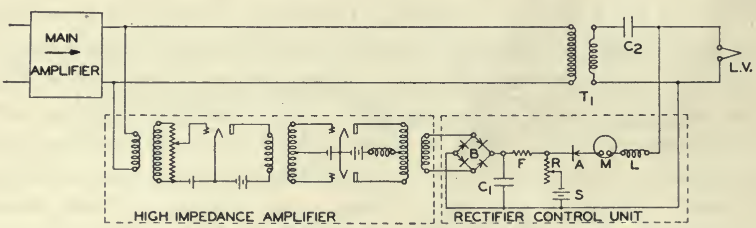

FIG. 1. Schematic diagram of circuit used for varying the spacing of the light valve ribbons.

ribbons during periods of no sound or of weak sounds, if in the presence of louder sound the spacing is in some manner increased sufficiently that the ribbons do not clash. Since this in no way interferes with the amount in which the ribbons of the light valve move during the presence of sound currents, it does not alter the change in light which these sound currents cause at the film surface. If the film be properly processed, the change in light which falls on the photoelectric cell during reproduction is an exact picture of the change in light at the film during recording. Therefore, the sound output from the photoelectric cell will be an exact copy, without volume distortion, of the sound input to the light valve, regardless of progressive changes of ribbon spacing.

Thus in the new system of recording, the mean spacing of the ribbon is not constant but is reduced to some predetermined value. This reduces the density of the negative unmodulated track, and consequently increases the density of the positive unmodulated track, decreasing the ground noise. As modulation is impressed on the valve, the mean spacing of the ribbon increases sufficiently to accommodate the further increasing input.

In the ideal case of noiseless recording, the light valve ribbons should open just to, but never beyond, the spacing required to prevent their clashing. However, due to more or less inherent circuit limitations, the building up of the current that controls the opening of the ribbons requires a certain length of time. Under these conditions, clash might result at the beginning of sudden impulses if it were not for the fact that an excess of current is supplied to the ribbons, causing

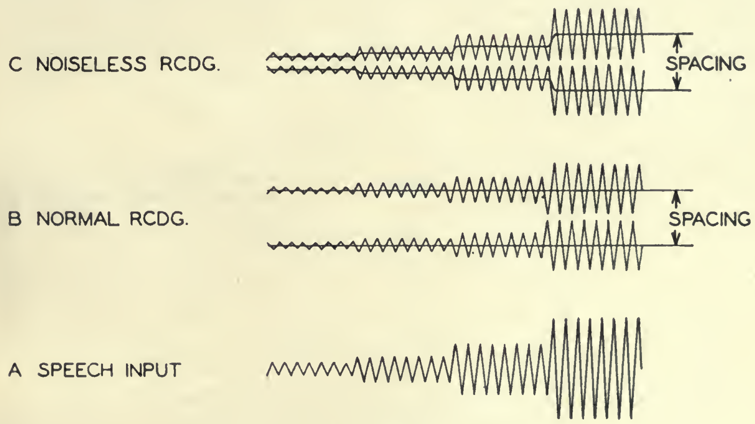

FIG. 2. Action of ribbons in recording.

them to open fast enough to prevent clash, even though they may eventually open beyond the required amount in the presence of sustained or steady sound. The excess of this opening over the required amount we will call "margin," and if the ribbons be opened twice the required spacing, the margin is considered as 6 decibels. The existence of this margin implies that when sound currents are present of such a magnitude that the light valve would be loaded up to its normal carrying capacity, sufficient current would be supplied to cause the ribbons to exceed their normal spacing. This would result in an excess of light passing through the ribbons, resulting in a negative darker than normal and a print lighter than normal, both of which would exceed the straight-line portions of the emulsion characteristic, and photographic overload would result. The ribbons of the light valve are prevented from exceeding the spacing that they would ordinarily have in normal recording as described later.

Were the device capable of instantaneous operation, it would, of course, be possible to reduce the margin theoretically to zero. Practically, of course, a small amount of margin is always essential. With extremely fast operating systems, it has been found possible to reduce this margin to as low as 2 decibels, although at the present time it is recommended that a margin of 6 decibels be ordinarily employed.

As explained in the second part of this paper, there is a direct

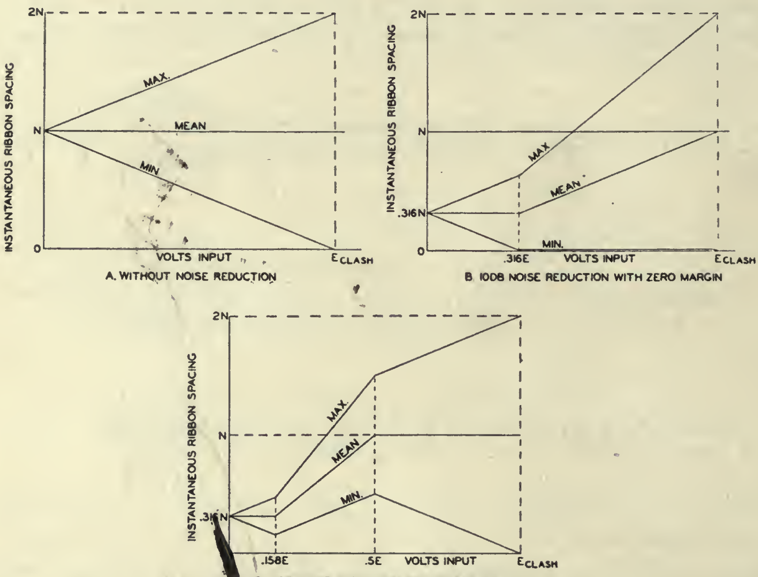

FIG. 3. Ideal characteristics of light valve ribbon movement.

relation between the noise reproduced from the sound track and the spacing of the light valve ribbons. Thus, for a given light valve spacing, if this spacing be reduced to one-half, the noise from the reproduced track will be reduced by 6 decibels. Since the normal spacing of the light valve ribbons is 1 mil (0.001 inch) the noise will be reduced by 10 decibels if the spacing of the ribbons is reduced to 0.316 mil. At the present time this is the most generally used value of noise reduction, although greater values of noise reduction can be used. Thus, we see that the light valve is not entirely closed during periods of very weak sounds, or in the absence of any sound at all.

This failure entirely to close the light valve assists in the recording of sudden sounds in that the ribbons, never being entirely closed, are effectively provided with a certain margin against clashing until the control system can function to open them. It is conceivable that the ribbons might be brought to full closure if, between the point at which energy is taken to operate the variable spacing device and the light valve itself, there could be introduced a delay circuit which would prevent sound currents from reaching the light valve ribbons until these sound currents had first acted upon the rectifier, which, in turn, had acted upon the ribbons to open them. Such a delay circuit has been employed in certain other forms of voice-operated switching devices employed in telephony.[1] Delay circuits are, however, expensive, and, in view of the fact that it is not necessary to close the light

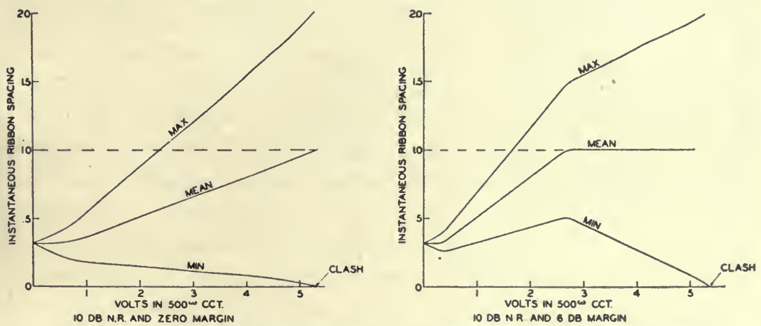

FIG. 4. Measured characteristics of light valve ribbon movement.

valve ribbons completely, appear not to be justified in this type of service at the present time.

In Fig. 1 is shown a schematic circuit of a device for varying the spacing of the light valve ribbons so that they are always capable of free vibration without clashing but, except on the very weakest of sounds, are always kept at the minimum possible spacing. The action of the circuit shown in Fig. 1 is essentially as follows: speech currents are applied directly to the light valve in the normal manner through the transformer and condenser placed between the light valve and the main amplifier. A high impedance amplifier with adjustable gain supplies the power necessary to operate the rectifier B, which in turn controls the spacing of the light valve. The light valve LV is strung, spaced, and tuned just as though it were being used for normal recording, *i. e.*, with a 1-mil spacing.

Current from the battery S is applied to the light valve through the rheostat R and causes the light valve to be partially closed to the required extent. When speech is supplied from the speech line, the output of the rectifier B opposes the voltage of the battery S and reduces the current in the light valve, allowing the ribbons to open. Because of the action of the rectifier, which would normally transmit to the light valve impulses of each half-wave of the speech currents, it is necessary to interpose between the rectifier and the light valve a smoothing circuit which will remove the minor variations of the current and cause the light valve to follow the true envelope of the

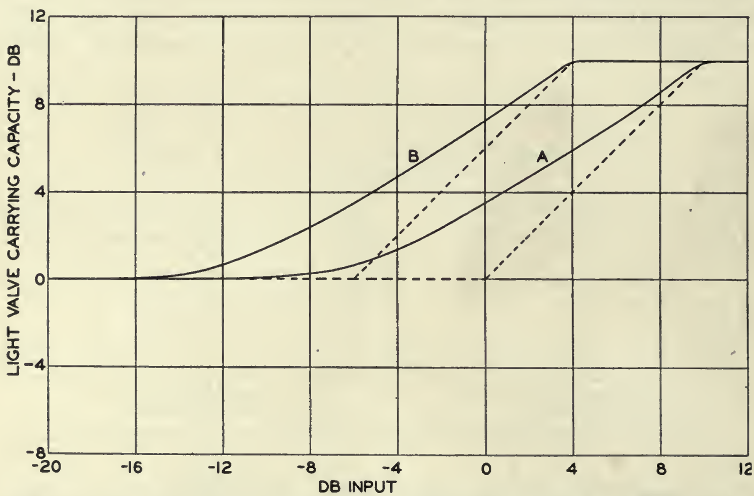

FIG. 5. Theoretical and measured curves similar to those in Fig. 3; *A*, 10-db. noise reduction with zero margin; *B*, 10 db., with 6-db. margin.

speech currents. Condenser C_1, resistance F, and inductance L provide the necessary filtering action on the output of this rectifier. The resulting current will be of a very low frequency pulsating nature, the peak value of its pulsations being proportional, of course, to the strength of the sound currents received from the speech line. Since the spacing of the light valve ribbons varies directly with the amount of current in the ribbons, then the spacing of these ribbons will be increased conformably to the variations in current received from the rectifier. By properly regulating this action, we may make the spacing of the ribbons of the light valve always just sufficient to permit the movement that the sound currents received from the speech line will require in these ribbons. Condenser C_2 prevents the transformer T_1 from short-circuiting the biasing current supplied to the light valve. The meter M indicates the biasing current at all times.

As previously mentioned, in cases where an appreciable margin is used in the set-up, when the speech currents exceed the value that reduces the bias in the light valve to zero, there would ordinarily be a reversal of current in the light valve, and it would overshoot or open beyond the value corresponding to the normal spacing. In order to prevent this, the anti-reversing rectifier at A is inserted, which prevents reversal of the current through the light valve ribbons and prevents their overshooting.

Fig. 2 illustrates the behavior of the ribbons in a normal light valve and under the action of the circuit shown in Fig. 1. It will be seen that in the normal method of recording, the ribbons have a constant average spacing and their movement is essentially simple, corresponding to the variations of the voice current only (Fig. 2*B*). However, in the method of noiseless recording, the ribbons may be regarded as having two motions: first, the motion due to the voice currents only, exactly as in the normal method of recording; and second, a superimposed slower movement which follows the envelope of these voice currents. This is plainly illustrated in Fig. 2*C*.

A graphical analysis of the movement of the light valve ribbons under steady-state conditions, with and without noise reduction, is shown in Fig. 3. Fig. 3*A* illustrates the extreme limits to which the ribbons move during normal recording without noise reduction. It will be seen here that as the input to the ribbons is increased, the extreme limits to which they travel is proportional to this input, and that the clash of the ribbons occurs when the instantaneous minimum becomes zero, *i. e.*, the ribbons strike together. Simultaneously, of course, their instantaneous maximum is double the mean. The mean spacing, it will be observed, has remained constant.

Referring to Fig. 3*B*, where noise reduction is applied, at low inputs the mean spacing is reduced from the normal according to the reduction of noise desired. Thus, if a noise reduction of 10 decibels is desired, the spacing is reduced to 0.316 of the normal. In the ideal case, as the input to the ribbons is increased, the minimum spacing of the ribbons, due to their amplitude, decreases, while the mean spacing remains constant until the ribbons are almost ready to clash, just as in Fig. 3*A*. However, just before clash occurs, when the input is increased, the mean spacing also increases just sufficiently to prevent this clash until the mean spacing reaches the normal spacing, at which time no further action takes place. It will be seen here that the mean spacing of the ribbons in the absence of sound currents is never reduced to zero, but is reduced by a ratio corresponding to the reduction of the noise.

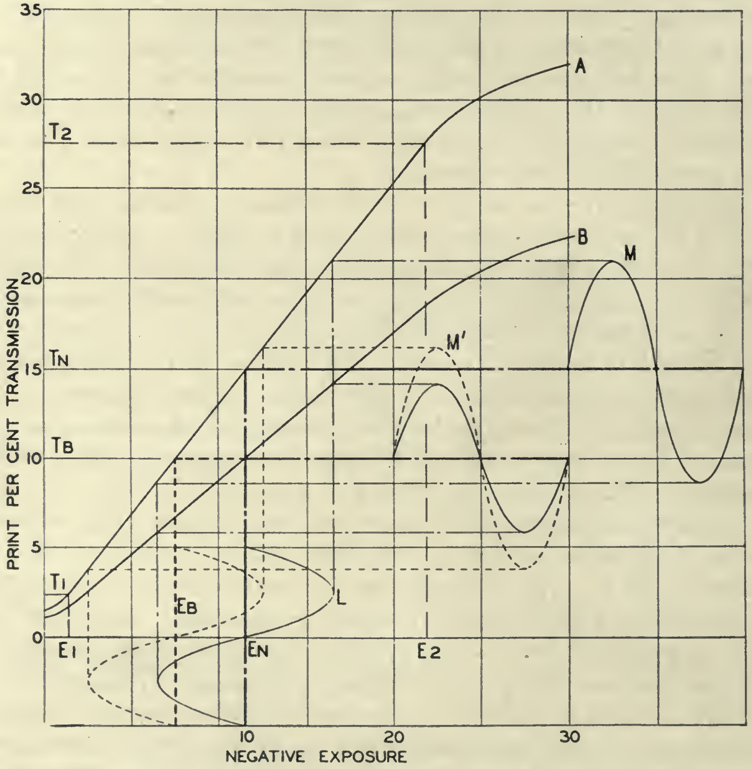

FIG. 6. Curves showing relation between projected transmission and negative exposure for two different printer light settings; gamma = 1.

If the system be set up to operate with margin, the ideal conditions are shown in Fig. 3*C*. It will be noted that the mean spacing begins to increase well before the ribbons are quite ready to clash, and since this figure has been drawn for a 6-db. margin, the minimum spacing to which the ribbons travel is never less than one-half the mean spacing. When the normal spacing of the ribbon has been reached, no further increase occurs. Actual measured steady-state characteristics under the above conditions with the existing noiseless recording equipment are shown in Fig. 4, and are seen to agree closely with the corresponding theoretical curves of Fig. 3.

In Fig. 5 have been plotted theoretical and measured curves similar to those shown in Fig. 3, except that the mean spacing has been plotted as the carrying capacity of the valve. Decibel scales instead of current or voltage scales have been employed.

It has already been pointed out that in this type of recording, the exposure through the light valve on the negative film is reduced during periods of silence, while at the same time provision is made for increasing the exposure automatically with increasing modulation of the light beam by the light valve ribbons. It follows that the density of the resulting negative sound track will be a minimum during silent intervals, and will rise to a maximum value with increasing input, while the density of the print made from this negative will be a maximum during silent intervals, and will decrease to a fixed minimum with increasing output from the film.

The question may be raised as to whether any volume or wave-shape distortion is introduced into the sound reproduced from a print made in this manner. To clarify these points we shall refer to the curves in Fig. 6, showing the relation between projected transmission and negative exposure for two different printer light settings, the effective over-all gamma of the developing process being unity. In this paper, over-all gamma is defined as the slope of the straight-line portion of the curve obtained by plotting densities of a series of unmodulated tracks, as measured by a photoelectric cell in the sound reproducer, against the logarithm of the light valve openings through which the exposures were made on the negative.

We shall consider only the straight-line portion of the curves in Fig. 6, as the range of negative exposure must be confined to this region if we are to have linearity between projected print transmission and negative exposure, with a resulting undistorted wave-shape for the print. In recording with a normal light valve, the mean exposure is adjusted to the value E_n, which is the average of the upper and lower exposures, E_1 and E_2, of the straight-line portion of the over-all transmission-exposure curve. In noiseless recording, the exposure of the negative during intervals of silence is reduced to some predetermined fraction of E_n of value E_b, while the transmission of the resulting point on the print will be reduced to some corresponding value T_b. The carrying capacity, which may be defined as the maximum permissible modulation of the print, is limited at this point to a transmission modulation of amplitude $T_b - T_1$, but is automatically raised to its normal maximum by the increase of exposure which results from increasing the input to the light valve.

Referring to Fig. 6, it will be observed that the normal exposure E_n of the negative will give mean transmission values of the print of 15 and 10 per cent, respectively, for the two curves A and B. If a sine wave of exposure L is now made on the negative, a corresponding sine wave of transmission will result on the print, the amplitude of the latter being lower for curve B, which represents the darker print. If the mean exposure is now reduced to E_b, the same sine wave of exposure on the negative will give for curve A a sine wave of transmission M' of unchanged amplitude, even though the transmission of the carrier gray has now been reduced to the same value as that previously given for the darker print. It is apparent, therefore, that for a constant printing light, so long as the negative exposure is at no time reduced below the value E_1, the amplitude of a transmission wave resulting from a negative exposure wave will be independent of the mean exposure on the negative and the resulting transmission of the carrier gray of the print. This allows the signal volume to be maintained, while it permits the reduction in ground noise by decreasing the transmission of the carrier gray of the print.

Since we have experimental evidence that the output of ground noise from an unmodulated sound track falls off linearly with transmission over the usual range of transmission used in sound reproduction, we secure a reduction in noise output by this process similar to what would be introduced into the signal output if the transmission of the carrier of the print were reduced by printing, as shown in Fig. 6. This explains why a movement up and down a definite over-all transmission-exposure curve, as in Western Electric noiseless recording, results in noise reduction without distortion of volume. This process should not be confused in any way with that of the common practice of controlling output by varying the transmission of the carrier gray in the printing process. In this case, by alteration of the transmission of the carrier gray, both signal and ground noise will be reduced in the same ratio, and hence no effective reduction of noise is obtained. It is accordingly apparent that any scheme, that starts from a negative recorded in the normal manner and varies the transmission of the print by controlling the printer light, will result in volume distortion of the original sound and will not increase the signal-noise ratio.

The equation of the straight-line portion of curve A in Fig. 6, may be expressed as follows:

$$T = CE + K$$

Where C is the slope of the straight-line portion

$$\therefore \Delta T = C \Delta E$$

or

$$\frac{\Delta T}{T} = C' \Delta \frac{E}{E}$$

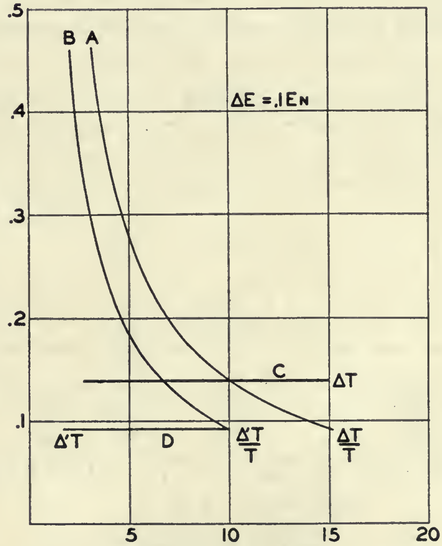

FIG. 7. $\Delta T/T$ plotted against T, for the two curves A and B, of Fig. 6.

Now $\frac{\Delta T}{T}$ is proportional to the percentage modulation of transmission of the print, and we may calculate its value for any value of T when ΔE is assigned a definite value. The curves of Fig. 7 show $\frac{\Delta T}{T}$ plotted against T for curves A and B of Fig. 6. ΔE in this case has been assigned value corresponding to 10 per cent of the normal exposure E_n in Fig. 6. While both these curves show that percentage modulation of the print varies inversely with decreasing transmission of the carrier gray for a given input to the valve, the two straight lines C and D show that the product $\frac{\Delta T}{T} \times T$ is constant throughout the range of transmission allowed the carrier gray. This is consistent with the usual requirement that the output be equal to the product of the percentage modulation and the amplitude of the carrier, familiar in radio electrical phenomena. Furthermore, since the output of the photoelectric cell depends only on ΔT, the fact that this is independent of the transmission of the carrier gray, and consequently of the mean exposure of the negative, serves further to show there is no volume distortion in the process in which the mean transmission of the print is allowed to vary to accommodate increasing output.

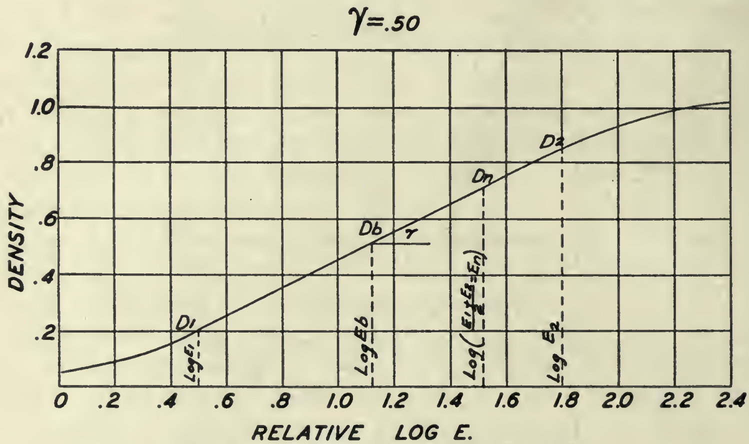

FIG. 8. Typical negative H & D curve.

The characteristic of the emulsion used in recording sound may be a factor in limiting the amount of noise reduction permissible with this system of recording. For example, for an over-all characteristic such as that in Fig. 6, the theoretical limit is determined by the ratio of the exposure E_n to the exposure E_1, at which the straight-line portion begins. Since the curvature at this point is due to the toe region of the negative H & D curve, we may neglect the positive film characteristic as a factor in determining the limits of noise reduction.

Fig. 8 shows a typical negative H & D curve in which visual diffuse densities are plotted against log exposure, the exposures having been made in a time-scale sensitometer equipped with a tungsten lamp. We shall assume that this curve simulates the manner in which exposures are made through the light valve on film passing through the recording machine. The scale of this particular H & D curve is approximately 20. If we follow the usual practice of making the normal exposure 10 times the toe exposure, then we have a permissible light valve modulation of 90 per cent without operating at the toe. The shoulder exposure will not be reached before 100 per cent modulation (double opening) of the valve is attained. For this particular characteristic the normal exposure may be reduced to one-tenth its normal value before entering the toe. This corresponds to a maximum noise reduction of 20 decibels without any change of exciting lamp current.

The amount of noise reduction realized from a print will equal the reduction made in the negative exposure only when the over-all gamma is unity. Let us assume that a noise reduction of n decibels is desired. This necessitates, for the ideal case, an equal reduction in exposure of the negative. We have, therefore:

$$n = 20 \log \frac{E_n}{E_b}$$

or

$$\frac{n}{20} = \log E_n - \log E_b$$

where E_b is the reduced value of negative exposure. Referring to Fig. 8:

$$D_n - D_b = \Gamma (\log E_n - \log E_b) = \Gamma \times \frac{n}{20}$$

or

$$D_n = D_b - \Gamma \times \frac{n}{20}$$

If we call the corresponding projection densities of the print made from this strip $D_n{}^1$ and $D_b{}^1$ we have the relation:

$$D_n{}^1 = D_b{}^1 + \Gamma \times \frac{n}{20}$$

where Γ is the over-all gamma or slope of the line obtained by plotting projection print densities *versus* log negative exposure.

The amount of noise reduction realized is given by the relation:

$$N = 20(D_n{}^1 - D_b{}^1) = \Gamma \times n$$

$$\therefore \text{ when } \Gamma = 1,\ N = n$$

In general, therefore, it may be stated that the amount of realized noise reduction, expressed in decibels, is directly proportional to the value of the over-all gamma of the processed print. It is highly desirable, of course, that the amount of noise reduction realized should agree approximately with the amount expected, for otherwise the processing will tend to impair the quality of the reproduced sound.

The fact that the negative film characteristic, rather than the positive, limits the maximum attainable noise reduction is graphically illustrated in Fig. 9. It is possible, with this combination of negative

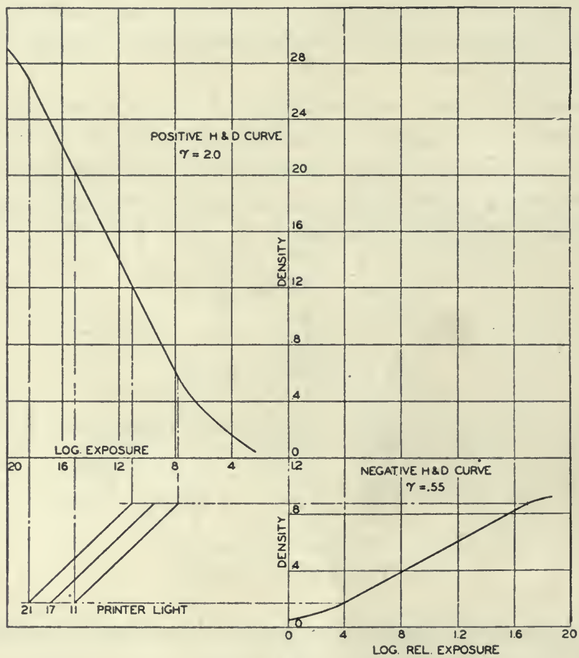

FIG. 9. Illustrating the manner in which the characteristic of the negative, rather than of the positive, limits the maximum attainable reduction of noise.

and positive H & D curves, to use printer light settings ranging from 11 to 21 in a typical printer without transferring any part of the straight-line portion of the negative H & D curve into either the toe or shoulder of the positive H & D curve. In ordinary processing, the upper printer lights are seldom utilized, and projected densities seldom exceed 2.4 in order to obtain the maximum output from a print without resorting to the maximum electrical amplifications available in the reproducing systems. This indicates that the density of the biased unmodulated positive track is well below the initial shoulder density of the positive H & D curve, and proves definitely that the positive characteristic is not the deciding factor in limiting the amount of noise reduction attainable.

While it is evident that in a properly processed print, no wave-shape distortion is introduced into the sound output, the question may be raised as to whether there is any relative loss of output at the higher frequencies in sound reproduced from the darker portions of the print. In order to test this, a 1000- and a 5000-cycle frequency recording were made for various openings of the light valve, the input to the valve being held sufficiently low so as to eliminate any possibility of ribbon clash for the minimum spacing of the ribbons. These test recordings were all printed at the same printer light, giving a print with a wide range of densities. The results of this test are shown in Fig. 10, where the relative difference in decibels between 1000 and 5000 cycles is plotted against the density of the unmodulated track corresponding to each setting of the light valve. This curve shows that the difference in output for 1000 and 5000 cycles remains essentially constant over a range of print transmission corresponding to 10 decibels of noise reduction. The relative loss at 5000 cycles amounts to less than 3 decibels for a 14-db. noise reduction. These facts indicate that noiseless recording does not produce any serious loss of high frequencies.

The processing of noiseless recordings offers no peculiarly new problems. The lamp current of the exciting lamp in the film recorder is adjusted to give an exposure on the negative that will allow modulations of the light valve of the order of 90 per cent, without operating into the toe of the negative H & D curve. This is identical to the method employed in setting the lamp current in ordinary methods of recording, and is, in fact, made without regard to the fact that the noiseless method of recording is being used. The development of the negative film is carried out according to standard practice, the gamma of the development being chosen so as to permit the attainment of an over-all gamma of unity, for the particular contrast that is used in the combined sound and picture print. In order to facilitate printing of the negative and to act as a guide in setting the printer light, it is customary to shut off the biasing current and to record a strip of unmodulated track at the beginning of each roll of film or at the beginning of each scene. The density or transmission of this track may then be used in the usual manner for determining the correct printer setting required to secure a given transmission of the print.

It is desirable to keep a record of the printer light settings used in making the daily prints, so that the assembled inter-cut negatives for release printing, from which the guide densities have been cut away, may be printed on the proper lights. It is desirable to insert a strip of negative unmodulated track or other form of standard density in the leader of each roll of assembled negative. This will give a strip of normal carrier gray on the print, and a check on the transmission of this strip will serve as a partial indication of the development of the

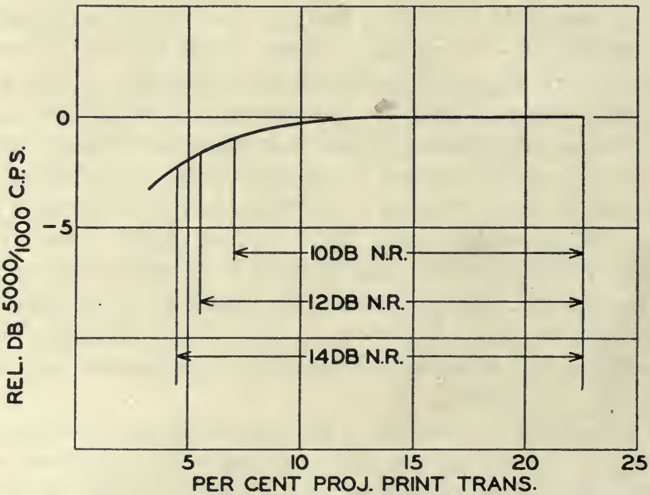

FIG. 10. Results of tests, showing ratio of loss at 5000 cycles to that at 1000 cycles, for various values of light valve openings.

positive. Even though a simple theoretical relation exists between the densities of unbiased and biased unmodulated sound tracks, it has not been found desirable as yet to rely upon the latter for setting printer lights, as the difference in these densities is sensitive to fluctuations that might be misleading.

We have assumed in this paper that the classical doctrine of straight-line H & D recording has been adhered to. Since the considerations of picture processing often make it desirable to have an over-all gamma greater than unity, it is desirable to examine what limitations this condition imposes upon noiseless recording.

D. MacKenzie[2] has shown that for an over-all gamma as high as 1.4, a relation may be obtained between the projected print transmission and the negative exposure, which is essentially linear over a limited range of transmission. The curvature that might be produced by high over-all gamma in this print is partially offset by extending the operations into the toe of the positive H & D curve. This introduces a symmetrical curvature about the mean point, and introduces similar distortion into both halves of the wave-shape of the projected sound. Dr. MacKenzie concludes that with an over-all gamma as high as 1.4, a noise reduction of 10 decibels may be safely attained, as compared with a noise reduction of 14 decibels, which he considers

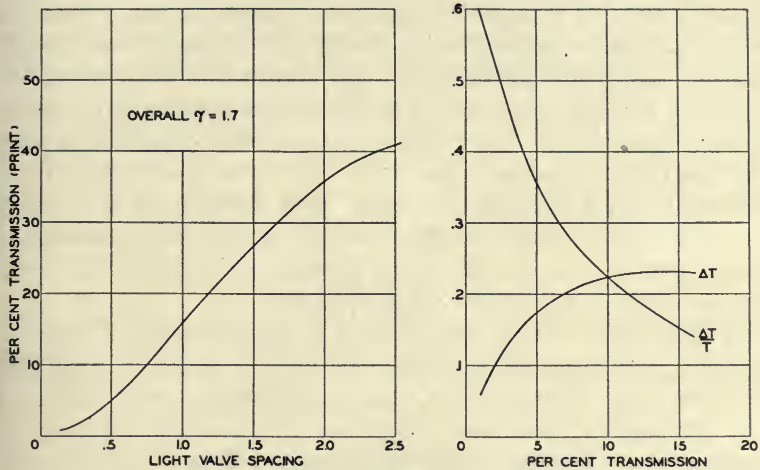

FIG. 11. Illustrating how considerable curvature is introduced into the low transmission region of the over-all curve, when gamma is considerably greater than unity.

safe for classical recording. However, if the over-all gamma is raised considerably above unity, as, for example, in Fig. 11, where it has a value of 1.7, considerable curvature is introduced in the low transmission region of the over-all transmission-exposure curve. A curve of this sort introduces volume and wave-shape distortion, since the output fails to increase proportionally with increasing modulation of the negative.

Fig. 11 shows the percentage print modulation $\frac{\Delta T}{T}$ and $\frac{\Delta T}{T} \times T$, or ΔT, plotted against T, for such a case of high gamma, ΔE being chosen as 0.05 E_n. It will be noticed that ΔT is no longer constant, as was shown in Fig. 8. This shows that a film processed in this manner will give decided volume distortion, the sound output decreasing with a decrease in transmission of the print. This effect, combined with the introduction of harmonics due to wave-shape distortion, will give very poor quality of projected sound. In order to avoid entirely volume distortion in this print, the valve spacing should not have been reduced by the biasing current below 0.7 of its normal setting. While this would mean setting for a 3-db. noise reduction, it would give an apparent actual noise reduction of 3×1.7 or 5.1 decibels, since the over-all gamma is 1.7 in this case.

While it is possible to obtain an approximately linear relation between the print transmission and the negative exposure when the over-all gamma is greater than 1, and obtain undistorted output for ranges of negative modulation that are confined to the straight-line portion of the over-all curve, it is desirable in practice to adhere as closely as possible to the classical straight-line recording methods with the over-all gamma equal to unity. This is especially to be recommended for noiseless recording, as it permits the attainment of a maximum of noise reduction without introducing distortion of volume or of wave-shape, and makes it posible to obtain the full benefit to be expected from this type of recording.

We have seen that in the Western Electric method of noiseless recording, the exposure through the light valve is varied: first, according to the voice currents in the usual manner and, second, according to the envelope of these voice currents. These variations reduce the transmission of the positive for low inputs and allow the transmission to increase as the sound currents increase; thus, when a film recorded by this method is passed through a projector, the ground noise that results from the film itself is low during intervals of silence of small sound currents. As the transmission increases with increasing sound currents, the ground noise will also increase; but since the sound output increases at the same time the signal-to-noise ratio remains essentially constant, and the increase in ground noise is obscured by the increase in signal volume. The net effect of this is to give an apparent reduction of ground noise that is very real during intervals of silence, when the ground noise is most objectionable.

We have seen that the processing of noiseless recordings is not essentially different from that of normal recordings, as both kinds require a linear relation between the projected transmission of the print and the exposure on the negative through the light valve. It has been seen that this condition exists when the effective over-all gamma of the developing process is unity and, to a lesser degree, when the over-all gamma is somewhat greater than unity. It has also been pointed out that if considerable curvature exists between the print transmission and the negative exposure, volume as well as wave-shape distortion will be introduced, thus distorting the range of sound output as well as introducing harmonics.

We have seen that the amount of noise reduction that can be realized by this process is limited by the characteristic of the film emulsion used in recording the negative, rather than in the positive from which the sound is reproduced. It has been shown that in a print made by the noiseless recording method, the loss at 5000 cycles relative to 1000 cycles is of the order of 1 decibel for a noise reduction setting of 10 decibels, a negligible loss of high frequencies, resulting in no loss of brilliance in a print made with noiseless recording. From the photographic standpoint, therefore, it may be stated that sound recorded in this manner should be equally of as good quality as that recorded in the normal manner and, in addition, will appear more natural due to the virtual suppression of all spurious film noise.

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DISCUSSION

MR. JENKINS: When the noise reduction method is applied to glow-lamp recording, is a similar procedure carried out, of superimposing a control current on the speech current, thus varying the brilliancy?

MR. SILENT: Our experience with glow-lamp recording has been limited to a few laboratory experiments. From our experience, the answer to that is yes. There may be other methods.

MR. PALMER: We have often been told that the reason why we could not obtain good reproduction in the theater was not because the sound was not recorded on the film, but that we could not reproduce it. Mr. Frederick's demonstration, reproducing sound from special hill and dale disk records, shows that it is possible to obtain high quality reproduction from the speakers that we have. The only two elements in the system by which film records are recorded, that are not present in the methods used for recording on the disk, are that we use a light valve to modulate the light and photographic emulsion to record the sound. Now, why is it that the photographic emulsion cannot do the job as well as the material of which Mr. Frederick's record was made?

MR. SILENT: I may safely say that there is no loud speaker available to the theaters at the present moment that is quite the equal of the one to which you refer. The loud speaker generally used in the theaters cuts off approximately at five thousand cycles. The film is, at the present time and with the present improved technics, capable of accommodating a frequency range appreciably greater than is at present being reproduced in the theaters, so that the limitation of the range cannot be said to be due entirely to the materials used in recording. The condenser microphones that have been used in the past for recording constituted, themselves, a limitation in recording.

The moving coil microphone that is now used for recording will provide an opportunity for the film to prove its recording capabilities. The film is, however, subject to the limitation that when processed under the commercial conditions existing in the studios and laboratories, a certain amount of high frequency loss occurs. It is not possible to state definitely to what this loss should be ascribed. We believe that the characteristic of the film may be made essentially flat, to a frequency perhaps half an octave higher than is now usual in the theater, and there is no question but that the film can be made to respond to frequencies an octave above what was reproduced by the special disk to which Mr. Palmer referred.

On the other hand, noise constitutes a limitation for the film at the higher frequencies, and the response at frequencies in the neighborhood of twenty thousand cycles or higher is considerably attenuated by printer losses and diffusion in the film; and probably by other causes that enter into the processing system.

RECENT DEVELOPMENTS IN THEATER LOUD SPEAKERS OF THE DIRECTIONAL BAFFLE TYPE*

HARRY F. OLSON**

Summary.—*This paper describes a group of directional baffle loud speakers that are designed to combine high efficiency of transformation of electrical into acoustical energy, with directional characteristics that are particularly adapted to large-scale reproduction of sound with good fidelity. Three types of directional baffle loud speakers have been designed, each satisfying a certain set of requirements. The 60-inch directional baffle covers an extremely large frequency range and is designed for theaters with good acoustic characteristics. The 37-inch directional baffle is designed to compensate for the acoustics of theaters with high reverberation characteristics. The 25-inch directional baffle is designed for theaters in which the space behind the screen is extremely limited. Response measurements show that the output of these loud speakers is uniform over a wide frequency band. The uniform directional characteristics of these loud speakers eliminate the possibility of frequency discrimination for points removed from the axis. These loud speakers, due to the high efficiency and rugged construction, are capable of delivering large acoustic outputs without distortion.*

INTRODUCTION

The transformation of electrical into acoustical energy may be accomplished in a multitude of ways. At the present time, while practically all loud speakers may be classed as of the diaphragm type, the essential distinguishing characteristic lies in the coupling between the diaphragm and the medium into which sound is to be radiated, and in the method of driving the diaphragm. In general, loss of coupling between the diaphragm and the medium occurs at the lower frequencies. Among the common methods employed to increase low frequency radiation from diaphragms are: (1) the use of large diaphragms, (2) groups of diaphragms, and (3) various shapes of baffles and horns.

To obtain the maximum of efficiency and minimum of interference from reflecting surfaces, directional sound radiators have been almost

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* Received December 14, 1931.

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universally employed for large-scale* reproduction of sound. The directional characteristics of any acoustic radiating system are functions of the dimensions, configuration, and phase of the elements.

The combination of high efficiency and directional characteristics that is adapted to large-scale reproduction of sound precludes the use of many possible types of sound radiating systems. An examination of the inherent characteristics of the directional baffle** type shows that this loud speaker is particularly suited to satisfy these stringent requirements. It is the purpose of this paper to describe a group of directional baffle loud speakers that are designed to combine high efficiency of transformation of electrical into acoustical energy with directional characteristics particularly adapted to large-scale reproduction of sound with good fidelity.

GENERAL CONSIDERATIONS

A brief discussion of the functions of the essential parts of a directional baffle type of loud speaker will now be presented. A diaphragm vibrating with constant velocity, coupled to an infinite tube, generates

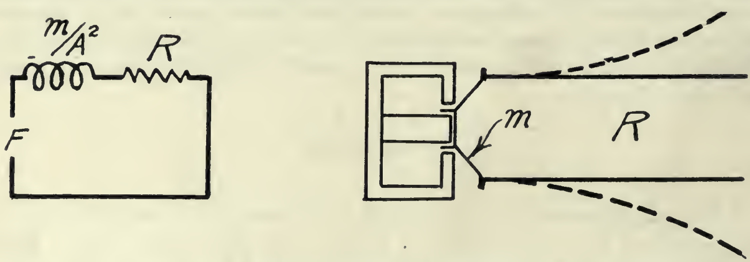

FIG. 1. Equivalent electro-acoustical diagram of dynamic cone and acoustic impedance.

the same acoustic power at all frequencies. Assume that the diaphragm is a dynamic cone of mass m coupled to a tube of acoustic impedance R (Fig. 1). If the mass m of the cone is chosen so that the acoustic reactance of the cone is negligible compared with R for the range in which we are interested, we will obtain a system that dissipates the same power in the acoustic resistance at any frequency within the range.

* The term "large-scale" reproduction of sound is used to designate the acoustic powers necessary for reproduction of sound with good fidelity in auditoriums, theaters, and open-air stadiums and theaters.

** The term "directional baffle" loud speaker has been used to designate a large throat horn coupled to a cone driving unit.

For the infinite tube of constant cross-section we will substitute an infinite tube of exponentially increasing cross-section. It has been shown by Webster[1] that the acoustic resistance at the small end of this tube will be a constant at all frequencies above the cut-off frequency. The cut-off frequency[2] is determined by the rate of flare, and may be located below the lowest frequency to be produced. If we now cut this tube at some point along its length and terminate the open end in air, the action will be altered, depending upon the cross-section of the resulting mouth. If this cross-section is sufficiently large, very slight reflection will occur at the transition from the mouth to the medium (air), and the impedance presented to the cone by the tube will be practically constant above the cut-off frequency. The system, as before, will dissipate the same power into the tube for the frequency range we have chosen; and consequently, neglecting slight reflection at the mouth, will dissipate constant power into the medium for this range. This system, consisting of a finite flaring tube of exponentially increasing cross-section, coupled to a dynamic cone, essentially constitutes the directional baffle type of loud speaker.

In the wave equation[3] for the axial motion in an exponential horn it is assumed that the phase is the same over a plane normal to the axis of the horn. This condition is practically satisfied provided that the cross-section is not greater than a wavelength. It has been found experimentally that, for any particular frequency within the transmission band, additional length of horn beyond a certain point (the radius of ultimate impedance) does not affect the performance of the horn. That is, the working portion of the horn decreases with increase of frequency. Therefore, in a horn *in which the axis is a straight line*, the condition of the same phase over a plane normal to the axis is automatically satisfied.

To maintain the same phase over a plane normal to the axis in a folded or curled horn is exceedingly difficult. The condition is practically satisfied provided that the diameter at any bend is less than the wavelength of the highest frequency reproduced. This places a limitation upon the amount of folding or curling that may be accomplished without impairing the horn action. If these conditions are not satisfied, destructive interference will result, and, in addition, certain portions of the horn will act as reflectors at the higher frequencies. These conditions ultimately result in a non-uniform response characteristic.

To obviate the occurrence of a non-uniform frequency characteristic due to folding, we have employed exclusively a horn with a straight-line axis. In a horn with a large throat this objective may be accomplished without making the horn excessively long.

The low frequency cut-off of a finite exponential horn is determined by the rate of flare and the mouth opening. When the cut-off frequency has been set, the mouth opening and the rate of flare are fixed. There now remains one factor that determines the length of the horn, namely, the throat area.

At this point we will digress to point out the limitations imposed upon the size of the theater loud speaker. In motion picture theaters in many instances the space behind the screen is limited; and in theaters having a stage presentation in addition to the motion picture, portability is a great factor. In view of the fact that the space occupied by the loud speaker is an important factor, it is essential that the loud speaker be as short as possible. To accomplish this objective it is necessary that the throat be made as large as

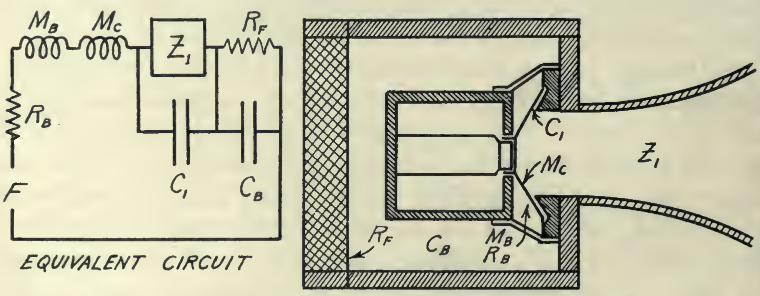

FIG. 2. Complete equivalent circuit of dynamic cone.

practicable. The question then arises as to the proper driving unit that will properly match the acoustic impedance at the small end of a large throat horn. It can be shown theoretically, and has been substantiated experimentally, that a cone type of unit can be designed for a large throat exponential type of horn to yield high efficiency and good fidelity of reproduction over a wide frequency range. This type of loud speaker[4] is now supplied with RCA Photophone equipment. A specific discussion of the essential parts of this loud speaker follows.

SPECIFIC CONSIDERATIONS

The directional baffle type of loud speaker comprises a number of essential elements, each of which has certain acoustical constants as shown in Fig. 2.

(1) A large throat horn, Z_1,
(2) A paper cone and voice coil, M_c,
(3) A box having a felt back, C_B, R_F,
(4) An air chamber between the cone and horn, C_1.

By means of the equivalent circuit, Fig. 2, the magnitude of the component parts may be adjusted theoretically to yield the greatest efficiency and best frequency characteristic. It is beyond the scope of this paper to give a detailed account[5] of how this was carried out. However, a brief discussion of the functions of the important component parts will now be given.

1. The Horn.—The horn used in this loud speaker is of the exponential type. The horn is a kind of acoustic transformer which matches the acoustic impedance of the relatively heavy diaphragm to a relatively light sound medium. Two factors influence the radiation characteristics of an exponential horn, namely, the rate of flare and the mouth opening. These two factors determine the low frequency response of the loud speaker. Due to the characteristics of certain auditoriums, it is desirable to reduce the low frequency response of the reproducing apparatus. Therefore the average characteristics of auditoriums will determine the rate of flare and mouth opening. With the rate of flare and mouth opening fixed, the length of the horn is determined by the dimensions of the throat. The size of the throat, that will present a tolerable acoustic impedance to the cone and, at the same time, will not impair the high frequency response due to absorption along the walls or cause destructive interference in the air chamber, has been found to be 4×4 inches. The impedance of the horn at the throat is indicated by Z_1 (Fig. 2).

2. The Cone Unit. The unit of this system consists of a paper cone fitted with an aluminum wire voice coil. An air chamber couples the area of the cone to the area of the throat of the horn. The back of the cone is enclosed by a box with a felt back. The response and dynamic characteristics of a six-inch cone were found best adapted to this type of loud speaker. As will be seen from the equivalent circuit (Fig. 2), in order to maintain uniform dissipation in Z_1, it is important that the mass of the cone and voice coil, represented by M_c, shall be small. This was accomplished by employing an aluminum wire voice coil and an extremely light, rigid cone. The non-uniform frequency response at the higher frequencies, commonly encountered when light paper of great stiffness is employed, was obviated by suitable corrugation of the cone. The air load upon the back of the cone is represented by R_B and M_B.

3. *Cone Box.*—The impedance presented behind the cone must be considered. The air chamber behind the cone is enclosed by a box having a felt back. The purpose of the felt is to absorb sound striking it and thus prevent standing wave systems that would cause abrupt changes with frequency in the impedance presented to the cone. At the higher frequencies the absorption of the felt is unity and the sound wave flows from the cone into the felt. At the lower frequencies the absorption of the felt is not unity, and a stiffness due to the volume of the cone box is presented to the cone. Therefore, the cone box is

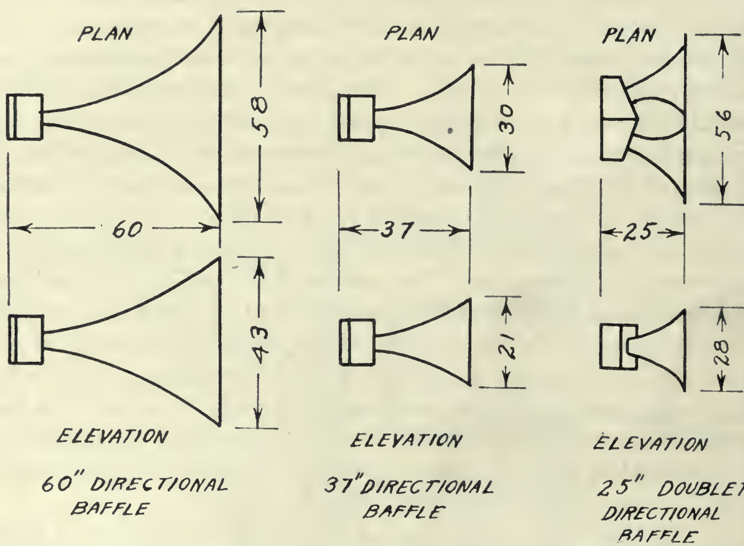

FIG. 3. Configurations and dimensions of the three types of baffle loud speakers.

made large enough so that this stiffness will not reduce the response of the loud speaker at the lower frequencies. The capacitance of the cone box is represented by C_B and the resistance of the felt by R_F (Fig. 2). The actual size of the cone box and the felt cover is determined from this circuit.

4. *The Air Chamber.*—The purpose of the air chamber is to act as a transformer between the area of the cone and the smaller areas of the throat of the horn. To allow freedom of motion of the cone it is necessary to space the cone from the face of the air chamber. The volume of this air chamber results in a capacitance indicated by C_1 in the equivalent circuit (Fig. 2). This capacitance is in shunt with

the horn impedance. Therefore, to avoid impairing the frequency characteristic of the loud speaker, the impedance of the air chamber must be made large as compared with the horn impedance Z_1. This indicates that the spacing must be small. At the same time it is necessary that the spacing between the cone and air chamber shall be sufficiently large to allow full power output at the lower frequencies where the excursion of the cone is large. It has been found that a spacing of $^1/_8$ inch allows full power output of the cone at the lower frequencies without impairing the response at the higher frequencies due to the capacitive reactance of the resulting air chamber.

5. *The Assembly.*—Three types of directional baffle loud speakers have been designed, each one satisfying a certain set of requirements encountered in large-scale reproduction of sound. The essential distinguishing characteristic in these three loud speakers lies in the design of the horn. The general configuration and dimensions of the three units are shown in Fig. 3. A discussion of the performance and the application of these loud speakers will now be given.

RESPONSE AND DIRECTIONAL CHARACTERISTICS

At the present time, response and directional characteristics are the best criteria of the performance of a loud speaker. The response*

* The response measurements shown in this paper were made using a microphone calibrated with a Rayleigh disk. This gives the sound pressure in the undisturbed sound field. For the diaphragm type of microphone, the pressure at the face is twice that in free space at the higher frequencies. In addition, most condenser microphones exhibit a resonance due to the cavity in front of the diaphragm, which results in a further increase in response at the resonance frequency. In general, in sound motion picture recording, the practice is to ignore the greater response exhibited at the higher frequencies by the diaphragm type of microphones, and to equalize the system for constant sound pressure at the diaphragm. The argument often advanced in favor of this procedure is that it overcomes transfer and other losses that occur at the higher frequencies. However, this is a rather weak argument, because the greater response exhibited by the diaphragm type does not occur at the proper frequency to compensate for these losses, and the net result is frequency distortion. If the response characteristics were made with a microphone of the diaphragm type without correcting for these effects, the loud speaker would show greater response at the higher frequencies than actually exists. From the standpoint of the performance of the loud speaker, the logical procedure is to measure the actual sound pressure in free space and not the pressure at the diaphragm of a microphone, which, obviously, will depend upon the size and geometrical configuration of the instrument employed. One way in which this may be accomplished is to calibrate the microphone by means of a Rayleigh disk.

of this loud speaker was taken on the axis at a distance of 20 feet from the mouth in an unobstructed[6] medium, air. It is perhaps needless to say that response curves made on loud speakers in rooms have an extremely limited significance unless many curves are taken and a careful analysis made to determine the influence of the room.

1. The 60-Inch Loud Speaker.—The response characteristic (Fig. 4) and associated directional characteristics (Fig. 5) indicate that the acoustic power delivered by this loud speaker does not show any abrupt change with frequency. This is partially accomplished by presenting to the cone an acoustic impedance that does not exhibit abrupt changes with frequency. The uneven response sometimes

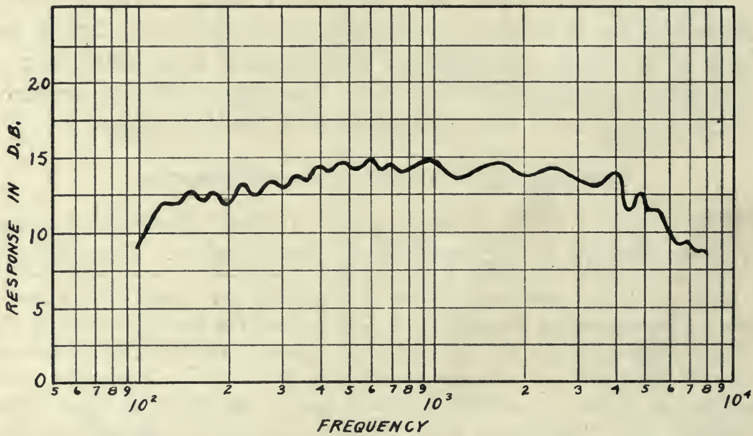

FIG. 4. Response-frequency characteristic of the 60-inch directional baffle loud speaker.

encountered in cone type loud speakers has been eliminated by the reduction in the mass of the cone and moving coil system, by suitable processing of the paper cone, and by the load imposed by the horn. As will be seen from Fig. 5, the directional characteristics are uniform over the range from 130 to 4000 cycles. Therefore, this loud speaker will not produce frequency discrimination at points not on the axis, an inevitable result in loud speakers exhibiting non-uniform directional characteristics. The response characteristic shows that the output is uniform from 100 to 7000 cycles, the maximum deviation being 2.5 decibels.

2. The 37-Inch Loud Speaker. For theaters that exhibit high reverberation characteristics and other acoustic difficulties, it is necessary to attenuate the low frequency response of the loud speaker to obtain the most satisfactory results. The response characteristic of the 37-inch loud speaker is shown in Fig. 6. As will be seen, the response is attenuated below 300 cycles, falling to 13 decibels below the 1000-cycle response at 100 cycles. In general, theaters that exhibit acoustic difficulties show excess reverberation at the lower frequencies. By using a loud speaker with a response as shown in Fig. 6, the acoustic characteristics of the theater are compensated for by the loud speaker, providing a reasonably uniform over-all acoustic characteristic. The directional characteristics are quite similar to the 60-inch directional baffle above 250 cycles.

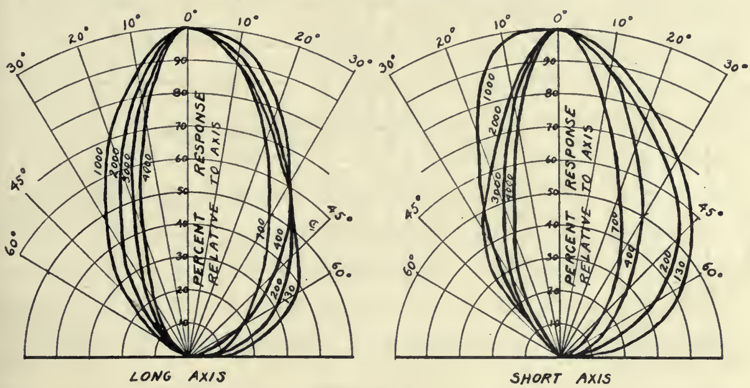

FIG. 5. Directional characteristics of 60-inch directional baffle loud speaker.

3. The 25-Inch Loud Speaker.—In many theaters the space behind the screen is extremely limited, and in theaters having a stage presentation, portability is an important factor. In these instances it is desirable to fasten the loud speaker to the screen framework, so that the entire assembly can be hoisted out of the way in a single operation. A loud speaker suitable for these conditions must be extremely short. Again the inherent characteristics of the directional baffle type make it possible to design a loud speaker that will satisfy these conditions and at the same time retain high efficiency and good directional characteristics.

There are two general defects of speakers occupying small space; namely, a deficiency in low response and non-uniform directional characteristics. A brief discussion will now be given to show how these defects have been overcome in this loud speaker. This loud speaker is not designed to operate as a single unit, but two or more units must be used. Two units are termed a doublet, shown in Fig. 3. A single unit would exhibit a deficiency in low frequency response. However, by placing two or more units with their mouths close together, the impedance at the mouth of each speaker is increased due to the greater pressure into which each speaker operates. If the distance between the units is adjusted to match the acoustic impedance of the individual directional baffle, the response can be maintained at low frequencies. The response characteristic of the doublet is shown in Fig. 7. It will be seen that response of this loud speaker is uniform

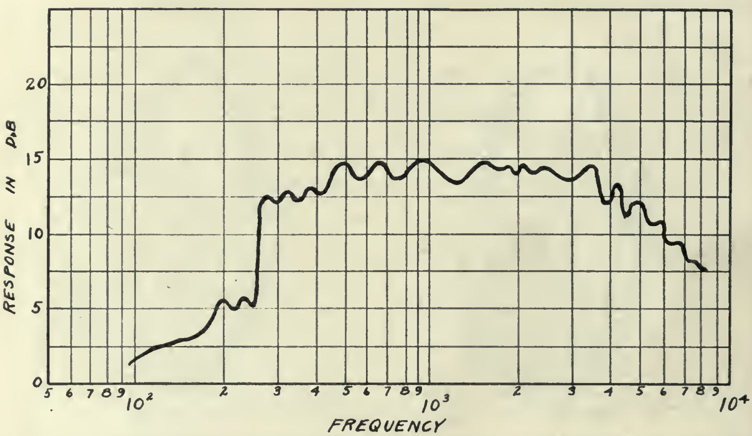

FIG. 6. Response-frequency characteristic of the 37-inch directional baffle loud speaker.

over a large frequency range. If greater low frequency response is desired, it can be obtained by using more than two units. The response of four units is indicated by the dotted curve (Fig. 7).

The directional characteristics of a single unit of the dimensions required would show considerable variation of the frequency range. The directional characteristic of two or more units will be a function of the directional characteristics of the individual units, the distance between the units, and the angle between the axis of the various units. A theoretical analysis was made to find the values of these various factors that would make the result and directional characteristic of the multiple units speaker practically independent of the frequency. The results are shown in Fig. 8. It will be seen that the directional characteristics of the doublet are uniform in the horizontal plane. Therefore, the doublet loud speaker could be used in a single floor house without introducing frequency discrimination resulting from non-uniform directional characteristics. In a theater with a balcony four units are used, in which case the directional characteristics are uniform for all planes.

EFFICIENCY

The efficiency of a loud speaker is the ratio of the sound power output to the electrical power input. In this type of reproducer the efficiency was determined by three methods: namely, theoretically;

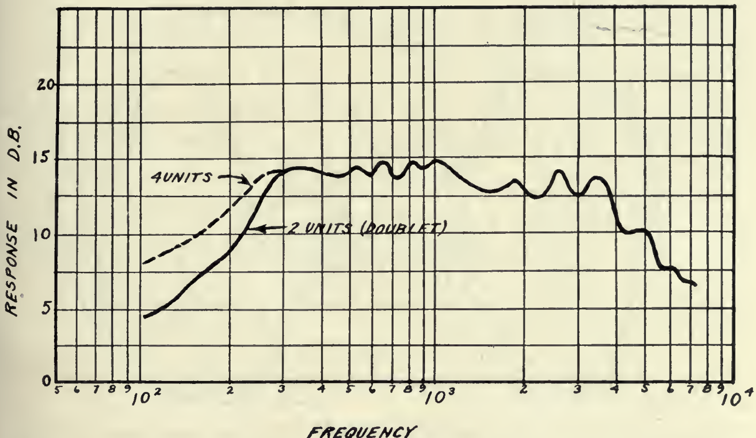

FIG. 7. Response-frequency characteristic of the 25-inch doublet directional baffle loud speaker.

experimentally, by motional impedance measurements; and by the total sound output determined from a calibrated microphone.

Using the equivalent circuit in Fig. 2, the ratio of the sound power output to the electrical power input was computed from the constants of the component parts. The results for the 60-inch directional baffle are shown in Fig. 8. The theoretical efficiency cannot be predicted by simple analysis above 2000 cycles because the mode of vibration of the cone above this frequency is not that of a simple piston. Above 2000 cycles, the inherent stiffness of the cone reduces the effective mass of the cone. For this reason the output of the cone is greater than that of a simple piston. This is a desirable characteristic in view of the fact that the acoustic output is increased.

The motional resistance[7] was determined experimentally, and the efficiency computed in the customary manner. The results are shown in Fig. 9.

The efficiency of the reproducer was also determined by measuring the total acoustic output by means of a calibrated microphone, comparing this to the electrical input. Pressure measurements were made on the surface of a sphere with the loud speaker at the center. The surface of the sphere was divided into elements and the energy traversing each element determined. The summation of the increments of the energy gives the total energy emitted by the loud speaker.

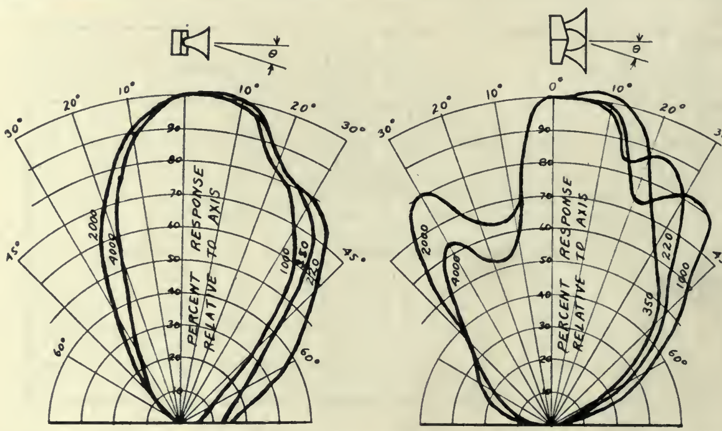

FIG. 8. Directional characteristics of 25-inch doublet directional baffle loud speaker.

It will be seen from Fig. 9 that the results obtained from the three methods are in close agreement.

The decrease in efficiency with frequency (Fig. 9) is not serious when cognizance is taken of the fact that efficiency is proportional to the square of the delivered pressure. For this reason, efficiency expressed in per cent is an extremely sensitive measure of the performance of a loud speaker. Expressed in terms that are more descriptive from the standpoint of sound reproduction, the maximum deviation is 3 decibels. As will be seen from the response and directional characteristics, the slight difference in directional characteristics between the high and low frequencies, together with the above efficiency characteristic, leads to a uniform response characteristic.

The high efficiency exhibited by this loud speaker, as compared with cone loud speakers operating in a flat baffle, is due to the action of the large acoustic load of the horn upon an extremely light vibrating system. The uneven response, commonly encountered when a cone of light paper of great stiffness is employed, is obviated by suitable corrugations. This is an extremely important factor in that it reduces the effective mass of the cone at the higher frequencies, accounting for the large output at those frequencies. The large load imposed upon the cone further assures uniform response and high efficiency.

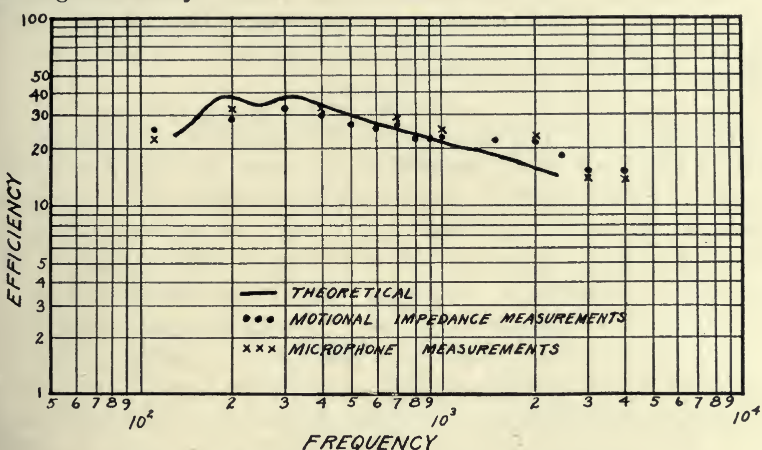

FIG. 9. Efficiency of directional baffle loud speaker.

This loud speaker, due to its high efficiency and rugged construction, is capable of delivering large acoustic outputs (from one to two watts of sound energy) without distortion.

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GAMMA BY LEAST SQUARES*

D. R. WHITE**

Summary.—*It has been found convenient and time-saving to compute gamma by the method of least squares from data obtained by printing exposures through a developed sensitometer strip as negative. The computation by this method reduces to the addition of a set of numbers obtained from tables, one for each density involved. The paper describes the method followed.*

With the H & D printer[1] that was developed for making tests of positive film that would accurately represent printing conditions, exposures of the positive are made through a negative, and consist of a developed time-scale sensitometric exposure. A typical characteristic curve of such a negative is shown in Fig. 1. The densities of the strips can be regulated by varying the exposure to obtain equal increments of density between steps, but this involves considerable trial and error testing that has not been attempted. Instead, strips are used which are exposed increasingly by factor two steps. The resulting negative densities do not, therefore, increase by uniform amounts so that, when printed, the points of the positive characteristic curve that correspond to these negative densities are correspondingly non-uniformly placed on the log E axis of the curve. Plotting such data proves laborious, time-consuming, and not as accurate as might be desired, since two workers cannot always draw the same line through the same group of experimentally determined points, as these points do not, in general, lie in a mathematically straight line (Fig. 2.)

It was found that by applying the method of least squares the problem was simplified to such a degree that gamma could be computed very simply on an adding machine. The value of gamma thus obtained required no plotting, and each person operating the adding machine would obtain the same value of gamma from a given set of points. On the experimental side, no requirement was introduced except that in all tests the printing light intensity level must be adjusted to such a value that the densities, produced on the positive

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

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behind a chosen group of densities of the negative, are all on the straight-line portion of the positive characteristic curve. This group, and only this group, of densities enter into the calculation of gamma. In practice, this condition is not difficult to realize, because within the relatively narrow speed range of positive materials, a suitable exposure, when once obtained, will serve directly for all other normal positive materials similarly processed.

The equation of the straight-line portion of the characteristic curve, relating density, D, with the logarithm of the exposure, $\log E$, may be written

$$D = D_0 + \gamma \log E \tag{1}$$

where D_0 is the density corresponding to $\log E = 0$, *i. e.*, to $E_0 =$ unity, and γ is the slope of the straight line (Fig. 3). In general, any

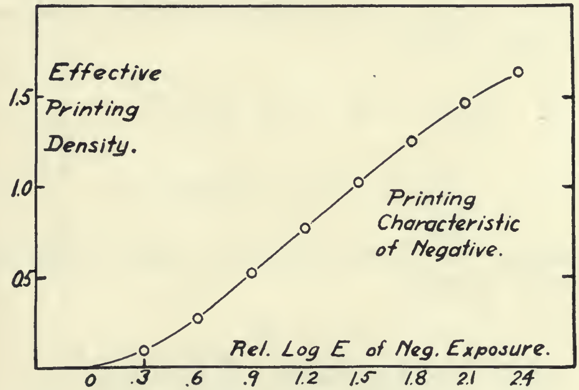

FIG 1. Typical characteristic curve of negative film.

observed density, D_i, in the straight-line portion of the curve, obtained from exposure $\log E_i$ will differ from the value of D calculated from (1) above, due to experimental errors, by an amount

$$D_i - D = D_i - (D_0 + \gamma \log E_i) \tag{2}$$

Values of γ and D_0 may be chosen from a series of observed pairs of values (D_i, $\log E_i$) such that the sum of the squares of the differences of the type indicated is a minimum. The expression takes the form for pairs of points (D_1, $\log E_1$); (D_2, $\log E_2$)$\ldots\ldots$(D_N, $\log E_N$):

$$[D_1 - (D_0 + \gamma \log E_i)]^2 + [D_2 - (D_0 + \gamma \log E_2)]^2 + \ldots\ldots + [D_N - (D_1 + \gamma \log E_N)]^2 = \text{a minimum} \tag{3}$$

Written more briefly:

$$\sum_{i=1}^{i=N} [D_i - (D_0 + \gamma \log E_i)]^2 = \text{a minimum} \tag{4}$$

The minimum value of this summation is attained when, of all the possible values of γ and D_0, those values are chosen for which the rate of change of the value of the summation with small changes of γ or D_0 is zero. Mathematically, this is stated by:

$$\frac{\partial}{\partial \gamma} \sum_{i=1}^{i=N} [D_i - (D_0 + \gamma \log E_i)]^2 = 0 \tag{5}$$

and

$$\frac{\partial}{\partial D_0} \sum_{i=1}^{i=N} [D_i - (D_0 + \gamma \log E_i)]^2 = 0 \tag{6}$$

Performing the partial differentiations indicated, and simplifying somewhat, there result

$$\sum_{i=1}^{i=N} [D_i - (D_0 + \gamma \log E_i)] \log E_i = 0 \tag{7}$$

$$\sum_{i=1}^{i=N} [D_i - (D_0 + \gamma \log E_i)] = 0 \tag{8}$$

as two equations which maybe solved for γ and D_0. Solving these equations and writing

$$K = \frac{N}{N \sum_{i=1}^{i=N} (\log E_i)^2 - \left(\sum_{i=1}^{i=N} \log E_i \right)^2} \tag{9}$$

$$M = \frac{\sum_{i=1}^{i=N} \log E_i}{N \sum_{i=1}^{i=N} (\log E_i)^2 - \left(\sum_{i=1}^{i=N} \log E_i \right)^2} \tag{10}$$

$$\gamma = (K \log E_1 - M) D_1 + (K \log E_2 - M) D_2 + (K \log E_3 - M) D_3 + \ldots\ldots + (K \log E_N - M) D_N \tag{11}$$

where the expressions in parentheses can be calculated as soon as the values of relative log E are known. Gamma is thus obtained as the sum of a series of terms, one term for each exposure used on the straight-line portion of the curve.

The nature of equation (11) is such that an error in determining the density has greater and greater effect as it departs more and more from the average of all densities observed.

In practice the values of the terms $(K \log E_i - M)$ are calculated for a given negative as soon as the effective printing densities are determined, since it can be shown that these expressions depend only upon the relative exposures, not upon their absolute values. As an aid in routine work, tables are prepared showing values of the product $(K \log E_i - M) D_i$ for the range of densities likely to be encountered in

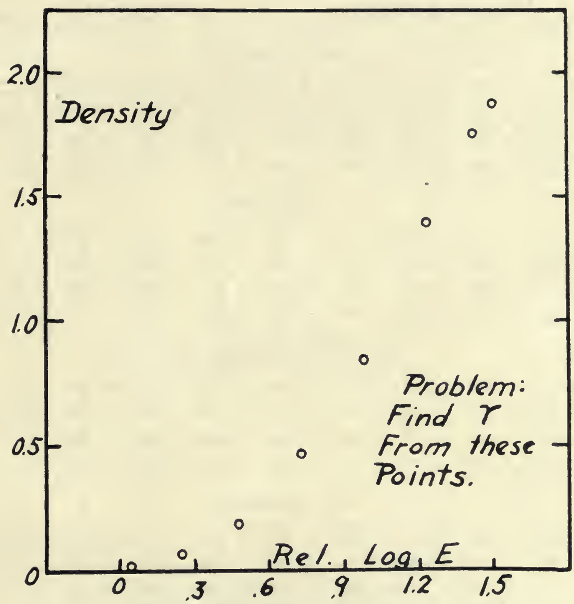

FIG. 2. Characteristic curve of positive, showing non-uniform spacing of points.

the testing. After preparing these tables, the computation of gamma becomes merely the operation of using the tables in order to find the contribution toward gamma of any density occurring experimentally, and adding the tabular values thus found. The term *adding* is here used in the algebraic sense, as one or more of the factors $(K \log E_i - M)$ will always be negative. Density is always positive, hence some of the terms are negative and will be subtracted when finding the sum, gamma, in the adding machine.

Values taken from tables calculated for the negative film of Fig. 1

TABLE I

Values of $(K \log E_i - M)D_i$

The body of the table gives the values of the terms of equation (11) calculated for the positive densities indicated at the left and top of the table. The computations are based upon the negative of Fig. 1, of which, taking the exposure through the fog area as represented by $\log E_1 = 1.50$ (E is in arbitrary units), the relative log E values are

$$\log E_1 = 1.50; \quad \log E_2 = 1.41; \quad \log E_3 = 1.23; \quad \log E_4 = 0.98.$$

Positive Density	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
					$+D_1$ (Add)					
1.8	2.51	2.52	2.54	2.55	2.56	2.58	2.59	2.61	2.62	2.64
1.9	2.65	2.66	2.68	2.69	2.71	2.72	2.73	2.75	2.76	2.77
2.0	2.79	2.80	2.82	2.83	2.84	2.86	2.87	2.89	2.90	2.91
2.1	2.93	2.94	2.96	2.97	2.98	3.00	3.01	3.02	3.04	3.05
					$+D_2$ (Add)					
1.7	1.40	1.41	1.42	1.42	1.43	1.44	1.45	1.46	1.47	1.48
1.8	1.48	1.49	1.50	1.51	1.52	1.52	1.53	1.54	1.55	1.56
1.9	1.56	1.57	1.58	1.59	1.60	1.61	1.62	1.62	1.63	1.64
2.0	1.65	1.66	1.66	1.67	1.68	1.69	1.70	1.70	1.71	1.72
					$-D_3$ (Subtract)					
1.3	0.41	0.42	0.42	0.42	0.42	0.43	0.43	0.43	0.44	0.44
1.4	0.44	0.45	0.45	0.45	0.46	0.46	0.46	0.47	0.47	0.47
1.5	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50
1.6	0.51	0.51	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.54
					$-D_4$ (Subtract)					
0.7	1.33	1.35	1.37	1.39	1.41	1.43	1.44	1.46	1.48	1.50
0.8	1.52	1.54	1.56	1.58	1.60	1.62	1.64	1.65	1.67	1.69
0.9	1.71	1.73	1.75	1.77	1.79	1.81	1.82	1.84	1.86	1.88
1.0	1.90	1.92	1.94	1.96	1.98	2.00	2.02	2.03	2.05	2.07

For the set of positive densities of Figs. 2 and 3;

$$D_1 = 1.87; \quad D_2 = 1.75; \quad D_3 = 1.39; \quad D_4 = 0.84;$$

the gamma computation is

D	Corresponding Term from Table
$D_1 = 1.87$	+2.61
$D_2 = 1.75$	+1.44
$D_3 = 1.39$	−0.44
$D_4 = 0.84$	−1.60
Therefore γ =	2.01

are given in Table I. These are arranged for use when the fog area and the three lowest densities of the negative are printed on the straight-line portion of the positive. Using the densities plotted in Fig. 2, the gamma is obtained by adding the four tabular values as shown just below the table.

This application of the method of least squares has been an outstanding aid, and a time-saver in obtaining gamma from the prints through a negative sensitometric strip. The saving of time is not as

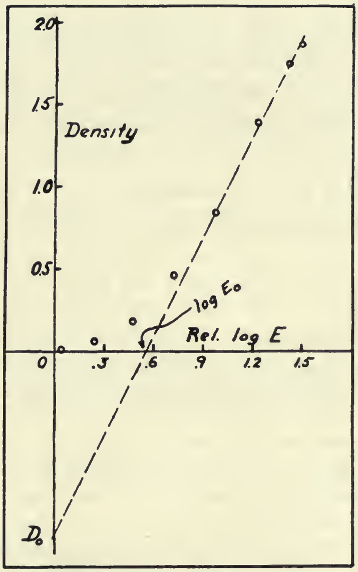

FIG. 3. Construction used for deriving equation (1).

important in cases when the values of log E representing the exposures are separated by equal intervals on the log E axis. For such cases, where δ is the uniform interval of separation for the log E's, the equation for γ reduces to

$$\gamma = \frac{D_1 - D_2}{\delta} \quad \text{for 2 exposures} \qquad (12)$$

$$\gamma = \frac{D_1}{2\delta} - \frac{D_3}{2\delta} \quad \text{for 3 exposures} \qquad (13)$$

$$\gamma = \frac{3D_1}{10\,\delta} + \frac{D_2}{10\delta} - \frac{D_3}{10\delta} - \frac{3D_4}{10\,\delta} \quad \text{for 4 exposures} \qquad (14)$$

$$\gamma = \frac{2D_1}{10\delta} + \frac{D_2}{10\delta} - \frac{D_4}{10\delta} - \frac{2D_5}{10\delta} \quad \text{for 5 exposures} \tag{15}$$

All of these equations are written to make gamma positive when D_1 is the highest density of the series, $D_1 \ldots . . D_N$ being successively decreasing densities. Equation (12) is merely the algebraic solution for the slope of a line passing through two points separated by the amount δ on the log E axis and by the amount $(D_1 - D_2)$ on the density axis. The other equations give gamma as the sum of a series of terms.

The calculation of the term D_0 of equation (1) would follow similar lines, but this is of relatively little interest by itself since it is not a constant customarily used in the discussion of H & D curves. The point of intersection of the straight line and the log E axis (call it log E_0) is frequently of interest, as it is associated with the H & D speed of the emulsion. This point of intersection may be found from equation (8) above by making the substitution (Fig. 3):

$$D_0 = -\gamma \log E_0 \tag{16}$$

which follows as a consequence of the fact that D_0 is the intercept of the straight line on the density axis and log E_0 its intercept on the log E axis. There results from this substitution:

$$\sum_{i=1}^{i=N} [D_i - \gamma (\log E_i - \log E_0)] = 0 \tag{17}$$

from which results:

$$\log E_0 = \frac{\sum_{i=1}^{i=N} \log E_i}{N} - \frac{\sum_{i=1}^{i=N} D_i}{\gamma N} \tag{18}$$

or

$$\log E_0 = \text{av. of the } \log E_i\text{'s} - (\text{av. of the } D_i\text{'s})/\gamma$$

this is not quite as simple to solve, though it offers no great difficulties because the first term may be calculated for all tests of the negative as soon as the log E's are determined, and the second term is obtained by adding the densities occurring in any test and dividing by γN, leaving only the subtraction of the two to give log E_0. In closely related tests in which only relative values of log E_0 are desired, only the last term needs be calculated, since the first is constant when the source of light and the negative are maintained the same.

Carrying out the computation of equation (18) for the positive test shown in Fig. 3, we have:

$$N = 4; \ \Sigma \log E\text{'s} = 1.50 + 1.41 + 1.23 + 0.98 = 5.12;$$
$$\Sigma D\text{'s} = 1.87 + 1.75 + 1.39 + 0.84 = 5.85; \text{ and}$$
$$\gamma = 2.01 \text{ (as previously computed), yielding}$$
$$\log E_0 = \frac{5.12}{4} - \frac{5.85}{4 \times 2.01} = 0.55$$

Although this locates the point of intersection of the straight line with the log E axis, it does not appear in practice to give an exact measure of the speed of the emulsion as it is judged in picture work, and hence is of less importance than gamma.

REFERENCE

[1] WHITE, D. R.: "Two Special Sensitometers," *J. Soc. Mot. Pict. Eng.*, **XVIII** (Mar., 1932), No. 3, p. 279.

DISCUSSION

MR. CARLTON: Quite often a point occurs considerably out of line, perhaps due to a temporary thickness of the emulsion, or some idiosyncrasy of development. And while a method of this kind may be applicable for a man who does not understand the technology of films, I think he is liable to err considerably by using a formula of this type.

All that is required to determine the gamma or contrast of a set of plots is to line up a piece of transparent film, and to read the gamma directly. Using this method it is easy to see whether something is out of order at this point or that. But if merely the reading is taken for the density, the fact that that point is out of place will not be noticed. And as Mr. White has derived his formula from the departures of these points from the mean, the one point in question might be large enough to cause a considerable variation in the results. Has it occurred that after determining the gamma by this method, one point was later found to be greatly off?

MR. WHITE: That occurs, of course. There are two answers to the question: First, that a person using this method can, after some little experience, very readily determine by inspection whether the densities are reasonably correct and whether there are large errors.

Second, as will be noticed by the form of the equation, if one point (indicating equation) is off, it would not appreciably affect the value of gamma, even for large errors.

Small errors do, of course, occur; but if a plain blunder occurs in making a reading, or some unknown things disturb the reading by one- or two-tenths, as sometimes inexplicably occurs, such extreme cases usually can be detected by the person doing the work; by glancing over the data and by having a "feel" for it, as it were. When the differences are small, it is an open question as to what may be the best method of making the determination; whether to take the three points that lie on the line and ignore the fourth, which does not; or to draw the line between the points, throwing some errors one way and some the other.

The mathematical method assumes the line drawn between the points, giving value to all of them.

It is my belief it is best to assign equal weights to all the points; in other words, to let the deviations fall where they may in computation, so long at large blunders have been avoided.

MR. MACNAIR: A method is known, of making the least square adjustment of a number of points in what might be called a purely mechanical way. All that is needed is a large drawing board, on which the line is drawn on a large scale, a rubber band being used for each point. To imitate the line a bar is used. According to a well-known method of laying out the points and using the rubber bands, the bar can be suspended in such a way that it will automatically assume the least square relation with all the points. If a large amount of such work is to be done, it is easy to train a young laboratory man to do it by this means in five minutes, for one set of points.

MR. WHITE: There are several such ways of obtaining the same results, but the computation of gamma by the method described here requires much less than five minutes. However, I am glad that you called attention to the mechanical methods of doing such work.

MR. CARLTON: I assume that this method is being used for evaluating gamma on a positive development machine. Why can we not make our exposed strip in the same way and have an automatic milliammeter on the end of the machine? As the exposed strip comes out, either before or after it is dry, a standard curve could be drawn, in terms of transmissions, of course, rather than in terms of density. A person used to the technic of reading these curves would soon be able to tell what the degree of development was, in terms of transmission, instead of in terms of density, because, after all, gamma is only a superficial quantity that has been established for the purpose of interpreting what is going on. With a very little development work, it ought to be possible to design a recorder that would automatically record the degree of development of each roll, so that a permanent record would be produced that could be inspected the instant the end of the roll was reached. No calculations would be required afterward, so that the technician could immediately determine whether or not the developer was exhausted and needed replenishing.

MECHANICAL ADVANTAGES OF THE OPTICAL INTERMITTENT PROJECTOR*

J. L. SPENCE**

Summary.—*The mechanical problems of optical intermittent projectors, related to threading of film, gate structure, running time per reel, operating characteristics, and difficulties more intimately connected with sound film itself, are briefly described. In addition, some attention is given to the economic problems involved in film damage and wear, in the wearing of machine parts, in the use of duplex film on thinner film base. The paper refers to these problems specifically in relation to 16 mm. machines.*

No continuous projector can hope to improve upon the screen picture produced by an intermittent machine. In the intermittent projector, the ideal arrangement of a stationary image and lens is found. With a machine of the non-intermittent type providing definition the equal of that obtained with present-day projectors, the inventor could forget his old arguments (correct or otherwise) of more light on the screen and less eye-strain in view of the many mechanical advantages.

The mechanical and economic advantages are arguments which will enable the continuous type of projector to take its place as an equal in the professional field and a superior one in the amateur 16 mm. field. In the latter case, the addition of sound to the 16 mm. film will emphasize the inherent advantages of this type of machine. The questions of cost and simplicity of operation will undoubtedly determine the extent of its use in this field. It is not the initial expenditure made for the projection equipment, but rather the expense involved in obtaining various films for home projection, that causes the amateur machine to remain upon the shelf.

The intermittent mechanism which complicates film threading and which requires pressure at the gate, is a major factor responsible for film damage. This film damage is one of the important causes of

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Akeley Camera, Inc., New York, N. Y.

the high rentals which must be charged the user in order to assure the film exchange a proper return on its investment. With a projector of the optical intermittent type, film damage would be greatly decreased, permitting a considerable reduction in the rental fee, which, in turn, would conduce to more extensive circulation of films, to the advantage of all concerned.

Experimentation now being carried on with 16 mm. sound-on-film is proving the desirability of a machine of the non-intermittent type. Indications are that satisfactory results are obtainable from a sound track, the speed of which is reduced $2^1/_2$ times, when care is taken in designing the film propelling and guiding mechanism. When this

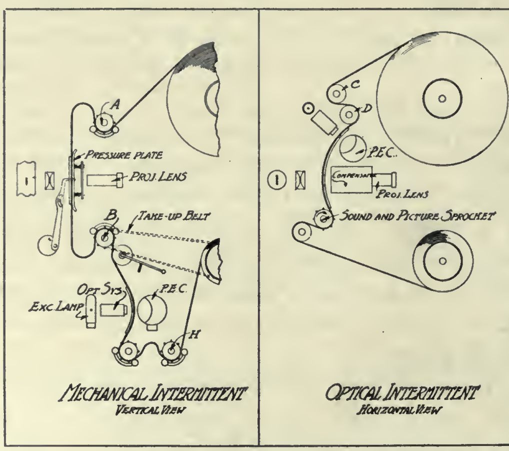

FIG. 1. Comparison diagrams illustrating the relative complexity of threading the mechanical and the optical intermittent projectors.

sound reproducing mechanism is incorporated in a projector of the present intermittent type, certain undesirable features are found to exist.

The fact that the film must move uninterruptedly for sound reproduction but intermittently for the picture, means that there would always be necessary two film feeding systems. In an optical intermittent, the sprocket is already propelling the film correctly for the sound in drawing the film for the picture, and therefore one sprocket will perfectly fit both requirements.

The intermittent motion and the "slapping" of the film loops produces vibration, which is amplified in light, portable machines and is apt to cause interference in properly reproducing sound from film or disk. In an optical machine, no loops are required and, of course, no intermittent exists.

The intermittent motion and the film loops cause noise. In most 16 mm. installations, the projector is unenclosed, and the noise may be very objectionable. In an optical machine, the gearing can be completely encased, eliminating by this means all noise other than the slight hiss of the film in its smooth journey from one reel to the other.

A speed of 24 frames per second or greater causes strains in the present-day light-weight 16 mm. mechanism. As the running speed

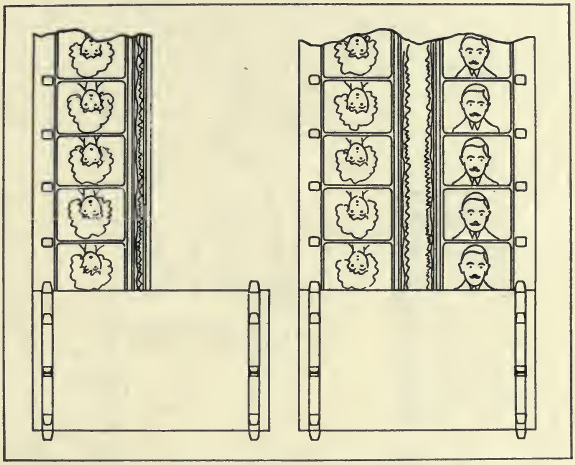

FIG. 2. Sprocket for driving either single- or double-width film.

is increased, the gate pressure on an intermittent machine must necessarily be increased also. In the continuous machine, the speed is practically unlimited and can be obtained by merely increasing the motor speed without other adjustment.

Pressure is required at the gate of an intermittent machine to stop and hold the film. The resulting film friction is one of the principal detriments to a long film life, as is universally recognized. No pressure is required at the gate in an optical machine, flatness being secured by virtue of an arcuate form. With the film running on the celluloid surface, damaging of the emulsion can never occur.

Complexity of threading is exemplified in Fig. 1. In an intermittent machine, it is necessary to form a loop above and below the pull-down mechanism. To obtain this loop the film must pass over a sprocket before and after passing the gate and the intermittent mechanism, resulting in an average of nine operations for threading. The addition of another sprocket, which would be necessary for sound-on-film, adds at least four more operations. Improper threading by the operator in any of these operations could result in severe film damage. In some projectors, sprockets *A* and *B* are combined into a single sprocket. The sprocket *H*, acting as a hold-back sprocket, might also be eliminated in practice, but at present it does not seem

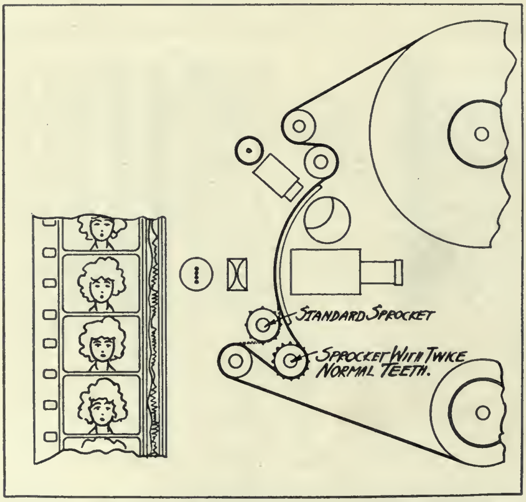

FIG. 3. Method of feeding film having standard or doubled perforations.

advisable to do so. In a non-intermittent machine the rollers *C* and *D* could be eliminated, and the film could pass directly over the sound and picture gates. No doors or pressure shoes would be necessary, as the film would remain true owing to the arcuate form. The film then passes around the sprocket and over the idler roller, which may be stationary and separated a sufficient distance from the sprocket teeth to permit fitting the film on the sprocket. It is not necessary in threading this type of machine to see that the holes of the film engage the teeth of the sprocket. The starting of the machine will cause proper engagement immediately.

It should be noted that in Fig. 1, horizontal film reels are shown.

(See projection lamp position.) This is not, of course, imperative; nor is the design solely applicable to optical intermittent machines. Experimentation will prove that the horizontal reel has many advantages over the vertical type. The operator will find it easier to thread a reel lying in a horizontal plane, and the reels may be single-flanged, greatly facilitating threading. A uniform take-up tension can readily be designed, depending for its action on the increased weight

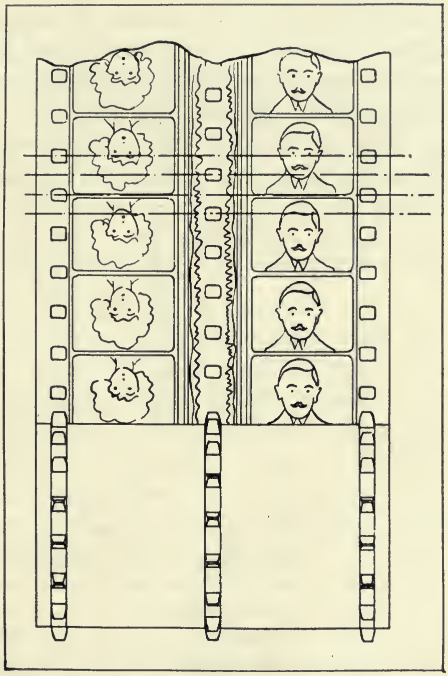

FIG. 4. Double-width film having doubled and staggered perforations, for increasing the perforation frequency.

of the film roll. With this type of take-up governed by weight, a substantially constant drag is maintained from start to finish. A Porro prism will, of course, be necessary to erect the image for the screen, but the loss of light due to the prisms is a small price to pay for the many advantages derived from the horizontal reel.

In using a single sprocket in a non-intermittent machine, it will be found desirable to have the pull on the film in the direction of the supply reel greater than the pull in the direction of the take-up reel. This will result in the sprocket teeth always being in contact with one side of the film perforations, eliminating the tendency to hunt.

Another desirable, and perhaps necessary, feature will be an increase in the running time per reel. At a speed of 24 pictures per second, the present 400-ft. roll gives a showing of only eleven minutes. A considerable increase in capacity is possible in three ways:

(1) Increased roll diameter (easily practicable when the horizontal film reel and weight-actuated take-up are used).

(2) A double-width film carrying two rows of images, as shown in Fig. 2, one row to be projected first, the reel reversed, and then the second row projected. This provides the added advantage of having the rewinding done automatically.

(3) A decreased thickness of base. Not entirely practicable with a claw-type intermittent, due to the shock encountered at the per-

TABLE I

Comparison of Intermittent with Non-Intermittent Projectors

Items	Intermittent Projector	Non-Intermittent Projector
Sprockets or sprocket contacts	3 Minimum	1
Rollers or equivalent	5	1
Vibrating film loops	2	None
Intermittent claw or sprockets	1	None
Pressure gate or shoe	1	None
Noise	Disturbing in portable projector	None
Vibration	Apt to affect sound reproduction	Insignificant
Threading	Intricate	Simple
Wear on film	Considerable	Minimum
Wear on machine	Maximum	Minimum
Sliding contact of film emulsion	At gate	None
Oiling	Necessary at a number of points	None
Speed	Limited	Unlimited
Take-up tension on film	Maximum to minimum	Constant minimum
Possibility of threading error	9	3
Possibility of film damage	Great	Small
Possibility of using thinner film base	Not very good	Excellent
Application of duplex or double-width film	Inconvenient	Simple

foration edges. There is reason to believe that a film $3^1/_2$ mils in thickness will be found desirable and practical in the optical intermittent machine, which will give an increase of more than 50 per cent in the running time per given roll diameter. It appears doubtful that the thin 16 mm. film can be handled by the laboratories in processing, owing to its tendency to curl. However, the same film could be used if the width were increased to 32 mm., accommodating two rows of pictures. The use of double-width film would impose greater demands on the present type of 16 mm. intermittent machine, which is already heavily taxed at a speed of 24 pictures per second.

An important difference between 16 mm. sound-on-film and 35 mm. is the difference between the perforation frequencies, the conditions being much more favorable in the latter case. It may be found that the frequency must be increased in the case of 16 mm. film, thus necessitating additional perforations per picture. In Fig. 3 is shown a film having twice the number of perforations. Obviously, a special sprocket with a greater number of teeth would be required, and in the case of the continuous projector, such a sprocket could be incorporated as shown, without interfering with the use of standard perforated film. Fig. 4 is an elaboration of this idea, providing for the same perforation frequency as the present 35 mm. film.

Table I clearly points out, in a comparative manner, the characteristic features of the two types of machine.

In conclusion, it is believed that recent developments, which have taken place, point to the appearance, in the near future, of a 16 mm. projector of the optical intermittent type.

DISCUSSION

MR. COOK: Will Mr. Spence tell us something about the possibilities of the non-intermittent machine which he mentioned last?

MR. SPENCE: It is a machine that realizes the possibilities of the non-intermittent machine, as outlined. I hope and feel confident that in the near future we shall have a machine that will project a picture on the screen the equal of those that are now projected by intermittent machines.

MR. RICHARDSON: What do you mean by "optical intermittent"?

MR. SPENCE: An optical intermittent projector is one in which the film moves continuously, the successive pictures being rendered stationary on the screen by an optical mechanism. The difference between an optical intermittent projector and a continuous projector would be: In continuous projection the pictures fade one into the other, whereas, in the other case, dark spots occur between pictures, equivalent to the effect produced by a shutter but not of as long duration as in intermittent projection.

THE MECHANISM OF HYPERSENSITIZATION*

BURT H. CARROLL AND DONALD HUBBARD**

Summary.—*Ammonia treatment of photographic materials used for hypersensitizing leaves them with excess silver over bromine. Working with known dyes in experimental emulsions, the Bureau of Standards has shown that this excess silver accounts for the photographic effects of the ammonia.*

As hypersensitization has been a controversial subject, some authorities denying even its existence, it will be well to begin with our definition. We mean by hypersensitization an increase in the effect of sensitizing dyes on an emulsion, produced by the addition of some other material. We are, therefore, including materials added to a dye bath, as well as those used for treating finished panchromatic emulsions; the mechanism is the same in both cases. Hypersensitization always involves some increase in speed to white light, but the characteristic feature is the improvement of the relative color-sensitivity, for example, the ratio of yellow to blue sensitivity.

We propose to show that the treatments used in hypersensitization leave the emulsion with an excess of silver over halogen, and that the resulting increase in silver-ion concentration, plus the alkalinity of most of the baths, can account for the observed results.

There are apparent exceptions to this in the literature. A general discussion of these is unnecessary, although it seems worth while to point out the possibilities of error resulting from inadequate controls. The first is the assumption that because treatment with a solution of some material improves the color-sensitivity of a panchromatic emulsion, the dissolved substance is necessarily responsible; it may have been merely the water. We have had cases of emulsions whose sensitivity to red light was tripled simply by washing out the soluble bromide. Lack of controls is apparently responsible for claims that have been made for a mixture of hydrogen peroxide and difficultly soluble silver salts, ammonia being added to dissolve the latter. As

* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Publication approved by the Director of the Bureau of Standards.

** Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

the effect was attributed to the formation of new silver nuclei by the peroxide, a theory inconsistent with our results, the experiments were carefully repeated, using the same plates as the original investigator. The mixture undoubtedly hypersensitizes, but we found that the best results were obtained with the ammonia alone. The peroxide was only a handicap.

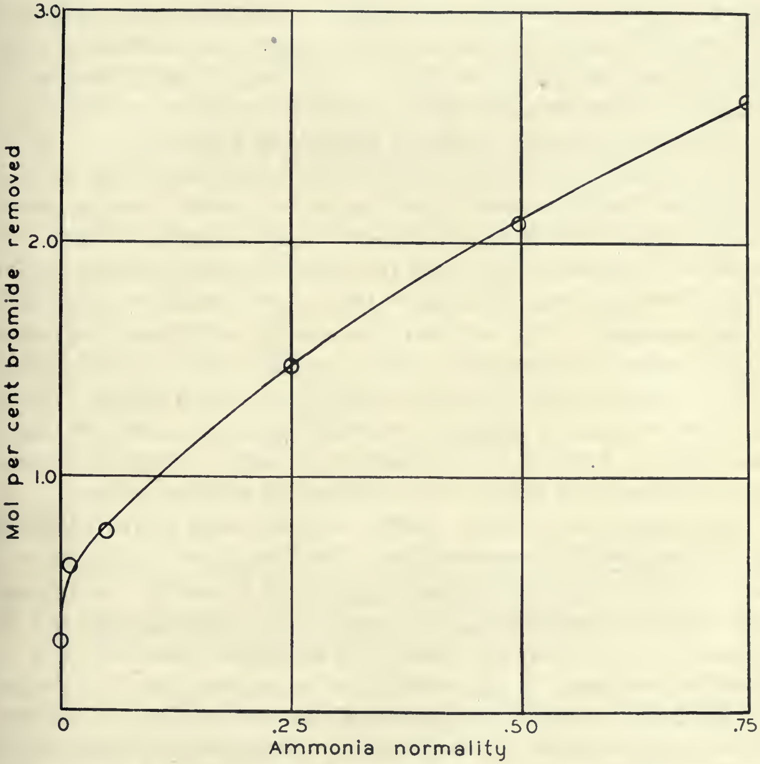

FIG. 1. Bromide removed from emulsion by ammonia treatment.

Another source of conflicting reports is the dependence of hypersensitization on the dye, and to a lesser extent on the emulsion, which we hope to show in this paper. We found, for example, that different brands of panchromatic plates and films from a single maker varied widely in their capacity for hypersensitizing.

For hypersensitization, in practice and for the purpose of discussion as well, we need consider only the use of ammonia and of ammonia plus small amounts of dissolved silver salts. Let us take first the results of bathing a photographic plate or film in ammonia, as in hypersensitizing. The ammonia, of course, extracts silver bromide in amounts increasing with the concentration. But, after this effect has been eliminated by evaporating or neutralizing the ammonia, the solution is found still to contain soluble bromide, in amounts increasing with the original ammonia concentration. The curve in Fig. 1 is a plot of this soluble bromide, expressed as molecular per cent of the silver bromide in the emulsion, against the normality of the ammonia solution used in bathing. This was for Seed's 23 plates; the results with other emulsions are very similar. Practically all emulsions contain small amounts of soluble bromide as a preservative, but extraction with water only will remove this. Analysis by other methods established that there was no such amount of soluble bromide present in the original emulsion as was found in the ammonia extracts. It, therefore, must have come from the silver bromide in some way, and, if there is excess bromide in the extract, there should be excess silver in the emulsion. This last fact was readily established; extraction of the ammonia-treated plates with very dilute acid (0.01 N acetic, or 0.001 N sulphuric) removed silver equivalent to the bromide. Hypersensitized emulsions, therefore, contain as much as one per cent of their silver in some form other than the bromide. Other experiments have demonstrated that it is in combination with the gelatin.

An explanation of these results requires more physico-chemical theory than we wish to present here; it will be given in full in an early issue of the Bureau of Standards *Journal of Research*. We changed our theories repeatedly in the course of the investigation, but the excess of the silver in the emulsion is an experimental fact and was therefore unaffected by the reliability of our explanation. The reason for the nearly unique effectiveness of ammonia is that it is alkaline, volatile, and capable of dissolving silver bromide by forming a positively charged complex ion containing the silver; all these properties are essential if the emulsion is to be left with excess silver after treatment.

Before going on to the experimental demonstration that the behavior of dyes is the same whether ammonia treatment or addition of soluble silver salts is used to introduce excess silver into the emulsion, it will be necessary to review some of the physical chemistry of the emulsion. There is always a considerable amount of water even in air-dry gelatin. In the emulsion, this water will be saturated with silver bromide, which is a very difficultly soluble salt, but has nevertheless a real and definite solubility, so that there are always silver and bromide ions present. These obey one of the familiar laws of physical chemistry: the product of their concentrations in a saturated solution is always equal to a constant at a given temperature. In the case of silver bromide, this is 10^{-12}; that is, if there is no excess of silver or bromide ions, each is one one-millionth normal. Because the solubility product is so small, small amounts of either ion can produce enormous changes in the relative concentrations. For example, if we add to a saturated solution of silver bromide 0.1 gram of potassium bromide per liter, the bromide-ion concentration is 10^{-3}

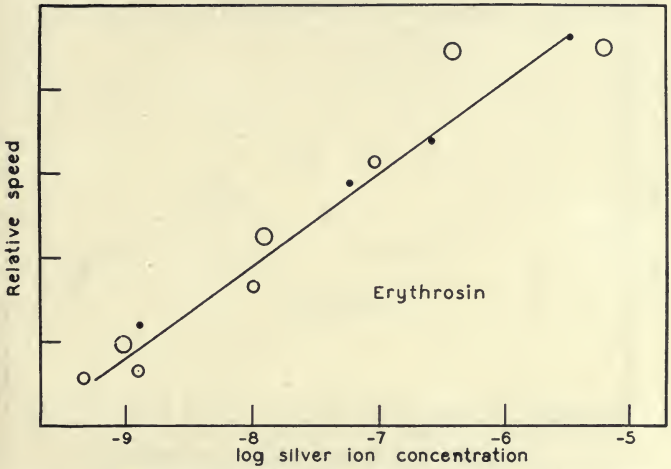

FIG. 2. Change in color-sensitivity of erythrosin-sensitized emulsions with silver-ion concentration.

normal, while the silver-ion concentration becomes 10^{-9}—that is, it is divided by one thousand. The stability of an emulsion decreases with increasing silver-ion concentration, so that small amounts of soluble bromide can greatly improve the keeping qualities, as is well known to emulsion makers. Conversely, it is obvious that hypersensitized emulsions, with excess silver, must necessarily be relatively unstable. The increase in silver-ion concentration with increasing excess silver is fortunately much slower than the corresponding changes produced by excess bromide. This is caused by the strong affinity of gelatin for the silver ion, with a consequent "buffer" action; most of the excess silver is bound by the gelatin, and only part is available to raise the concentration of free silver ions. A somewhat similar principle is used in most of the hypersensitizing baths containing silver salts dissolved in the ammonia; silver chloride or some other difficultly soluble salt is used so that the final silver-ion concentration in the plate, after bathing and drying, is determined by the solubility of the salt. Saturated silver chloride gives a silver-ion concentration of 1.5×10^{-5} *N;* this is very much greater than that of a bromide emulsion with excess bromide, but silver chloride in excess of the amount required for saturation remains as solid so that this value is the maximum that can be produced. The advantage, if any, of these baths, is that a higher silver-ion concentration can be obtained with

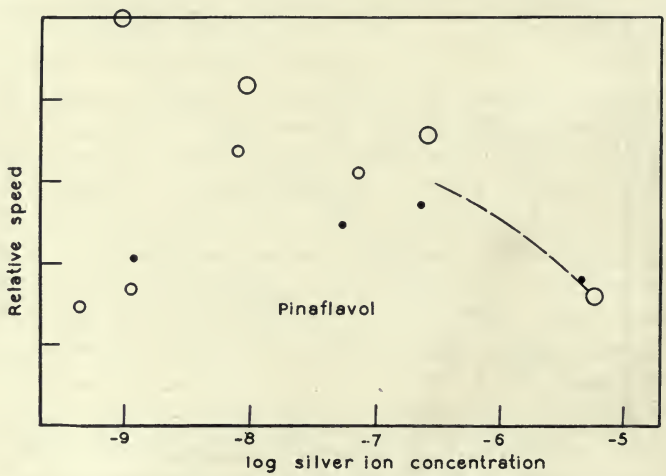

Fig. 3. Change in color-sensitivity of pinaflavol-sensitized emulsions with silver-ion concentration.

dilute ammonia and correspondingly low alkalinity, but we have so far found no marked advantage over plain ammonia.

Increase in silver-ion concentration causes little increase in photographic sensitivity in the absence of dyes, but in many cases it produces a marked improvement in sensitivity of a given dye-emulsion combination to the longer wavelengths. Using known dyes in experimental emulsions, we have compared the effect of excess silver added to the emulsion, and of ammonia treatment of finished plates, and have found it to be qualitatively the same in both cases. These experiments have also brought out very clearly the dependence of hypersensitization on the dye. We report here on three sensitizers representing different classes: the acid dye, erythrosin; and the basic dyes, pinacyanol and pinaflavol, which in water are probably in colloidal and true solution, respectively.

Figs. 2, 3, and 4 show the change in color-sensitivity of experimental emulsions with varying silver-ion concentration. Batches of emulsion were sensitized with one of the dyes, then subdivided into smaller portions to which were added appropriate amounts of soluble bromide or silver salts.

We have plotted the speed to light screened by an appropriate lter (usually the Wratten Minus Blue) against the logarithm of the

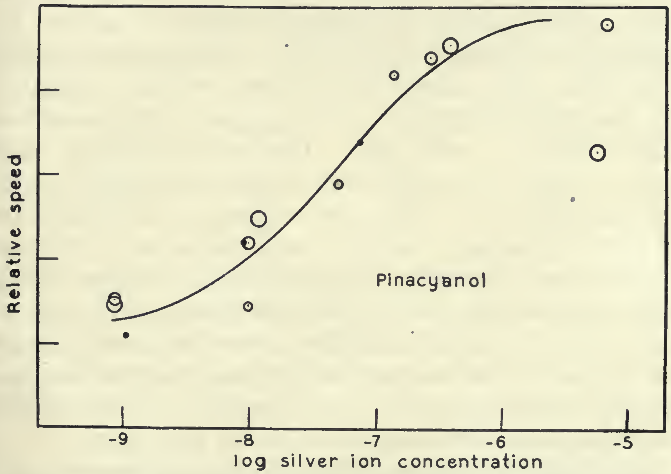

FIG. 4 Change in color-sensitivity of pinacyanol-sensitized emulsions with silver-ion concentration.

silver-ion concentration; γ was nearly constant so that the speed number was a fair measure of sensitivity. Each illustration gives the results for a single dye. The results for separate batches of emulsion, representing both neutral and ammonia types, have been plotted on different scales, so that it was possible to make a graphical average into a single curve indicating the general trend.

Taking first the erythrosin (Fig. 2), there is a steady increase in speed with increasing silver-ion concentration. This is to be expected on theoretical grounds. Erythrosin ionizes into the colorless sodium ion and a negatively charged dye ion. Since the dye ions are negatively charged, they should be attached to the positive silver ions of silver bromide crystal surfaces. If bromide ions are present, they compete with the dye ions for the surface of the silver bromide grains. The resulting change in adsorption of the dye was readily detected in these experimental emulsions.

Pinaflavol and pinacyanol are both basic dyes, the iodides or bromides of complex nitrogen bases. Since the dye ions are positively charged, the theory just applied to erythrosin predicts that their adsorption to silver bromide should *decrease* with increasing silver-ion concentration, in contrast to the acid dye, erythrosin. Experimentally, we found that the sensitivity of the emulsions containing pinaflavol fell off at the higher silver-ion concentrations, as indicated in Fig. 3. The results were difficult to reproduce, because the dye has a strong tendency to cause fog, and are difficult to measure because the region of sensitization lies so close to the natural sensitivity of silver bromide. We cannot say positively whether pinaflavol also has the decrease of sensitivity with increasing excess bromide which is characteristic of most dyes. Pinacyanol-sensitized emulsions increased in sensitivity continuously with increasing silver concentration, as shown in Fig. 4. We have no evidence to account for this failure of the photographic effect to correspond with the adsorption theory. We can only point out two things. In the first place, pinacyanol is almost certainly a colloid in water, and the ionic theory may not apply. In the second place, it is a reasonable assumption that the photochemical sensitivity of the dye-silver bromide system increases with increasing silver-ion concentration, so that this independent factor opposes the adsorption effect for basic dyes.

In comparing these data with the following data on the effect of ammonia, again remember that the experimental results can be considered, independent of our explanations of them.

Comparative data on the effect of ammonia on these dyes are

TABLE I

Erythrosin

Comparison of color-sensitivity of erythrosin-sensitized emulsions with and without ammonia treatment.

Dye in	Emulsion	Speed through Filter With Ammonia	Without
Bath	*B*	43	22
	C	13.2	3.0
	44	20.3	13.9
Emulsion	87	40	30
	92	49	31.5

TABLE II

Pinaflavol

Comparison of color-sensitivity of pinaflavol-sensitized emulsions with and without ammonia treatment.

Dye In	Emulsion	Speed through Filter With Ammonia	Without
Bath	*A*	13.5	15
	44	2.6	6.0
Emulsion	87	13.8	15.2
	93	43.5	43.0

TABLE III

Pinacyanol

Comparison of color-sensitivity of pinacyanol-sensitized emulsions with and without ammonia treatment.

Dye In	Emulsion	Speed through Filter With Ammonia	Without
Bath	*A*	54	26
Emulsion	93	79.5	57.5
	92	35	33

presented in Tables I, II, and III. The commercial emulsions (designated by letters) were first washed, then bathed in solutions of the dyes with and without ammonia. The experimental emulsions were sensitized before coating, and were bathed in pure water and in ammonia solutions. Silver-ion concentrations could not be measured in the set emulsions, but working from the amounts of bromide extracted we may say that after the ammonia treatment the excess silver was about the same as the maximum used in the experiments where it was added to the emulsions. The water wash left little excess of either bromide or silver. The silver-ion concentration must have been about 10^{-6} to 10^{-7} N. Contrast being nearly constant, we have again given speed numbers as measures of color-sensitivity using the minus blue filter as before.

It is evident from these figures that erythrosin-sensitized and pinacyanol-sensitized emulsions are readily hypersensitized by ammonia, while those containing pinaflavol are unchanged or actually depressed in sensitivity. This corresponds exactly with their behavior on increasing the silver-ion concentration, thus completing our chain of proof.

The alkalinity of ammonia is a further asset in hypersensitizing, as most dyes are more effective when the emulsion is slightly alkaline

(pH 8.0 to 8.5) than when it is strictly neutral or faintly acid. It also appears that, with a given excess of silver, there is less fog in faintly alkaline emulsions, because the free silver-ion concentration is lower. At any rate, while it is possible to hypersensitize by bathing in dilute solutions of silver salts, the results are distinctly less satisfactory than with ammonia.

In this case, a better understanding of a previously obscure process does not lead at once to practical improvement. The instability of the emulsion with excess silver imposes a limit to the increase of color-sensitivity in this way. We have, however, demonstrated the correlation between other properties of the dye and its capacity for hypersensitization, and hope to extend this line of investigation further.

DISCUSSION

PAST-PRESIDENT CRABTREE: The speed and temperature of drying has a great effect on hypersensitization. Have you made tests on the keeping qualities, growth of fog, and loss of speed?

MR. CARROLL: The keeping qualities were about the same in both cases, for plates treated with ammonia and for those in which silver was added to the emulsion.

MR. PALMER: What is the best way in which to preserve the excess sensitivity as long as possible?

MR. CARROLL: The only thing to do is to put it into the ice-box and to hold the temperature as low as possible; the lower it is the better, provided that it does not freeze. The effect of moisture should also be considered. It would be expected that anything of this nature would keep better if kept thoroughly dry, or as dry as possible without stripping the emulsion from the support.

ADVANTAGES OF USING 16 MM. SUPERSENSITIVE PANCHROMATIC FILM IN MAKING MEDICAL MOTION PICTURES*

HARRIS B. TUTTLE** AND R. PLATO SCHWARTZ†

Summary.—*Due to the great speed of supersensitive film to Mazda lights, it is possible to make satisfactory medical motion pictures under lighting conditions impossible with regular panchromatic film. The high red sensitivity of this new film permits the recording of detail lost in the past. Telephoto lenses can now be used, giving both the photographer and the surgeon more freedom of movement, with less danger of interfering with aseptic precautions.*

Although the use of motion pictures as a means of revealing operative procedures for the training of physicians and surgeons is not expected ever to become of commercial importance to the motion picture industry, it is believed that this is an instance where values greater than economic assets must be considered. Human life and comfort are dependent on the results of any major surgical operation. Not all branches of surgery lend themselves readily to the use of motion pictures in the teaching of surgical technic. It follows, therefore, that care should be taken in selecting the field chosen for our initial efforts, lest motion pictures be censured, when in reality the fault lay in the selection of the subject.

Individual patients present wide variations in the same condition which requires surgical treatment. All surgeons may agree in principles governing operative procedures but differ in methods of execution. The method by which motion pictures are to be made available for teaching surgery cannot, therefore, be the same as that which is represented by Hollywood in the field of entertainment. Honest effort in this direction has failed, at the cost of several hundred thousands of dollars, chiefly because these two facts were not considered of great importance in relation to the outcome of the undertaking. Because of these prevailing conditions, our course is, for the present,

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Eastman Kodak Company, Rochester, New York.

† Strong Memorial Hospital, Rochester, New York.

well defined. It should be directed toward the solution of the problems confronting the individual surgeon interested in the application of motion pictures to the problems of surgery.

One of the greatest difficulties is the making of motion pictures in the operating room. The advent of 16 mm. film and the reversal process considerably lessened the expense to the medical profession of making surgical motion pictures. The manufacture of compact and efficient lighting units has helped considerably in the progress of making surgical pictures.

Even with panchromatic film, which is sensitive to all colors

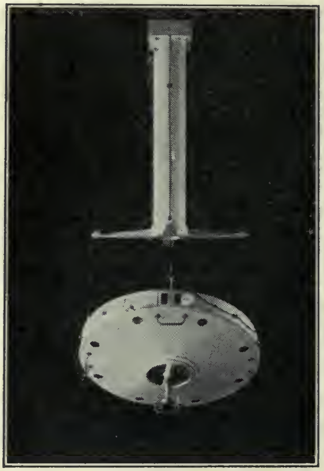

FIG. 1. Bausch & Lomb operating room lamp.

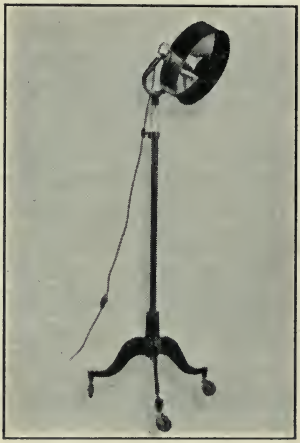

FIG. 2. Bausch & Lomb floor lamp.

(but slightly more sensitive to blue and to green than to red), and with modern lighting equipment, surgeons have been unable to record and reproduce perfectly all the necessary details. However, the results obtained during the past year or two have been much more satisfactory than anything previously attained.

In this branch of motion picture photography there have been a great many difficulties to overcome. Principal among these was the rendition of the operative field and of the tissues surrounding the incision, which are always reddish in color. On the old regular film, which was not sensitive to red light, these reddish areas in and around the incision would always come out black, showing little or no detail in the delicate structures where clarity of detail was very important. With the use of 16 mm. panchromatic film, this objection was somewhat overcome. While the red areas were rendered more accurately than before, there was still considerable difference between the photographic reproduction on the screen, and the actual subject.

The second important difficulty in making such pictures was the size and inconvenience of using artificial lighting equipment. Lighting units consisting of three 500-watt bulbs were not readily accepted by the average surgeon, and the necessity of having an $f/1.9$ lens cam-

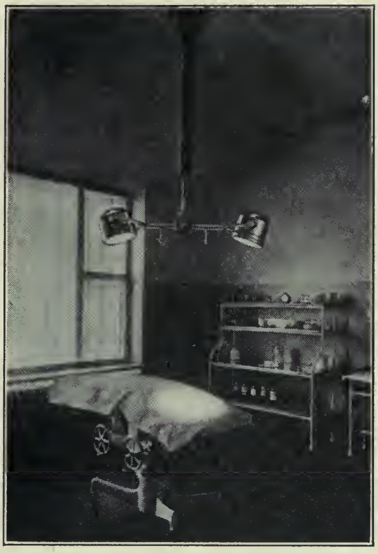

FIG. 3. Macbeth operating room lamp.

era limited somewhat the field of surgical motion pictures. For those few who had lighting units available, the heat, together with the necessity of meeting the demands of asepsis, prevented the close proximity of lamps, camera, and the operator to the operative field to make clear, well-defined motion pictures.

Recently a new emulsion for amateur use, called Ciné Kodak supersensitive panchromatic film, has been placed on the market. While this film is twice as fast to daylight as panchromatic film, its chief advantage lies in its great speed when exposed to artificial light, to which it is three to four times faster than is the regular panchromatic film. Supersensitive film is especially sensitized in the red portion of the spectrum, so that most of its speed lies in the area in which artificial light is richest.

While this emulsion was designed for high speed work in motion picture studios where artificial lights are used almost exclusively, it was later adapted to the 16 mm. reversal process so as to enable amateurs to make pictures with low intensity lamps. It so happens

FIG. 4. Scialytic operating room lamp.

that its characteristics are ideal for making surgical motion pictures

Probably the most important advantage of this film from an economic point of view is the fact that it is no longer necessary to use any additional artificial light. The lights which are installed over most operating tables are sufficient for making good motion pictures. With the light found in most hospitals, it is possible with supersensitive film to expose at diaphragms $f/3.5$ or $f/4.0$.

It is also possible with fast film and regular operating room lighting to use telephoto lenses. It can readily be seen that this is a very important factor, as heretofore, with a one-inch lens, it has been necessary for the operator to hold the camera from three to four feet from the operative field in order to get an image size which would show sufficient detail to be recognizable on the projection screen. With a three-inch lens placed six feet from the operative field, it is now possible to get an image the same size as could be obtained with the one-inch lens at two feet from the subject.

When using the 3- or $4^1/_2$-inch telephoto lens, it has been found advisable to use a tripod. It is almost impossible to hold a camera absolutely steady. While the small amount of body movement which does exist is not objectionable when a one-inch lens is used, and the resulting field is fairly large, the long focus lenses magnify this movement many times so that the smaller field is unsteady.

Camera Distances	*Approximate Field Size in Inches*	
1" lens		
2 feet	7 ×	$9^1/_2$
3	$10^1/_2$	14
4	$14^1/_2$	19
5	18	24
6	$21^1/_2$	$28^3/_4$
3" lens		
6 feet	7	$9^1/_2$
9	$10^1/_2$	14
12	$14^1/_2$	19
15	18	24
$4^1/_2$" lens		
9 feet	7	$9^1/_2$
12	9	12
15	12	16
18	$14^1/_2$	19

The data given above for the use of supersensitive film are for operating rooms which are illuminated only with artificial light, in other words, pictures made with no daylight present.

A large percentage of all surgical operations are performed in daylight. Because of the diffusion of daylight in most operating rooms, the surgeon requires additional illumination of incisions and cavities by a spotlight such as the Bausch & Lomb or Scialytic, 100-watt, 110-volt, floor lamp. This combined use of daylight and tungsten illumination provides advantages both for the surgeon and for the photographic recording of surgical procedures. A diaphragm opening of $f/4.0$ to $f/5.6$ is correct when these two sources of illumination are combined.

Variations of season, weather, and time of day so alter the intensity of daylight that it is impossible to give precise data on the proper exposure. That this variation of daylight in the operating room is dis-

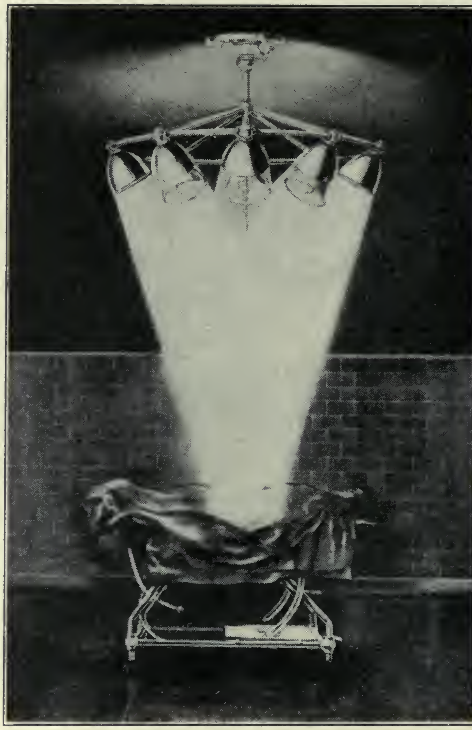

FIG. 5. Mayo operating room lamp.

advantageous to the surgeon, has become more generally recognized with the development of efficient sources of illumination. For some years past many operations have been regularly performed to advantage in special rooms where no daylight was present. It has been suggested by Dr. J. J. Morton, Professor of Surgery, Rochester University School of Medicine, that in the future design of operating rooms, all daylight should be excluded. It is apparent that such conditions would be helpful to the surgeon and would further the application of motion pictures to the problems of surgery.

On regular panchromatic film, it was sometimes advisable to use a *K*-3 or *G* filter to render the red areas more faithfully. The use of such filters, however, made it necessary to allow two or three stops difference in exposure, thus sacrificing some depth of focus and general definition. Supersensitive panchromatic film is highly self-corrective, making it unnecessary to use filters in photographing operative work.

The first experiments with supersensitive film were carried out at the Strong Memorial Hospital in Rochester, New York. Tests were made with three very different types of operating room lights having 110-volt circuits. All experiments were conducted at night so that no daylight or room illumination could cause variations in results.

In order to have a cross-section of results obtainable with other types of 110-volt lamps, similar experiments were made at three other Rochester hospitals.

The summary of these tests showed that in operating rooms having from 400 to 600 watts available, at approximately 40 inches from the operative field, satisfactory exposures could be made at diaphragms $f/5.6$ to $f/8.0$; where 200 to 400 watts were available, diaphragms $f/2.8$ to $f/4.0$; and where only single units of 100 watts were available, diaphragms $f/1.9$ to $f/2.8$.

Strong Memorial Hospital.—Bausch & Lomb mirror spot dome lamp, 500-watt, 110-volt lamp, 40 inches from operative field, at diaphragms: $f/1.9$ to $f/5.6$, and telephoto $f/4.5$.

	$f/2.8$—satisfactory exposure
	$f/4.0$—satisfactory exposure
3″ telephoto	$f/4.5$—satisfactory

Scialytic, one 100-watt, 110-volt, mirror reflector, 40 inches from operative field, at diaphragms: $f/1.9$ to $f/5.6$, and telephoto $f/4.5$.

	$f/2.8$—satisfactory exposure
	$f/4.0$—satisfactory exposure
3″ telephoto	$f/4.5$—under-exposed

A 100-watt, 110-volt auxiliary operating room spotlight should be used with a 100-watt, 110-volt Scialytic.

Macbeth, twin operating room light, two 150-watt, 110-volt lamps in twin dome receptacles diffused 40 inches from operative field, at diaphragms: $f/1.9$ to $f/5.6$, and telephoto $f/4.5$.

$f/2.8$—satisfactory exposure
$f/4.0$—satisfactory exposure
3″ telephoto $f/4.5$—satisfactory exposure

Highland Hospital.—Regular operating room lights. Double dome, two 150-watt, 110-volts, diffused: $f/1.9$, $f/2.8$, $f/4.0$, $f/5.6$, and telephoto $f/4.5$.

$f/1.9$—correct exposure

Repeated with Scialytic spot, 100-watt, 110-volts, diffused: $f/2.8$, $f/4.0$, $f/5.6$, and telephoto $f/4.5$.

$f/4.0$—correct exposure
3″ telephoto $f/4.5$—satisfactory

Genesee Hospital.—Scialytic dome lamp, one 100-watt lamp in center, three 50-watt lamps in cluster, $f/2.8$, $f/4.0$, $f/5.6$, and telephoto $f/4.5$.

$f/4.0$—correct exposure
$f/5.6$—satisfactory
3″ telephoto $f/4.5$—satisfactory

Repeated with one 100-watt vent light spot added, $f/2.8$, $f/4.0$, $f/5.6$, and telephoto $f/4.5$.

$f/4.0$—correct exposure
$f/5.6$—satisfactory
3″ telephoto $f/4.5$—satisfactory

General Hospital.—Mayo lamps, eight single, 60-watt, 120-volt: $f/2.8$, $f/4.0$, $f/5.6$, and telephoto $f/4.5$.

$f/4.0$—correct exposure
3″ telephoto $f/4.5$—satisfactory

Repeated with 100-watt Bausch & Lomb lamp added: $f/2.8$, $f/4.0$, $f/5.6$, $f/8.0$, and telephoto $f/4.5$, $f/5.6$, $f/8.0$.

$f/5.6$—correct exposure
$f/8.0$—satisfactory
3″ telephoto $f/5.6$—correct exposure
3″ telephoto $f/8.0$—satisfactory

Bausch & Lomb, 100-watt, 120-volt lamp alone: $f/2.8$, $f/4.0$, $f/5.6$.

$f/4.0$—correct
$f/5.6$—satisfactory

Summary of Tests

Hospital	Lamp	Number of Lamps	Wattage (110 v.)	Distance (inches)	Best Exposure (*f*/number)
Strong Memorial	Bausch & Lomb	1	500	40	2.8 or 4.0
	Scialytic	1	100	40	2.8 or 4.0
	Macbeth	2	100	40	2.8 or 4.0
Highland	Regular	2	100	60	1.9
	Regular plus Scialytic Spot	3	100	40	4.0
Genesee	Scialytic	1	100	40	4.0 or 5.6
		3	50		
	Scialytic plus vent light	1	100	40	4.0 or 5.6
		3	50		
		1	100		
General	Mayo	8	60	72	4.0
	Mayo plus Bausch & Lomb floor spot	8	60	72	5.6 or 8.0
		1	100	40	
	Bausch & Lomb floor spot	1	100	40	4.0
In the average hospital	With average lights		250–300	40–45	3.5 to 4.0

DISCUSSION

MR. KURLANDER: I noticed the lack of blood in the last operation. Was the subject a live one or not?

DR. SCHWARTZ: For the most part, we have considered the possibility of making for students, better pictures of a cadaverous foot. For definition of detail of the various structures in this foot, as compared with the colors of the tissues, we had a rendition of proper value in grays, blacks, and whites, in order to set apart the different structures. In other words, when the tendons came out and could be seen, there was not in this operation, or in any other, the possibility of the blood's interfering with the definition recorded on supersensitive film, as compared with the recording of the same operation on any film which we have had heretofore.

The cadaver lends itself particularly well to the teaching of orthopedic surgery, in as much as the parts are easily available. The depth that we have to reach, either in a knee, hip, or an ankle, is not great enough but what we can get to that depth and reveal the details at the bottom.

MR. COWLING: Would it not be a great help if these pictures were made in color?

DR. SCHWARTZ: When we shall have film available that has a sensitivity sufficiently great to permit us to reduce the great illumination now required, we shall be better off. We have made several pictures, including this particular operation, in color, and the detail that is recorded is remarkable. It is better than anything that can be obtained in black and white. Kodacolor film serves the purpose beautifully. I should like, however, to have an emulsion that is comparable with supersensitive film in Kodacolor.

MR. MITCHELL: I happen to have seen several Kodacolor pictures, taken with the aid of low wattage lamps, preferably automobile head-lights—the idea being to use several automobile lights in series. The light thus obtained is almost "cold" light. Plenty of illumination is obtained for Kodacolor, and no heat; and all one has to do is to mask the excess of red in the light either by reversing the ratio diaphragm or by using adhesive plaster over the red portion of the Kodacolor filter, as some surgeons do. The results are very satisfactory.

MR. KELLOGG: If the heat of the lamp is one of the important problems, one wonders whether there are not possibilities in the same sort of device as is used in television, in order to make the exposure with a minimum heating of the subject; namely, flashing the source synchronously with the opening of the shutter. Much would not be gained in a quick pull-down camera, but many cameras have a 180-degree shutter opening, or not much more than that, under which circumstances there might be a considerable decrease of heating.

Another question that comes to my mind is whether Kodacolor is the logical choice under the circumstances. As the motions are quite slow, I wonder whether the old cinema color system, coupled with flashing lamps of different colors, would not be almost as efficient, or fully as efficient, as the present system, especially if one did not try for extremes of color saturation.

DR. SCHWARTZ: The lack of progress in this field is obviously proportional to the lack of money available for its development. We have taken the line not only of least resistance but of least expense, and we have found Kodacolor sufficiently satisfactory that we have been willing to use it for the present, hoping that in the meantime something would happen that would permit us to work along other lines.

MR. MAURER: Has the attempt ever been made in this work to run two cameras slightly separated, later projecting the images through a viewing device that would give a stereoscopic effect? It would seem that such a way of getting additional relief would be very valuable to the medical student who would wish to study these pictures.

DR. SCHWARTZ: Obviously, the same answer I gave previously applies to this question. Undoubtedly a third dimension given to this shadow would be of great value in the teaching of orthopedic surgery.

SOME COLOR PROBLEMS*

GERALDINE GEOGHEGAN**

***Summary.**—Some of the difficulties attending the taking and projection of motion pictures in actual colors are briefly discussed, particular attention being paid to the need of matching the taking and projecting lights spectrally. The author concludes that, despite the great amount of research work being done in emulsions, optics, etc., little will be accomplished in achieving motion pictures in natural colors unless the same particular care be taken with the light sources.*

Motion pictures in natural color seem to have developed in a somewhat jerky fashion. It is quite common, among the various concerns dealing with color, to have an expert on one or two subjects concerning the many problems arising in natural color photography, but, generally speaking, these experts are concerned only with their particular specialized knowledge, and can offer little or no help when outside problems upset their calculations.

If the color is produced by an optical arrangement, an expert on optics is employed; if by dyes, a specialized color printer, *etc.* It is quite possible that these men can, and do, produce motion pictures of astounding beauty and fidelity to color under the standardized conditions of the laboratory; but when used commercially, considerable trouble arises.

When we consider that color is not part or parcel of the article observed, but merely its capacity to absorb and transmit such part of the light waves that fall upon it, we are up against our first problem—the spectral quality of the "taking" light. If the latter wavers in wavelength in the slightest degree, the object being photographed changes its hue. At the same time the human eye is an accommodating organ and has a very short memory, so that if such changes be gradual, it is impossible to notice them while under the influence of the altered light; but, if the same observer and object be again placed under the correct light with an image taken under the deficient light,

* Received December 14, 1931.

** E. S. S. Color Filter Co., London, England.

the error can be seen at once. It is common knowledge that it is very difficult to produce artificially a light with a spectral approximation to daylight of sufficient volume without heat and noise. Even if this be done, the motion picture producer of color films is immediately up against another problem, the spectral quality of the "projecting" light.

After all, a color transparency is merely a collection of light filters that absorb and transmit, according to their power, the light that is projected through them. Therefore we can deduce from this, that to obtain pictures on the screen in natural color, the "projecting" light and the "taking" light must be one and the same spectrally. Compensation may be attempted, but all filters, it must be clearly understood, lower volume of illumination.

Let us say, for the sake of argument, that we have our taking and projecting lights spectrally balanced; minor problems now arise, such as the absorption and transmission of the screen, the influence of color in the decoration of the theater, and the general quality of the approach lights.

Some attempt should be made to screen all interior lights so that they approximate in quality that of daylight where neutral color films are to be shown, and only subdued schemes of decoration should be permitted.

The problem of voltage plays a part in projecting that does not arise with monochrome work. It would be quite possible for a motion picture in natural colors to be shown in one theater with exceedingly pleasing and beautiful results, while its exact duplicate might be shown in another theater with distorted and repulsive colors owing to a drop in voltage.

One has to consider that on the stage, where living actors and actresses appear, the colors of the dresses and the lights that play upon them are under the control of the producer. He views the effect as the audience sees it, and is certain that no radical change can occur; but the producer of motion pictures in color is by no means in that happy position. Monochrome pictures, once passed by their director and shown under ordinary standardized conditions, will please the man in the street even if the expert technician will notice an error or so. But with natural color pictures it appears that a private view is necessary in every theater in which each motion picture is shown, to see that no unforeseen spectral change has occurred. It was found that many theaters were not suited for the sound pictures; some even had to be scrapped, and many altered. Why not then take the same precautions with color?

Undoubtedly color pictures will take the place of monochrome; but only by a very strict attention to what may be looked upon as minor details, can success be obtained. A change in gradation of tones in a monochrome picture can occur without any appreciable notice on the part of the spectator, but a change in color will be seen by every two out of three. The normal vision is trained to recognize objects not only by shape, but by color; it is not really familiar with these in monochrome, and therefore allows false gradation to pass unnoticed.

The writer has purposely ignored such problems as fringing, *etc.*, as these are inherent in the processes themselves; and has adopted, merely as a theme, the difficulties that confront the producer, even though he have a perfect process of motion picture in color. It is doubtful whether such a process is yet on the market commercially, whence the path for color cinematography is beset with many thorns and snags. But at the moment it is felt that too much thought and research work are being directed to emulsions, optics, *etc.*, which, although of themselves invaluable, at the same time are useless unless the same care be taken with light, *etc.*

It would be a better box-office proposition to have color fantastically unreal than to show (as has been done in many cases) true color degraded and falsified by bad technic.

THE SELENOPHON SOUND RECORDING SYSTEM*

PAUL SCHROTT**

Summary.—*This brief description of the Selenophon process of recording was offered as a contribution to the Progress Committee Report of May, 1931. The process is employed to record sound photographically on film by the variable width method, employing a string oscillograph for varying the light intensity; a tightly strung fiber moving in sympathy with sound vibrations, and acting as a variable shutter in the path of the beam of light. The reproducer is briefly referred to, in which a selenium cell of the condenser type is used in conjunction with a five-stage amplifier.*

The Selenophon sound recording system is a process for recording sound photographically by the variable width method. The width of the sound track is that determined by international agreement, namely, 3 millimeters, and the film speed is 24 frames per second (456 mm. per second). The slit width is 12μ, making possible the reproduction of 8000 cycles.

A string oscillograph (Fig. 1) serves to vary the light intensity. A tightly strung metal fiber moves in sympathy with the sound vibrations and acts as a variable shutter in the light beam. The string is a wire about 0.1 millimeter in diameter, of aluminum bronze or tungsten (which has a high ratio of rigidity to mass, or tension to mass, which determines the natural frequency) so that the natural frequency (14,000 cycles) is above the highest recorded frequency. The string carries the amplified sound currents and hence is made to vibrate in a strong, uniform, magnetic field (Fig. 2).

As a result of the high natural frequency and the small amplitude, the displacement of the string is proportional to the current. The maximum current impulse is about 1 ampere and the resistance is 0.5 ohm; hence the string must carry 0.5 to 1.0 watt. The input energy from the microphone is amplified to 4 or 5 watts to provide sufficient

* A contribution to the Progress Committee Report of May, 1931. Translated by J. W. McFarlane, Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

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reserve power. The string shutter action results from the relatively high current from a 60 to 1 transformer. As mentioned above, the recording light beam must have a cross-section of 3 by 0.012 millimeters. The string, when at rest, intercepts half the beam, and is mounted at a small angle to the light beam (about 1 degree) so that for relatively small vibrations of the string a proportionally large part of the light beam is affected.

The optical system is arranged as follows: The rays from the source of light are concentrated by a condenser into the entrance pupil of an

FIG. 1. String oscillograph. (Wire with tension adjustment.)

objective. Directly behind the condenser is a slit diaphragm, imaged sharply by the objective in the plane of the oscillograph string. A second lens images the string and the slit image in the plane of the film, its focal length being such that the image is 0.12μ wide. A low voltage lamp is used as a source of light. An audible control can be effected by adding a light-sensitive cell and amplifier.

The mechanical design is such that the light beam is vertical, coming from underneath, and the film path is horizontal (Fig. 3). The main driving shaft is parallel to the housing, turning at 180 rpm., and is so designed that the driving, feed, and take-up sprockets are driven

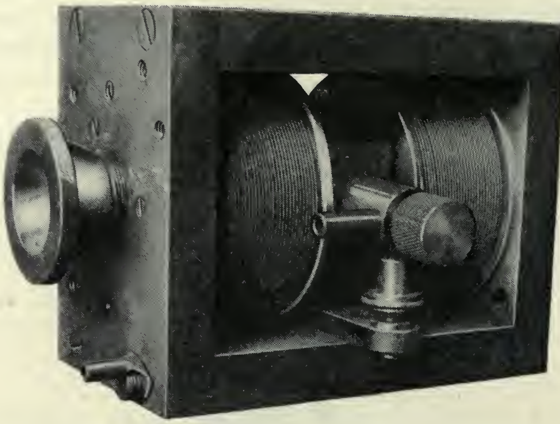

FIG. 2 String oscillograph and electromagnets.

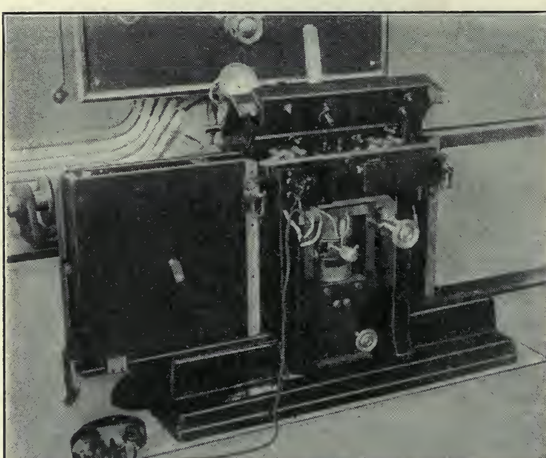

FIG. 3. Sound recorder, open, showing position of oscillograph.

from this shaft (Fig. 4). A single small motor drives the take-up spool in a retort for the exposed film. The main driving shaft is driven through an 8- to 1-gear reduction unit by a 4-pole synchronous

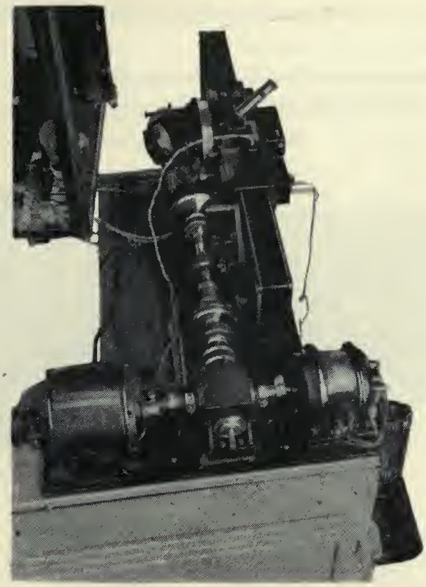

FIG. 4. Selenophon driving unit.

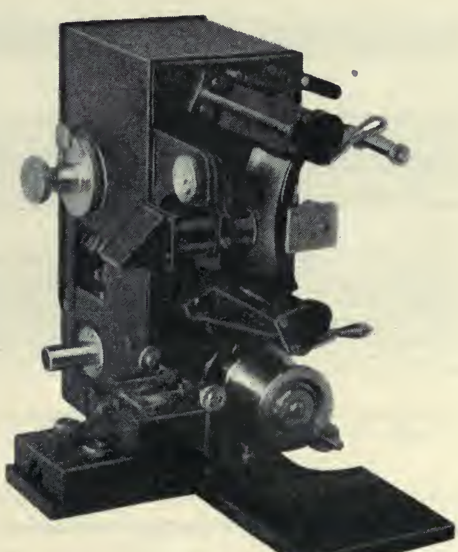

FIG. 5. The reproducer.

motor running at 1440 rpm., requiring a frequency of 48 cycles. The motor draws 250 to 300 watts.

The recording apparatus requires a floor space of 1.20 by 0.75 square meters and is 1.05 meters high. It is so designed that several

FIG. 6. (*a*) Home sound record outfit for paper records (closed). (*b*) Home sound record outfit (open).

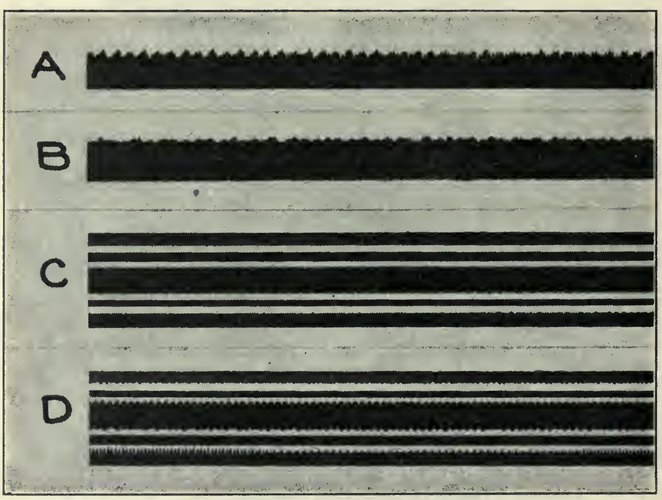

FIG. 7. Sound records on paper. *A* and *C* are printed photographically; *B* and *D* are printed mechanically.

sound tracks can be recorded side by side on the width of a standard film. For this purpose the whole exposing mechanism can be moved at right angles to the film drive so that the image of the slit can be placed on any desired part of the film. In this way, eight ordinary sound records can be arranged so that they will follow each other in the proper sequence.

The construction of the reproducer (Fig. 5) is similar to that of the recorder. A selenium cell designed by Prof. Thirring, a condenser type, is used as a light-sensitive element in conjunction with a five-stage amplifier. The record on the sound track, highly enlarged, is projected on to the cell and is condensed by a cylindrical lens.

The Selenophon Company has developed, at the same time, a home sound record outfit as a substitute for the gramophone (Fig. 6). The sound record is of the variable width type, and is printed on paper either photographically or mechanically (Fig. 7). This apparatus can be used with any radio amplifier and is capable of continuous performance up to four hours.

THE MOTION PICTURE INDUSTRY IN JAPAN*

MARCEL RUOT**

Summary.—*The history of the development of the motion picture industry in Japan is traced, beginning with the year 1895. The economic problems with which the Japanese producers have to contend are pointed out, as well as the extent to which motion pictures are used and theaters are patronized. The relation between the per capita wealth and the patronage of motion picture theaters is discussed, as well as the special uses to which motion pictures are put, such as for education and propaganda.*

EARLY HISTORY

It can be said of the motion picture business in Japan that it is almost as old as the invention itself. As early as 1895, K. Inabata, of Osaka, and the Nichiei Co., of Tokyo, imported, practically at the same time, the first projectors and films ever seen in Japan, and it is still a point of controversy as to which of the two importers was really the first in the field.

Inabata sold his Lumière Cinématographe and first series of French films to a young friend of his, E. Yokota, then only 20 years old, but today president of one of the most important Japanese motion picture companies. Messrs. Nichiei & Co., on the other hand, were at the same moment disposing of their newly imported cinema goods to K. Kawaura, owner of the firm of Yoshizawa & Co., in Tokyo.

Messrs. Yoshizawa soon gave a motion picture show in Tokyo, and it seems that, notwithstanding the claims since made by other parties, this was the very first time that a motion picture film had ever been shown to the public in Japan. The machine used was an Edison Vitascope projector, the films being of French origin, and, of course, all of extremely short length as compared with the present-day productions.

On his side, Yokota had already visualized the commercial possibilities of the invention, and also had begun to exhibit in public his newly acquired films. In order to widen his scope of action the Yokota Company was formed as early as 1896. In 1897, he visited

* Edited from a report submitted to the Progress Committee.

**Kodak, Ltd., London, England: formerly located at Osaka, Japan.

Europe to obtain fresh supplies, and while there he entered into a contract with Pathé Frères, becoming their agent for Japan. By 1904–1905 Yokota controlled no fewer than 11 circuits.

Due mostly to keener competition and public demand, Japanese exhibitors were soon to turn to the production of local subjects, and there again we find Messrs. Yoshizawa first in the field, when, in 1898, they commissioned the popular actor, Baiko Onoue, to produce *Ninin Dojoji*, a Kabuki dance performed by two young girls in the grounds of the Dojoji Temple at Gobo in the Province of Kii. The cameraman was Mr. Shibata, owner of the Shibata Studios in Kyoto. The camera used was a Gaumont, and the total length of the film did not exceed 180 feet.

The following year the same cameraman, working always for Messrs. Yoshizawa & Co., filmed *Momiji Gari* (*maple viewing*) in Tokyo; in this "super production" two leading stars of the legitimate stage were featured—Danjuro Ichikawa and Kikugoro Onoue the Fifth, father of the present equally famous actor, Kikugoro the Sixth.

The Yokota Company built their own studios in Kyoto. These studios were of the open-air type, as then used generally in America and Europe. In 1911, the Yokota Studios were transfered to another section of Kyoto, and a glass-roofed stage was built, which at that time created quite a sensation, as it was the first of the kind in Japan.

News events were filmed for the first time in 1899, again by Shibata, with his Gaumont camera. His first scoop was the filming of the funeral of the noted actor, Kikugoro Onoue the Fifth. Later in the same year a Sumo contest (Japanese wrestling) was similarly filmed for its news value.

In those early days, the exhibiting business meant going the rounds of the larger cities, renting a public hall, a legitimate theater, or any large building suitable for the screening of a motion picture program; but success, nevertheless, steadily rewarded the two pioneer firms.

From 1909 to 1930, the fortunes of the industry have been varied. Besides the two original firms of Yokota and Yoshizawa, other firms entered the field and trusts were established, until today the industry is controlled largely by six competing producers who also are exhibitors: namely, the Nippon Katsudo Shoshin K. K. ("Nikkatsu"), registered in 1912; the Teikoku Kinema Engei K. K. ("Teikini") in 1920; the Schochiku Cinématograph Co. in 1920; the Toa Co. in 1923; the S. Makino Co. in 1927; and the T. Kawei Co. During

1931, two producing companies were added to the list, Bantsuma Productions and Takarazuka Eiga K. K.

FILMS AND EMULSIONS

Three firms are now receiving yearly subsidies from the Japanese government to help them to manufacture sensitized film of good marketable quality. Roll film, plates, and papers are already being produced, and now the attention of these firms is centered on motion picture film: positive film to start with, and later on, negative emulsions. Toyo Kanpan K. K., who were the first to attempt to manufacture motion picture films, are a subsidiary of the Dai Nippon Celluloid Company. During 1930 the research work of both the Dai Nippon Celluloid Company and the Toyo Kanpan was diverted to the manufacture of safety film, possibly as the result of the several serious film fires that recently occurred in Japan.

The Oriental Photo Industry Company, Limited, who have earned a certain reputation in the Far East for their "Oriental" papers, have recently enlarged their Tokyo factory and imported from Germany all the machinery needed to make film in 1000-foot lengths. While the new buildings were going up and the machines were being erected, the Oriental research laboratories kept busy experimenting with film supports and emulsions. It is anticipated that their first film will appear on the market during 1932. Subsidized firms are encouraged by the government but their subsidies will be renewed only if, after a few years of research, a marketable article is produced.

The third runner up, in this subsidized raw stock race, is the Rokuosha factory, owned by R. Konishi & Co., one of the oldest and most prosperous wholesalers in photographic goods. Rokuosha entered the field of sensitized products in 1929 with their Japanese-made Roll Film, "Sakura." They are now bringing out filmpack, and are planning the more ambitious manufacture of motion picture film.

On February 25, 1931, the *Jiji Shimpo*, a daily paper appearing in Tokyo, announced the completion of the researches made by S. Hiraumi, who for the past ten years has been trying to make motion picture raw film in Japan. Manufacturing plans are well under way, and a factory is being built near Tokyo. Production plans call for three million feet to be made monthly.

By 1935 we should therefore see three, if not four, Japanese firms manufacturing 35 mm. positive, and perhaps negative film.

The annual capacity of the Far East market is at present:

	Positive 35 Mm.	Positive 16 Mm.	Negative 35 Mm.
Japan	55,000,000 ft.	2,500,000 ft.	8,000,000 ft.
China	15,000,000 ft.	500,000 ft.	1,500,000 ft.

It is difficult to visualize three film factories, or even two, sharing between them less than 80,000,000 ft. of raw film, assuming all the while that they can clear the Japanese market of foreign importation. This prospect is very doubtful, as in Japan, where quality sometimes gives way to price, the foreign manufacturers might come down to the lower prices that are bound to be charged by the Japanese manufacturers.

STUDIOS

During the past eighteen months, the Japanese studios have changed over from regular negative to panchromatic emulsions, and from arc lighting to tungsten lamps. The Teikine Company was the first to alter the studio lights, having used tungsten lamps for almost two years. From the older types of panchromatic film studios willingly passed on to the improved type, but they seem to be reluctant to adopt the new high speed panchromatic films since their use necessitates time development, a method that is yet practically unknown in Japan.

It seems that until the laboratories are convinced of the advantages of time development, and perhaps until automatic developing machines are installed, the Japanese studios will continue to use emulsions that can be handled under safelights, thus permitting the laboratory attendant to watch the appearance of the image.

Except for special features, the length of pictures is being limited to 5000 feet, in order to reduce production costs by 25 per cent. During the summer months of 1930–31, some Japanese studios closed completely for a week or two, this being done more for reasons of economy than for granting rest to the personnel.

In 1930, the number of stockholders of eight of the leading companies in the Japanese motion picture trade was five times greater than it was five years ago, amounting almost to 20,000 holders. Nearly 4000 people are employed by the Japanese studios, including "still" cameramen and costumers. The largest number is credited to the Shochiku Studios at Kamata, which has a payroll of 1412; of these, 180 are actors regularly employed, 125 are actresses, and 15 are directors. Teikine, however, leads in the number of actors and actresses, having 320 of the former and 120 of the latter. Nikkatsu claims the greatest number of directors, with 20. To improve the technic of camera work and laboratory processing in film production, the Shochiku Company has organized a research laboratory at their Kamata studio. All cameramen, laboratory, and electrical technicians are members of this department and coöperate according to their respective line of work.

PRODUCTION IN RELATION TO EXHIBITION

There are 1488 cinema theaters in the Japanese empire, of which 1413 are in Japan proper, 15 in Karafuto Island, 10 in Formosa, 35 in Korea, and 15 in Manchuria. These figures show an increase of 20 per cent in five years, the total for 1926 being only 1100. While such an increase might be considered as satisfactory proof of progress, yet it represents only one theater for 50,000 people, and many of these theaters have very small seating capacities as the following 1927 census tends to show:

Capacity	Number of Theaters	Percentage
Less than 250 persons	22	2
From 250 to 500	365	35
From 500 to 750	333	32
From 750 to 1000	213	20
Above 1000	112	11
Total	1045	100

Small theaters, seating from 250 to 750, represent more than two-thirds of all the cinemas of Japan. The larger houses, of more than 1000 seats, are usually old legitimate theaters converted into motion picture houses and, of course, are to be found mostly in the larger cities, like Tokyo, Yokohama, Nagoya, Osaka, Kyoto, and Kobe. Ten of the larger cinemas of Tokyo have a total seating accommodation of 13,000, the Denkikan heading the list with 1500, and the Hogokuza with about 1000. The Shockikuza in Osaka boasts of being the largest cinema in Japan with 1600 seats.

Yet, though the number of theaters in Japan is very limited and their seating accommodation small, they seldom have a full house. Only 158 million admissions were registered in 1930, slightly more than 300 admissions per day and per theater; and as the theaters are showing twice daily it only means an average house of 150 per show, which is a long way from a full house for most of the theaters.

It is apparent that, under present working conditions, there is sufficient seating accommodation throughout Japan to accommodate almost twice the present attendance, which should satisfy for a good many years the average increase in attendance. There is, of course, very keen competition between exhibitors in their efforts to secure the limited patronage available, and one of the means used has been to offer three features, instead of one or two as in other countries; and, furthermore, to issue these features in lengths of 8 or 10 reels, so that a program will sometimes last as long as 6 hours, even though projected at top speed.

As a rule the program is changed once a week, although recently some special features have had runs of two, three, and even four weeks. The program is shown every day, including Sundays, and, generally, twice daily. As it is usually made of three features, the theaters have to find 156 films each year, and it is this excessive demand for new subjects that has brought about in Japan a situation in the matter of production that has no equal elsewhere.

New subjects must follow new subjects, and in 1930 alone more than 550 features were produced in the Japanese studios to meet the requirements of the various renting organizations.

According to a recent investigation made by the *Movie Times*, Japanese producing companies are equipped as follows:

Name of Company	Stages	Cameras	Printers	Laboratory Capacity Daily	Staff	Feature Subjects Produced
Asia Eiga	2	6	..	....	81	4
Chiezo	2	..	..	....	57	12
Kawai	2	9	1	....	360	81
Makino	3	20	9	70,000	561	72
Nikkatsu	6	32	16	65,000	855	101
Shochiku, Kamato	3	30	8	100,000	815	74
Shochiku, Shimokamo	3	10	3	70,000	264	43
Teikine	6	26	..	20,000	655	98
Toa	4	20	..	30,000	441	97
Utaemon	1	6	4	....	104	19
Total	32				4193	601

Besides these larger companies, there are several smaller ones. Their productions brought the grand total of films made in Japan during 1930 to 630, as compared with 500 produced in America during the same year. In the number of features produced, Shochiku and Nikkatsu may claim to be the "biggest in the world."

The "big five" producing companies of Japan have a total production budget of $18,000,000, of which one-third goes to production of negatives and the balance to making the positive copies. This budget has to cover more than 400 features, so that not more than $50,000, on the average, can be spent on each production.

The average income of the Japanese is exceedingly small, when compared with the income per capita of other nationalities; it is only one-sixth that of the American, according to an index computed by the Bureau of Commerce and Industry. Furthermore, this average income is on the down grade, having dropped by 6 per cent within the past ten years. The average daily earning for manual workers during last November was one dollar for men and 40 cents for women.

33 per cent of the male manual workers earn less than $0.80 daily
16 per cent of the male manual workers earn less than $1.00 daily
21 per cent of the male manual workers earn less than $1.30 daily
10 per cent of the male manual workers earn less than $1.50 daily
20 per cent of the male manual workers earn more than $1.50 daily

After taking the necessities of life into consideration, and based on an income of $45 per month, the Bureau of Home Affairs reckons that individuals have only $1.75 left to spend on amusements and education.

With such a minute sum to spare, people can buy only a very few books and enjoy the cinema on rare occasions; and we have a somewhat easy explanation as to why Japanese people do not patronize motion picture theaters to the extent found in other industrialized countries; their average income simply does not permit it, most of them earning barely enough to exist.

SOUND PICTURES

Sound pictures were shown for the first time in Japan eight years ago at the branch office of Universal Pictures, by Y. Minagawa, and afterward at the Shimbashi Embujo theater, but people seemed only mildly interested in this new curiosity.

In 1929, a regular supply of sound films reached Japan, imported by the various branches of the American firms established there. The Shochiku Company, desirous of bringing something fresh into its chain of theaters, thought of experimenting with sound films, and placed an initial order for six sound reproducers for their key theaters in the larger cities of the Empire.

Their closest competitors in the exhibition field, the Musashino chain of theaters, immediately felt that they had to do likewise, and even managed to get ahead of the Shochiku group in showing two Movietone films, *Parade* and *Songs and Dances of Hawaii*, at the Musashinokan (Theater) in the Shinjuku district of Tokyo and at the Denkikan in Asakusa district on May 1, 1929. A few weeks later, on May 26th, the Shochikuza Theater and the Kogakuza Theater, in Tokyo, were both presenting *Redskin*, a Paramount production.

These première presentations of sound films to a regular Japanese cinema audience did not make the hit that was expected, mainly because they were shown with the loud speaker and the "Benshi" competing with each other.

In the days of the silent film, the Japanese audience was able to follow the action, for both foreign and Japanese films, through the words of a "Benshi" or announcer-interpreter who kept a running fire of flowery comments describing every action, word, or thought of the players, when not improving upon the scenario by "gags" of his own. When the talking films were introduced, the exhibitors discovered that the sound made so much noice that the Benshi could no longer be heard, and the audience could not understand him. Consequently, the sound was toned down, allowing the announcer's voice to stand out. This, of course, was not satisfactory to the foreign patrons, who found that they could not hear the words of the characters on the screen. Foreign patronage fell off to a minimum. Moreover, the large section of the Japanese public consisting of students of the English language and Japanese who have lived abroad, was almost completely alienated.

There was still another difficulty. In the days of the silent film, there was a considerable market in the smaller cities. The little theaters could not afford to install sound equipment and many were lost as clients for foreign films or continued with much dissatisfaction. The market for the foreign film in Japan contracted to a marked degree, and fears were expressed in many quarters that it would be necessary for the film exchanges to close and to do all their business through agents.

It was finally found possible to overcome this obstacle by running Japanese titles on a small screen at the side of the main screen, but this has not proved wholly acceptable as the Japanese audiences find that, while reading what is written at the side, they often miss the action on the main screen. One major company hit upon the idea of superimposing the titles upon the actual pictures, and several films handled in this manner have already been released, and proved to be quite successful.

Notwithstanding the luke-warm reception accorded to sound films, far-seeing producers decided to try their hand at Japanese talkies. To the late S. Makino, owner of the Makino Productions Company, should go the pioneer's laurels. In coöperation with M. Tojo, owner of the Eastphone Company, he produced *Modoribashi*, the first Japanese feature recorded with sound. The disk recording was carried out at the Nitto record factory. This was followed by *Kyoen-roku*, but soon after this second production the untimely death of Makino brought his meritorious efforts to an end. The Nikkatsu were soon to follow the lead shown by Makino and, also using the Eastphone system of disk recording, started on the production of *Hashisuka Koroku*, a classic feature in 12 reels. The first show of Makino's *Modoribashi* took place on the 17th of July, 1931, at the Daimai Hall, in Kyoto, whereas Nikkatsu's *Hashisuka Koroku* was put on at the Fujikan Theater in Asakusa district, Tokyo, on the 1st of August. Unfortunately, both these early sound productions were far from perfect, due mostly to the absence of recording experts; they, nevertheless, indicated what scope there was for the adoption of sound in Japanese productions and the real public demand there was for this type of film, even though its adoption may mean the ultimate dismissal of 6000 Benshis now employed by the Japanese cinema theaters.

Mr. Watanabe of the technical staff of Teikine is the inventor of a system that uses wax disks. One of the distinctive features claimed by the inventor is that, with his apparatus, the stylus progresses across the radius of the wax record instead of the record turntable moving over.

Besides the sound machines of Japanese manufacture already installed in various theaters, there are two or three newcomers now appearing on the market. Of these, is Shochiku's sound-on-film Shochikuphone, which was presented during August for the first time. While little detail is available concerning this apparatus, it is said to be built on lines very similar to RCA recorders.

Katsumi Toyoshima, of Osaka, has invented a recording apparatus for sound-on-film, the main characteristics of which seem very similar to those of the Movietone. The makers claim that it can be easily placed on a truck and will prove most suitable for outdoor work.

EDUCATIONAL AND PROPAGANDA FILMS

For many years the Japanese Government has made wide use of motion pictures for educational, health, and social propaganda, and advertising, through its various departments or ministries.

As regards educational films, while they do not yet form part of the school program, every encouragement is given to widen the use of motion pictures in the classroom, and there is good reason to believe that as soon as economic conditions permit, we shall witness the adoption of visual education by the Japanese Government; which means all schools throughout Japan, as education here is organized on a strictly national basis and even private schools have to follow the main lines of the education program as laid down by the Department of Education.

National education has been one of the most powerful factors in building up modern Japan. The Department of Education was established in 1870, and the educational law promulgated in 1873. The whole area of Japan was divided into eight districts, each one of which was subdivided into smaller middle school districts, which, in turn, were also divided into many primary school districts.

The educational expenditure on elementary and secondary schools is borne by the people of the particular localities in which the schools are situated, but the government gives an annual subsidy of more than 80 million yen, or 60 per cent of the average total expenditure of 135 million yen.

We have for the whole of the Japanese educational system a grand total of over 45,000 teaching centers with 300,000 teachers to run them and 12 million pupils attending them regularly; an immense field, yet almost untouched!

The Ministry some time ago planned a wide educational campaign by means of the screen, and a vast program of 180 pictures was decided upon. Several of these pictures were not for the schools but for the masses, having for their purpose the guidance of national thought on such things as "the necessity for the government to adopt a retrenchment policy." In one of those "Government Justification" pictures, three members of the Cabinet, including the former Prime Minister, Mr. Yamaguchi, appeared in the course of the action, addressing the public as they would have done on a platform. The Governors of Prefecture are strongly supporting the efforts of the government, by advocating the production of more films of educational value for both children and adults.

The Ministry of Education went even further, and announced that, in order to promote social education through amusements and recreations, their intention was to enlarge their field of action, which up to now was more or less limited to making or recommending films suitable for education in schools.

The Mombusho (Ministry of Education) would now give free cinema shows in cities and villages. Two touring units are carrying out the scheme, one operating from Tokyo, the other from Osaka. Many of the films shown by these units are specially produced to educate the adults more than the children, to their duties as good citizens of the Empire, as may be seen by a short list of the subjects screened:

> Promotion of street etiquette and prevention of street accidents.
> Prevention of fire.
> Duty to pay one's taxes and the need of thrift.

Other departments of the government have also been regular users of motion pictures but more for special propaganda than for education. The Ministry of Railways has had several films produced for free distribution in Japan and abroad with a view to inducing tourists to visit Japan and Korea. Several of these films had copies printed with English titles.

The Ministry of the Navy has subsidized production of historical films dealing with Japanese naval victories, while the Ministry of Home Affairs attends to the recording of the Emperor's and the Imperial family's activities and movements, as well as such other subjects as emigration.

All such films are circularized free of charge by the various ministries or prefectures responsible for their production, and a good many among them have been well received by the public, even special propaganda films explaining the causes of depression and retrenchment.

The two leading newspapers of Osaka, the *Mainichi* and the *Asahi*, self-appointed educators of the people of Japan, decided to use motion pictures as one of the better means of fulfilling their national task. They have released films of educational nature, as well as others of a more "newsy" style.

During the summer months the All-Japan Motion Picture Education Society runs a summer college for education by motion pictures, and success has rewarded their efforts, many teachers expressing their surprise at the speedy progress witnessed, especially in geography and biology lessons.

The Japanese branches of the League of Nations and of the Red Cross Society have also subsidized the making of special films, which they are now using for propaganda purposes; even the Korean Government has thought it well to use the screen to educate fishermen against the evils of casting their nets in forbidden waters, and the Hongangi Buddhist temple in Kyoto commissioned the production of a propaganda film, feeling certain that new adherents could be obtained with the help of the screen.

The latest gesture of the Ministry of Education has been the offering of three national trophies for the best pictures of educational value. There will be three classes, "Strictly Educational," "Recreational," and "Artistic," one trophy going to each class.

There are, in Japan, therefore, fine prospects for educational and propaganda films, and the same might be said of the purely advertising films. Everyone is convinced that the screen is the finest medium to inculcate knowledge or carry a forceful message to the public. The moment the government's budget and the various official funds will permit it, there is no doubt that important sums will be allotted to motion picture production and distribution.

JAPANESE EXPORT TRADE

There is no firmly established export trade in motion pictures. Most of the films exported until last year were interest films—scenic, industries or customs of Japan—the majority having been produced by the Ministry of Railways as tourist propaganda, or as Japanese productions for exhibition where Japanese communities in foreign lands are important enough to justify the transportation of such films.

The main problem is that of language and, with the wide adoption of sound by motion picture theaters throughout the world, there is the fear that before long there will be still smaller possibilities of exporting Japanese film. Export business will probably be limited to cities in which the Japanese population is sufficiently large to keep a Japanese theater going. The present distribution of Japanese motion picture theaters in foreign lands is as follows:

In Shanghai, China	2
In Manchuria	7
In California (permanent)	12
In California (traveling)	8
In Hawaiian Islands	8

Most of the Japanese films shown in the United States are second-hand films. They are sold outright for about \$.07$^1/_2$ per foot for regular subjects, and \$.15 per foot for feature films.

Of the motion picture theater companies in the United States, there are nine owned by Japanese: 4 in San Francisco, 4 in Seattle, 1 in Stockton, and 3 in Hawaii. On the other hand, there are no theaters in the South Sea Islands owned by Japan, although the number of immigrants there is continually increasing. On the whole, the export of Japanese films is steadily increasing.

POLICE REGULATIONS

Japan is a country where the police rule supreme, satisfied as they are with the "sanctity" of their mission and aware of the importance of their position as governmental and not mere municipal agents.

Censorship of films comes under the control of the Tokyo office of the police department. To each film submitted for censorship must be attached a statement as to the exact length of each reel, a detailed synopsis of the film in Japanese, a list of all titles and sub-titles in English, plus a translation in Japanese of each of them. With the advent of sound films, it became necessary to add to this already long list of documents, a copy of the spoken text and a translation in Japanese of all speech emanating from the loud speaker. This means a tremendous lot of work for the poor importer of foreign films, but the police want it and that's all there is to it.

Besides this, the Japanese words that the Benshi, or announcer-interpreter, is to use when "reading" and commenting on the plot of the film to the audience during the show must also be written down and submitted to the censor for his approval or correction.

Once a film has been passed by the police, no alteration or revision of the censored synopsis, censored film, or censored text as spoken by the Benshi is permitted. Fines are imposed whenever an infringement of these regulations is discovered, and the showing of the film is suspended until the matter is settled with the censor's office, which sometimes takes several days as there is only one censoring office in Tokyo.

Foreign films dealing with the army and with war are subject to a special and additional censorship by the press department of the gendarmerie headquarters. For some time, the gendarmerie was using the sound-wired projector owned by the police censor at the Department of Home Affairs, but this year they decided to have their own projector at the gendarmerie headquarters so as to be able to examine the films at greater leisure.

The gendarmerie, in this matter, represents the army or the navy, and it is as such that they also had to step in and issue new regulations concerning the making of motion picture scenes within the many strategic zones that one finds scattered all over Japan. Under their new regulations, the gendarmerie exercises an extremely strict supervision of the "shooting" operations as well as a supervision of all the film used, besides the censoring of the finished production.

Most important of all were the new regulations issued by the Tokyo police and in force since April 1, 1931. Under these regulations the projector speed must not exceed 28 meters per minute when running sound film and 24 meters when showing silent pictures; the duration of a single show must not exceed four hours, during which not more than 5500 meters of film can be screened.

These new regulations met plenty of opposition from the exhibitors, more specially those of the Asakusa district in Tokyo, where cinemas are many and do a flourishing trade on Sundays and holidays. During such days, in order to get the most people in, the duration of the show was shortened but without alterating the number of subjects shown, by simply increasing the speed of projection to its utmost limit, often at the rate of 115 feet per minute. Meetings were held, deputations were sent to the police bureau, all sorts of arguments were brought forward, and tests made to obtain a reversal of the regulations, but all to no effect. The police stood firmly on their ground, stating that the new rules made for greater safety and at the same time protected the public who were not getting "value" when seeing a film screened at double the normal speed.

SUB-STANDARD FILM

Amateur movies are becoming one of the most popular hobbies of the Japanese, and the user of amateur cameras and projectors can now find in Japan all the very latest accessories, many of which are already being made locally, even reproducing attachments for 16 mm. projectors. We have the "Marvel" attachment for sound on disk, retailing at $40. We have had, of course, for several years, Japanese-made 16 mm. ciné cameras and projectors offered at prices substantially lower than the imported article, but due to the poorer quality of the domestic apparatus, their presence on the market has never affected the sale of the foreign machines.

There is quite a large quantity of 16 mm. safety positive film being used in cameras in lieu of negative, simply because of its cheaper price. It is reversed by outside firms, who usually blame the film manufacturer for the unsatisfactory results obtained with the reversed positive film. This pernicious habit is growing, and unless manufacturers take steps to prevent it, the reputation of home movies for producing good quality films will be seriously damaged, as the amateurs are never told by the unscrupulous dealer that they are being supplied with a film never manufactured for use in a camera and, still less, for ultimate reversal.

A MACHINE FOR PRINTING PICTURE AND SOUND SIMULTANEOUSLY AND AUTOMATICALLY*

O. B. DEPUE**

Summary.—*This paper describes a machine designed for printing picture and sound records simultaneously and automatically. It is so constructed that it can print full-width pictures, with or without masking the sound track, or the sound track only. Provision is made for printing news weeklies or single-system negatives, as well as the double-system or separate sound negative. Two prints can be made simultaneously from a single negative, or one reel can be printed on one sprocket and a second and different reel on another. The capacity of the machine is 5100 feet per hour per finished print.*

With the adoption of sound pictures by the motion picture world came new demands on the laboratory to print both picture and sound on a single positive, but of necessity not at the same position on the positive. This has been accomplished in most cases by passing the positive through the printing machine twice, or by having two machines, one arranged for printing the picture with the sound track masked, the second for printing the sound track with the picture masked. This reduces the capacity of the printer to less than half its normal capacity when printing the picture only.

A printer that will not only print the picture but the sound track as well, both at the same time, should more than double the footage in a day's work. It would have other advantages as well: eliminating mistakes in handling the positive from machine to machine, and keeping records as to what has already been done or is still to be done. Instances have been known in which as many as ten reels in one lot have been marked as having been completely printed, only to discover after development that no sound track had been printed. The one-operation sound printer eliminates such possibilities. Also, in the matter of economy in operation, one has but to calculate the saving of employers' general overhead, in providing space for more printers, the insurance on employees, and necessary additional equipment for employees, such as lockers, washrooms,

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** O. B. Depue, Chicago, Ill.

recreation, *etc.* A printing machine that will print both sound and picture rapidly and automatically, and in a single operation, would appear to be very desirable. If such a machine could be used for regular printing as well, and to double the production by simultaneously printing two positives from a single negative, or simultaneously printing two different reels by simply threading the machine differently, its place in the laboratory should be assured.

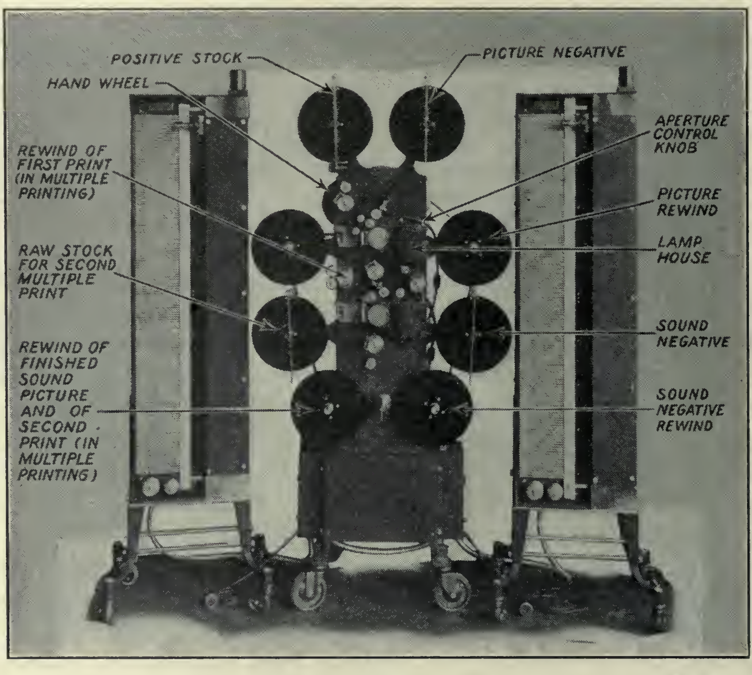

FIG. 1. Showing complete double machine with full automatic light control for each printing sprocket.

In the multiple sound and silent printer (Fig. 1) described in this paper all these features are combined. The machine is, in effect, two printers in one; each printing head is alike in construction and can print full-width pictures, with or without masking the sound track, or it can print the sound track only. Its high speed and automatic operation are two of its distinct features. Blinking, unsteadiness, and flicker have been overcome by the driving mechanism and by providing for perfect contact at the printing aperture.

The driving mechanism, as the rear view (Fig. 3) shows, is positive, from the directly coupled motor at the bottom to the sprocket at the top. The speed reducer is directly coupled to the motor, and a posi-

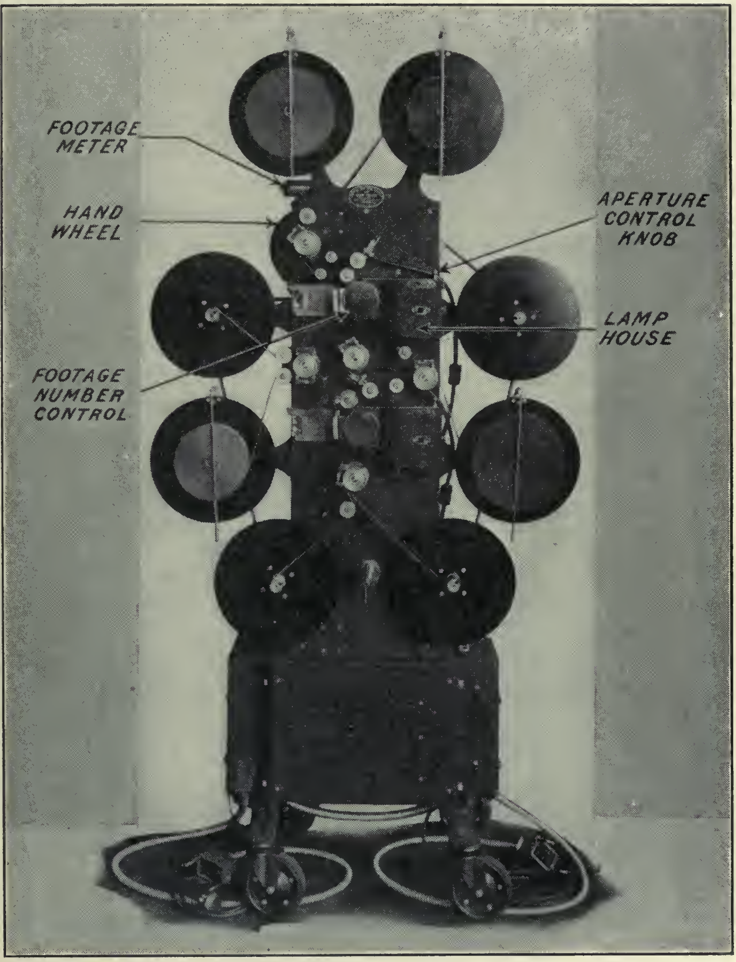

FIG. 2. Front view showing thread-up when printing two different reels at same time.

tive four-jawed clutch drives a single vertical shaft which, in turn, operates all the sprocket wheels by right and left helical gears, hardened and lapped. The one rewind belt is driven *positively;* and each rewind disk driven by it is individually controlled by an adjustable pair of knurled thumb-nuts and a coiled spring pressing together two friction plates separated by a thin pad of oil-soaked felt. Once adjusted, the pressure remains unchanged for months without further attention, the gentle tension thus provided allowing the stopping and starting of a 1000-foot reel at any stage of the printing, without unduly straining the film at the hold-back sprocket.

Referring to the front view of the printer (Figs. 1 and 2) attention is directed to the printing sprocket housing, which is also the lamp housing. It is here that one of the main features of the printer is to be found. The printing lamps have a capacity of but 40 watts, a frosted stock mazda lamp being sufficient to furnish ample illumination for printing at a speed of 85 feet per minute with an aperture opening $^5/_{16}$ inch. Referring to the rear view (Fig. 3) the three-way adjustment of the lamp base and socket will be seen. The scale is graduated uniformly in sixteenths of an inch, the forward and backward movement being $1^1/_2$ inches. The two lamps are easily matched and may also be easily matched to other machines in daily testing.

The light is controlled by a rheostat, the small filaments of the 40-watt bulbs responding more quickly to changes of voltage than larger filaments. The light controls provide for 152 changes and 22 densities, or a smaller number if desired. The rheostats are easily detached, and rheostats of any capacity up to 500 watts can be substituted. This provision, of adapting the control to other printers having different lamp capacities, is another economic feature of the machine. By merely shifting the lever provided on the back of the light control, one rheostat is substituted for the other. A 250-watt lamp is suitable for the optical printer, and a 40-watt lamp for the sound printer. A mechanical filter of sufficient latitude is provided by a Lovejoy flexible coupling having a four-point rubber element $^5/_{16}$ inch in diameter, which acts as a shock absorber when throwing in the positive clutch, and assures smooth operation while printing.

The multiple, or double, positive printing feature is worthy of mention. On the left of the front view (Fig. 1) will be seen an additional sprocket and rollers. The first printed positive is passed over the top of this roller and is rewound on the upper left disk. The negative passes down to the lower printing sprocket after passing under the tension roller and the interrupter roller, and the second unprinted positive film is taken from the lower disk and passes under the lower side of this feed sprocket. It then passes under the tension roller and joins the negative at the printing aperture,

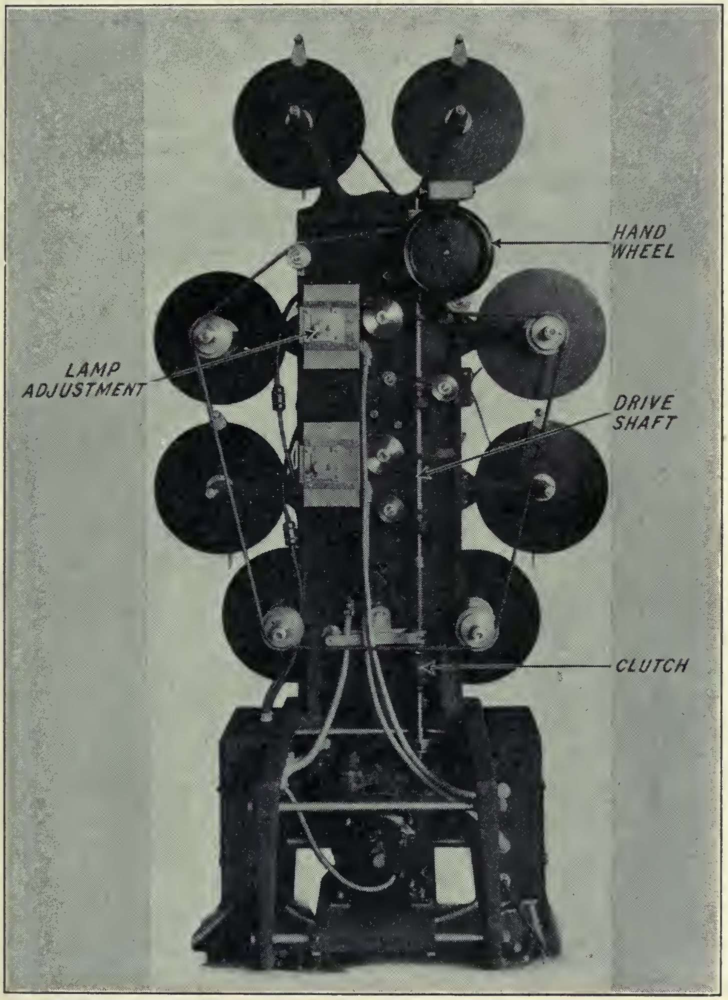

FIG. 3. Rear view showing motor speed reducer, main vertical driving shaft by helical gears.

and a second print is made and rewound on the bottom left-hand disk while the negative is rewound on the bottom right-hand disk.

The left-hand light control is connected to the upper printing sprocket, and the right-hand light control is connected to the lower printing sprocket. These light controls are provided with the male half of a three-circuit plug connector. The printer is provided with a flexible armoured cable terminating in the female half of the connectors, so that any light control can be connected to any printer so far furnished. At the top of the printer unit, on the left of Fig. 2, is located a footage meter, in addition to a hand wheel for enabling the operator to advance the film readily when threading and synchronizing.

On the lamp housing at the upper right-hand corner (Fig. 2) is a small plate with numbers *1*, *2*, and *3*, and a small knob and sliding lever. No. *1* is the sound track printing aperture, No. *2* is the picture aperture and sound track masked, while No. *3* is the full-sized picture aperture. On either side of both printing sprockets is a small screw knob which allows an almost instantaneous opening and closing of footage number apertures on each side of the sprocket. This simple device makes footage printing selective and useful in film printing, or in printing for disk reproduction of sound.

The machine is very flexible in use, being in effect a twin printer. News weeklies or single-system negatives may be handled as easily as the double-system or separate sound negative. Two prints from a single negative can be made; one reel can be printed on the upper printer sprocket and a second and different reel on the lower head, the No. *3* setting providing for two distinct printers, each one having its own light control independently of the other. Of course, both are operated at the same time. The capacity of the machine is 5100 feet per hour per finished print. In actual use, sound pictures have been printed at a rate greater than 4000 feet per hour. An output of 302,000 feet of film was recently made by this machine in 100 hours of continuous operation. When used as a multiple unit, printing two positives from a single negative, the capacity is somewhat greater than 60,000 feet per day. Only one negative has to be rewound and handled. A $^1/_4$-hp., 1750-rpm., 60-cycle, a-c. motor is used. The machine is wired for a-c. operation except for the two printing lamps, which are operated on a separate 110-volt, d-c. circuit The bearings are of bronze; space is provided at each sprocket wheel bearing for a felt pad soaked in oil, so as to assure proper lubrication.

TIME-AND-TEMPERATURE VS. THE TEST SYSTEM FOR DEVELOPMENT OF MOTION PICTURE NEGATIVES*

WILSON LEAHY**

Summary.—*Two methods are in current use for controlling the developed density of picture negatives. These are: (1) the test system, and (2) the time-and-temperature system. In this paper the two systems are compared briefly and their advantages and disadvantages are given.*

Upon the advent of sound as an integral part of the motion picture, and through the necessity of combining on one positive both the sound and the picture, standard laboratory practice at that time underwent an unprecedented change. After a rather hectic period of controversy with sound engineers it became obvious to most laboratory men that the heretofore satisfactory rule-of-thumb methods must be discarded; that the standardization of solution contrasts in processing sound tracks must be accompanied by a like standardization of densities and exposures of the picture negative, in order that the highest quality of picture may result in composite printing through a positive solution primarily formulated and maintained for sound.

The introduction of sensitometric measurements enabled the laboratory to control the degree of contrast and density in solutions; but opinion was, and still is, divided as to the most exact means of regulating the developed density of the picture negative. Two methods are in use at present: namely, (1) the test system, and (2) the time-and-temperature system. In this paper the two systems will be compared briefly, the facts on which the comparison is grounded having been gained from lengthy and intimate experience with both systems.

In a laboratory where the time-and-temperature method is employed, the first requisite is, of course, a smooth, evenly balanced, negative formula, maintained so as to provide a constant trans-

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Universal Pictures Corp., Universal City, Calif.

mission and gamma. It may be assumed, also, that there exists the coöperation between the laboratory and the cameramen requisite to assuring even and uniform exposures and to establish in the cameramen a feeling of security as to the unvarying development of his negative from day to day. Admitting this condition, the enumerated advantages of the method are as follows:

(1) Continuous machine development without alteration of speed or strength of solution and precluding the possibility of error on the part of the operator.

(2) Eliminating the need of making test shots on the set, which are at once expensive and in many cases inaccurate.

(3) Eliminating the personal variability of the man reading the tests.

(4) Reproducing on the screen a replica of what was shot without exaggerating or losing contrast or tone value.

(5) Securing full, deep development, proportionate to exposure.

(6) Eliminating the necessity of rewinding to detach and sort tests.

(7) In the end, producing an even and uniform release negative as a result of dispensing with the human element as much as is possible.

In a laboratory where the test system is employed, the same amount of care is necessary in maintaining the solutions. It is obvious, however, that the same spirit of coöperation between the cameramen and the laboratory cannot exist here as in the laboratory employing the time-and-temperature method. The timer, who is only human and who is therefore liable to err in his judgment, is as a rule the cause of no little friction between the two departments.

The necessity of obtaining good tests is also a contributing factor of contention. The system, however, has its advantages; it provides:

(1) Partial protection to cameramen who have inadvertently made mistakes in exposure.

(2) Partial protection to cameramen ignorant of solution conditions in the laboratory.

(3) Partial protection to cameramen who have been forced to shoot under adverse conditions.

It is notable that the test system seems to have been devised to protect the cameramen regardless of the cost of processing or of the hazards to which the film is exposed in the laboratory. Experience has shown that the average cameraman, possessing sufficient "film sense" to deserve the name, is plastic and ingenious enough to adapt himself to the time-and-temperature method in a comparatively short time; whereas, with the test system, and with negative development proceeding at varying speeds from night to night, he is unable to settle down to any standard of exposure.

The principal advantage offered by the test system is its ability to smooth off rough negative to conform to the laboratory printing scale regardless of quality. It is an acknowledged fact that the printing scale has an all-important bearing on the general appearance of the release print, particularly on the evenness and uniformity of the blacks. But in obtaining this uniformity of printing scale, it is often necessary in the test laboratory to under-develop an over-timed, flat negative, and to over-develop an under-timed, contrasty negative, procedures which at once sacrifice quality. This is self-evident and beyond dispute, and can be charged, first, to lack of coöperation between the cameramen and the laboratory and, second, to the maintenance of a system that permits a variable element to intrude between the cameraman and the screen. It is a condition brought about by under-developing an over-exposed negative that possesses considerable inherent contrast, and over-developing a comparatively flat negative, instilling in the cameraman a false confidence which in the end proves his undoing. For, without much thought or hesitation, he will over-time a flat subject and under-time a contrasty one.

In the time-and-temperature laboratory, this constant see-saw is avoided. The effect of exposure, filter values, lighting arrangements, *etc.*, are all illustrated clearly to the cameraman by the unjuggled negative and print. He assumes the mental attitude of a student, with his own work as a text, the result being almost immediately evident on the screen.

It has often been argued that this standardization of exposures stifles a cameraman's individuality, but such is obviously untrue. No restraint is exercised over the use of gauze, filters, or composition; the cameraman is free to use any means at hand to enhance the artistic beauty of his product; and an additional advantage is placed at his disposal through the consistently uniform development of his negative.

STUDIO PROJECTION AND REPRODUCTION PRACTICE*

JOHN O. AALBERG**

Summary.—*The number of projection rooms in Hollywood studios varies between one and fifteen, depending on the production capacity of the studio. Projection distances average about 60 feet. In general, reproducing equipment is furnished by the company whose recording apparatus is used. During shooting and editing of a picture, the sound track and picture are on separate films, practically doubling the amount of equipment needed and calling for special synchronizing devices.*

Daily and weekly routine checks covering frequency characteristics, power levels, and screen brightness are described, as well as small projectors and reproducers used for inspecting release prints in film processing laboratories. The paper also covers special applications, such as reproducers on stages (play-backs) used for furnishing music or for special work, as in split mat photography, special uses in scoring, trick work, etc.

The final link in the technicians' daily work of making motion pictures is projecting and reproducing them. Here on the screen, the art department, responsible for sets and costumes, sees the results of its work; the make-up artists see that their skill in beautifying the stars has registered properly; and the cinematographers check their photography and the processing of the film by the laboratory. From the screen, the sound technicians hear their recording and ascertain whether or not it matches the photographic action for sound perspective and for other points of recording finesse.

The studio projection rooms are small, ranging in seating capacity from ten to two hundred, and varying in appointments from a bare acoustic plastered room, where the film editor checks his picture cutting, to the elaborate rooms of the executives. A large studio may have fifteen such theaters and the smaller ones possibly one or two.

Care is taken in these theaters that the equipment produces only average theater quality so that the technicians do not become too optimistic about their results. To insure uniform work from day to day, routine tests are made on the equipment characteristics.

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** RKO Studios, Inc., Hollywood, Calif.

The latter is essential because scenes are made from day to day that must match sequences made weeks or perhaps months before in both picture and sound quality. Screen brightness is determined with a Macbeth illuminometer and is kept at approximately twelve foot candles. Daily power level tests are made on all reproducers by running a variable frequency film. During the day the sound level of the reproducers is verified frequently by reading the level obtained by running a piece of 1000-cycle sound track, the optimum level for each theater having been previously determined by the sound technicians. At one time it was practice in a studio here to attach a piece of 1000-cycle film to the end of each reel of "dailies" so that the level could be verified after every reel. It is essential that the equipment be maintained with systematic care and kept as nearly perfect as possible so as to disclose any imperfections in either picture or sound; otherwise costly retakes might be ordered when the imperfection noted was actually the result of faulty reproduction in either picture or sound.

Studio reproducing equipment is furnished by the company whose recording machinery is in use in the studio. It is usually maintained under the supervision of the sound department and is operated by skilled projectionists. During the filming and editing of a picture in the majority of studios, the sound track is kept on a film separate from that of the picture so as to simplify editing. This procedure practically doubles the reproducing equipment otherwise required, and necessitates special synchronizing devices, such as electrical interlocks for synchronizing the projector with its sound reproducer. Such an arrangement may also interlock two projectors so that the sound track and the picture may be viewed simultaneously by using the proper masks in the picture apertures. Projecting the sound track affords an easy method of inspecting it for dirt, scratches, placement, modulation depth, *etc.*

Every studio, in addition to the regular projection rooms, has a scoring room where appropriate music or special sound effects may be synchronized with the picture. These rooms are of such dimensions and acoustic design as to accommodate large orchestras for scoring. Projection rooms and recording channels are attached to them, and in many cases a re-recording channel. With the latter arrangement it is possible to add music and other effects to the sound that was recorded when the picture was photographed.

One laboratory has developed a small projector and reproducer for inspecting every reel of release print that they make. The picture projected by it is approximately two feet square and the sound is heard by the inspector through ear-phones. Special features of the machine are quick starting, stopping, ease of threading, and the absence of rollers or gates that might damage the film. In one of the color laboratories use is made of the Selsyn motor remote-control principle to allow focusing of the picture from the theater.

Unique uses are sometimes made of projection and reproduction apparatus. In one case the projected picture is utilized by the trick photographer to secure a scene usually made by special photographic processes. In this instance a picture background is projected on a treated glass screen by rear projection and rephotographed with foreground action. This process has been simplified by the electrical interlock which maintains synchronization between the camera shutter and the projector pull-down mechanism and may, therefore, operate with the projector shutter removed, insuring maximum light on the screen.

Another special use of reproduction is immediate play-back of a scene recorded on wax. Play-backs, whether from film or disk, are useful in instances where an actor is playing a dual role and must speak to his counterpart when it is necessary for both to appear on the screen simultaneously in the final result. He is photographed by split mat photography as he speaks the lines of one role. These are then played back for timing as he is photographed in his counterpart, allowing him to talk to himself.

The foregoing is not the practice of any one company, but a description of the general practices in Hollywood studios.

SIZE OF IMAGE AS A GUIDE TO DEPTH OF FOCUS IN CINEMATOGRAPHY*

J. F. WESTERBERG**

Summary.—*The questions discussed in this paper are:* (1) *The depth of focus vs. depth of field.* (2) *The size of the permissible circle of confusion. Should it be a constant value or should it vary as in still photography? It is concluded that it should remain fixed.* (3) *Magnification as an index to depth. The simple rule that depth varies inversely as the square of the magnification may prove to be a very practical yardstick in the appraisal of depth in the photographing of near-by objects. A table is shown in which the magnification is estimated from the size of the figures on the ground glass. The corresponding depth is given for various stops.*

In A. C. Hardy's paper on "The Depth of Field of Camera Lenses,"[1] several questions were brought up that merit discussion from the point of view of practical cinematography.

The common misunderstanding in regard to the terms "depth of focus" and "depth of field" was mentioned, and also the question of whether in motion picture photography the size of the permissible circle of confusion should vary or remain constant. The most significant point that was brought up, however, was the relation of magnification to depth. The simple rule, that depth varies inversely as the square of the magnification, may prove to be a very practical yardstick in the appraisal of depth in photographing near-by objects. In the past, too many factors have been involved to warrant any other method than direct visual examination of the image on the ground glass.

DEPTH OF FOCUS VS. DEPTH OF FIELD

It is common practice among photographers to refer to all problems of depth by the expression "depth of focus." Strictly speaking, depth of focus should only be used in referring to the leeway that one has in focusing upon an object at a fixed distance. Thus, under certain conditions, if it is desired to focus at 15 feet, a satisfactory

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Hollywood, Calif.

image may be obtained of an object at that distance if the point of sharp focus falls anywhere between 13 and 18 feet.

Depth of field, on the other hand, assumes that the lens has been focused correctly at the desired distance, in this case 15 feet, and indicates that all objects between 13 and 18 feet would be in practical focus.

It is doubtful if in most cases cameramen actually adjust to the exact focus, especially when following focus. Depth of focus is, therefore, an ever-present life-saver. When attempting to focus so that objects both near and far shall seem sharp, it would be technically exact to say that *depth of field* is under consideration, although practically it is much simpler to retain the term *depth of focus* in an all-inclusive sense.

FIXED CIRCLE OF CONFUSION

It is well known that in still photography a larger circle of confusion can be tolerated when the picture is big and the lens of long focal length than when the picture is small and the lens of short focal length. Big pictures are usually looked at from a distance, while small pictures have to be examined close at hand. It is assumed, therefore, that in still photography the size of the permissible circle of confusion may vary directly as the focal length. A value of $^1/_{1000}$th of the focal length is the accepted figure. This works out, for example, as $^1/_{100}$th an inch for a ten-inch lens and $^1/_{250}$th an inch for a four-inch lens.

Can this line of reasoning be followed in the case of a motion picture? Apparently not, because the size of the picture and the viewing distance are constant for any one spectator. The fact that the faces on the screen vary in size is evidently immaterial in this case.

The result of allowing a sliding scale is quite apparent to the eye when looking through a camera. The longer focal lengths, on the one hand, do not live up to their higher rating and the wide angle lenses, on the other hand, have depth to spare. A fixed circle of confusion of $^1/_{500}$th an inch seems to be about correct in practice. This is $^1/_{1000}$th of the focal length of a two-inch lens.

SIZE OF IMAGE A MEASURE OF DEPTH CAPACITY

Hardy's proposal to consider depth as a function of the magnification has practical possibilities that should not be ignored. Nearly all the scenes in a motion picture are made at close range, somewhere between a full-length figure and a close-up. The subject of depth becomes greatly simplified when we consider, for instance, that the depth in photographing a waist figure is always practically the same for any given stop, regardless of the focal length of the lens used. With this in mind it becomes possible to construct a table in which any reference to focal length or distance of object becomes superfluous. This simplifies matters considerably. All that remains to consider is the stop and the magnification. The stops are easily read, of course, and the magnification can be readily estimated with sufficient accuracy by reference to the ground glass.

Relation of Depth to Magnification in Motion Picture Lenses

Image Data *Based on aperture 0.6 × 0.8 of an inch*			Total Depth *At least one-half of total depth available beyond plane of critical focus*				
Magnification	Height of Subject Included at Point of Focus	Character of Scene	*F/2*	*F/2.8*	*F/4*	*F/5.6*	*F/8*
1/11.2	6.7 in.	Insert of hands	1.0 in.	1.4 in.	2.0 in.	2.8 in.	4.0 in.
1/15.6	9.4 in.	Action insert	2.0 in.	2.8 in.	4.0 in.	5.6 in.	8.0 in.
1/22.4	13.4 in.	Large head	4.0 in.	5.6 in.	8.0 in.	11.0 in.	16.0 in.
1/38.7	23.2 in.	Close-up	1.0 ft.	1.4 ft.	2.0 ft.	2.8 ft.	4.0 ft.
1/46	27.6 in.	Bust	1.4 ft.	2.0 ft.	2.8 ft.	4.0 ft.	5.6 ft.
1/55	2 ft. 9 in.	Waist figure	2.0 ft.	2.8 ft.	4.0 ft.	5.6 ft.	8.0 ft.
1/65.5	3 ft. 3 in.	Cutting at hips	2.8 ft.	4.0 ft.	5.6 ft.	8.0 ft.	11 ft.
1/77.5	3 ft. 10 in.	Hands showing	4.0 ft.	5.6 ft.	8.0 ft.	11 ft.	16 ft.
1/90.7	4 ft. 6 in.	Cutting at knees	5.6 ft.	8.0 ft.	11 ft.	16 ft.	22 ft.
1/110	5 ft. 6 in.	Cutting at ankles	8 ft.	11 ft.	16 ft.	22 ft.	32 ft.
1/130	6 ft. 6 in.	Full length	11 ft.	16 ft.	22 ft.	32 ft.	45 ft.
1/155	7 ft. 9 in.	Medium long shot	16 ft.	22 ft.	32 ft.	45 ft.	64 ft.

The above table illustrates the simplicity of this method when used for motion picture work. Purely minor variations such as the effect of distance on the *f/* value have been completely ignored.

It is hoped in this way to make the table simple enough to be of some practical use in production. A table of this sort should prove useful in many ways.

(1) It indicates at a glance the capacity in regard to depth of any particular set-up.

(2) It indicates to what extent stopping down the lens will improve depth.

(3) It indicates to what extent a larger stop is justified under any given circumstances.

A table like this, based on magnification of the image, should make it possible for any one to obtain an accurate yet simple grasp of the depth situation in photographing near-by objects with a motion picture camera, and to know, without difficulty, how much depth can be relied upon and utilized in any given case.

REFERENCE

[1] Hardy, A. C.: "The Depth of Field of Camera Lenses with Special Reference to Wide Film," *J. Soc. Mot. Pict. Eng.*, XVI (March, 1931), No. 3, p. 286.

SOUND RECORDING FOR INDEPENDENT PRODUCTIONS*

L. E. CLARK**

Summary.—*The conditions of independent production are contrasted with major studio activities, personnel, equipment, etc. The economics, time, and quality requirements for sound recording in the independent field are discussed, and the relations between independent producers and recording equipment manufacturers are briefly referred to, as well as the technical and business problems to be met, and the probable future developments.*

Practically every technical phase of sound recording in the motion picture field has been thoroughly discussed and reported in the great number of invaluable articles that have been prepared by the engineers in charge of this work. Several authors have discussed the major problems of operation and have touched upon the economic angles of studio recording; but all these papers have been written from the view-point of the large studio that maintains a complete sound department to operate its several sound channels. Independent production has been at such a low ebb during the past two years that the special problems of that field have not assumed sufficient weight to warrant reporting.

In the past six months the trend has turned toward this type of production, with the result that many new picture companies have been organized, while several of the older independents have proceeded with renewed vigor. And with this increase in production there is being developed a new method of sound operation, peculiarly adapted to suit the needs of this type of work. In the first place, independent production can be defined as production that must be sold to another organization for release. Sometimes the release agreement is completed before production begins, although many pictures are begun before definite sales arrangements are made. In any event, the producer is only certain of an outlet for relatively few pictures and consequently is not in a position to make heavy commitments over any considerable period in the future. He

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Clarco, Inc., Hollywood, Calif.

must write off his entire expense on one or two, or at the most, six pictures.

Because of the huge development charges and patent expense, the cost of owning and operating licensed sound equipment has been prohibitive to the independent producer. Frequently he is not in a position to make five-year, or longer, contracts; even in cases where his outlet is assured, the royalties owed to the sound equipment manufacturer accruing from a year's product fall far below the minimum that he must guarantee, while the initial cost and operating expense of even a single channel is an expensive item in itself. These reasons are the principal factors that tended to discourage independent production during 1929 and 1930.

An analysis of sound recording expense shows that fully 90 per cent of the cost of owning a channel of equipment appears as fixed charges—royalty, guarantees, amortization of the original capital investment, sinking funds for properly caring for changes and improvements in methods and equipment, and insurance on expensive equipment, being only a few of the major items under this classification. These fixed charges constitute a five- to ten-year contingent liability that is enough to make the owning of sound equipment practically an impossibility for the producer of small volume. It is essential to keep the sound equipment busy most of the time in order to reduce this enormous fixed charge to an operating point.

To this end, more and more of the independent companies are adopting the system of renting sound equipment and facilities. The company that rents out the sound equipment assumes the contingent liability, and depends upon a steady volume of work from many producers to keep its equipment busy. The individual producer pays for only his own expense—the royalty accruing against his particular picture and the operating expense of the sound rental company. In this way it becomes possible for any independent producer to secure the highest type of recording equipment and personnel, assuring him a job of sound recording equal to those turned out by the major studios, at a price that permits him to operate without the risk of long-term contracts and guarantees.

Experience with these rental companies discloses a considerable difference between recording methods in this field and in the major studios. The sound engineer in the latter case is held to a constant standard of speed and quality in every picture. He knows by experience on previous productions just how much time spent in rehearsals is economically justified for the particular type of product turned out. He works for the most part with relatively few actors and learns to correct for their individual voice characteristics. The sound engineer with the rental organization, on the other hand, must be prepared to be as careful and precise as the best when operating with a company that takes six months to complete a single production, and a few weeks later must be able to shoot as fast as any newsreel cameraman when shooting a serial for another company.

It is next to impossible to find a single mixer who can adapt himself to do both these types of work. If he is exactly the man for the first organization he will be too slow and precise for the serial company. In fact, the biggest single operating factor is the human equation. The personality of the mixer and his assistants must be suited to the particular type of work in hand: precise, patient, thorough-going mixers for the picture that takes months to complete, and quick-thinking, alert, well-founded men who know where time can be saved without materially affecting quality for the productions with ten-day schedules.

Equipment problems accordingly are reduced to a few paramount considerations; high quality, dependable, and easily operated equipment must be furnished always, the particular method of using this equipment depending upon the type of production under way. The equipment must be complete within itself. One channel with spares mounted in a panel-body truck, together with complete power supply for operating recorder and cameras, as well as the amplifiers, is the preferred layout. With this equipment, high-quality recording can be produced both on the sound stage and on location, as long as one of the licensed types of equipment is used. With equipment of either Electrical Research Products, Inc., or of RCA Photophone, Inc., assembled in such a fashion, the independent operator can rent sound recording and be assured of the best possible job, every bit as good as he could obtain by owning and operating equipment himself.

Summarizing, the rental system of providing sound recording facilities is greatly aiding the growth of independent production, while at the same time this growth permits more and more investment by the sound rental companies in equipment. What the future holds in store for this method of operation is of course unknown, but the great economies that are effected by it speak well for its permanence and growth.

SPECIAL PROCESS TECHNIC*

VERN WALKER**

Summary.—*The reasons for the increasing importance of special process photography in motion picture production are briefly discussed. The influence of sound in enlarging the scope of application of special process photography, the avoidance of difficulties of recording sound in many natural locations, the use of special process photography in avoiding hazardous stunts, the economic aspects, and various other phases of the subject are briefly treated of.*

The various methods in commercial use are outlined, and the technical difficulties encountered in special process and trick work, the mistakes to be avoided, and the solution of special problems are pointed out.

The improvements that have occurred in recent years in making "trick work" have brought about a complete change of method, the original single "stupendous trick shot" of the picture being supplanted by a number of shots, and, in many instances, entire sequences being made by utilizing trick photographic processes.

Process photography has been widely used for some time, although its general application was at first limited to the photographing of "stunts" and spectacular scenes that were impossible to photograph in the usual manner. The addition of sound to the picture brought about a situation that required special photographic processes, not only for stunts and spectacular scenes, but for the photographing and recording of sound in the regular production scenes in the studio under the requisite conditions that could not be obtained on actual location. For instance, a scene to be taken within a trolley car would be practically impossible from the standpoint of recording sound. The extraneous noises, the transporting of sound equipment, the tying up of traffic in the desired location, and the expense involved make a suitable case for the use of process photography.

To complete such a scene, using the methods of process photography, the specialist in this type of work obtains from the director instructions as to the angles required and the approximate footage

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** RKO Studios, Inc., Hollywood, Calif.

of the scenes to be processed. A camera crew is sent out to "shoot" the backgrounds for the scenes, under conditions exactly as they would be in the actual circumstances of life. The section of the trolley car is duplicated on the sound-proof stage, the action and the sound are recorded, the background being put in either at this time or after the foreground scene is completed, depending on the method used. After the processed scene is completed, the sound department puts in the desired background noises without impairing the dialog.

The economic value of utilizing process photography is quite apparent in the above situation, although this is a relatively unimportant example of what is being done. The expense of sending a troupe to distant locations is to be compared with the cost of sending only one or two men to the location to obtain the backgrounds, the action to be included in the picture at the studio. Other examples involve unusual locations that cannot readily be found, or imagined locations that do not exist in nature. Such are built in miniature, the action, including full-sized actors and sets, being processed in. Hazardous scenes that require the actors to ride fast cars, scenes of runaway wagons, aeroplane stunts, *etc.*, that in any way endanger life or property, are usually processed into the picture.

The different process methods commonly used are briefly described as follows:

The *Williams* processes, one of which employs the traveling matte for blocking out the foreground action while the background is being superimposed. This method allows the action to be shot first and the background to be put in later.

The *Handschiegl* process uses two films, when photographing the foreground action, and employs the principle of color separation for withholding the exposure of the portion of negative required for the background. The background is put in later.

The *Dunning* process is known as a transparency process; two films are employed when shooting the foreground action. The film in front of the unexposed negative is a transparent positive of the background, its color being complementary to the color of a backing placed behind the foreground set, the action being photographed with a light not complementary to the transparent positive of the background. This method puts in the background at the same time the foreground scene is photographed.

The *Projection* process, which, at this time, is being used with considerable success, consists in projecting on a transparent screen the background desired, placing the actors and set in front of the screen, and synchronizing the camera and projector at the time of photographing. The manner of illuminating the screen for most large shots has been quite a problem, but this difficulty will, no doubt, be overcome in the near future, whereupon this method should then be used extensively.

Many difficulties are encountered in making process shots, as two scenes very seldom call for the same kind of treatment. Not only does the photographic technic of superimposing the scenes become a problem, but there are added the actual mechanics involved in adjusting the action, the speed, and the lighting of the background and the foreground, so that the finished picture may appear as one in the same plane and atmosphere. Often these mechanical adjustments are not painstakingly and properly made and, as a result, the picture on the screen shows obvious signs of having been "faked." When properly done and cut into the picture, the average processed shot is not noticeable to the uninitiated.

The technical hazards in process work are numerous. Photographically, the worst is known as "phantom," or "ghost." This is the case when the foreground appears transparent, the background showing through. Another very common fault is known as a "fringe," in which an obvious line, black or white, appears around the foreground objects, giving an undesirable matte-like effect.

Mechanically, in the photographic phase of processing, about the only real trouble encountered is that of registration, necessitating micrometric adjustments of the cameras and printing apparatus. This trouble appears most often when a stationary foreground is processed over a stationary background. If the two scenes do not register exceedingly accurately, the projected picture appears unsteady, the background and foreground wavering slightly in opposite directions. The chance that this might be due to poor perforations in the film has been found negligible. The greater number of cases of poor registration are found to be due to the shrinkage of the film or to faulty matching of the registering pins of the printers and cameras.

The laying out of the process scenes is an engineering problem. Angles, heights, and speed are of very great importance. At the time the background is photographed, the height of the camera, the angle it is tilted, the lens used, and the speed, if traveling, are recorded. When the foreground is superimposed, the corresponding conditions of the camera must conform to these measurements or the results will appear obviously bad in perspective.

The things to be avoided in process work are so numerous, and so seldom appear twice, that no two men experienced in this kind of work will attack the problems in the same way, or even arrive at identical solutions of a given problem, so that it is impossible to prepare a blanket statement of what not to do.

A group of highly trained men specializing in nothing but process photography has been developed to handle this work for the majority of the Hollywood studios. Every day a new commercial use is being found for process technic, not only to overcome photographic and sound recording obstacles, but to save a considerable amount of time and money.

ERRATUM

The following corrections should be made in the paper, *Résumé of the Proceedings of the Dresden International Photographic Congress*, by S. E. Sheppard beginning on page 232 of the February, 1932, issue of the JOURNAL. The dimensions given on p. 234 should read:

(I) *Perforation Pitch* 475^{+1}_{-0} mm.

(II) *Width of Take-Up (also Feed) Sprocket between Centers of Sprocket Teeth* $28.15^{+0}_{-0.05}$ mm.

(III) *Over-All Width of Take-Up (and Feed) Sprocket* $35.00^{+0}_{-0.20}$ mm.

COMMITTEE ACTIVITIES

REPORT OF STUDIO LIGHTING COMMITTEE*

EQUIPMENT

The report of the Studio Lighting Committee presented at the Hollywood meeting dealt with the various illuminants that could be employed for motion picture photography. This report supplements the preceding one, and discusses the various kinds of lighting equipment, power supply, and distribution systems and wiring practice, in order to make available the information on lighting equipment and practices employed in producing professional motion pictures.

An analysis of the characteristics of studio lighting equipment is facilitated by grouping them into two general classes: (*a*) those employed for general illumination, and (*b*) equipment particularly adapted for modeling lighting. Lighting units of the first group are characterized by a broad light distribution, 60 degrees or more, and are used to produce a relatively uniform illumination over a considerable area. Into this class fall the Broadside, the Rifle, the Dome, the Scoop, Strip Lights, Backing Lights, Floodlights, and various other devices giving a wide distribution of light.

Modeling lighting equipment gives a relatively narrow beam spread, 2 to 30 degrees, producing high intensities over limited areas. Typical units of this class are the reflector spot (also called sun spot), the lens spot, and the soft spot.

This grouping of lighting equipment is based on their more general usage. However, studio lighting requirements frequently necessitate the use of modeling lights for general illumination, and *vice versa.*

GENERAL LIGHTING DEVICES

Broadside unit.—The broadside unit (Fig. 1), available with both incandescent and arc lamps, is provided with one, but more often two, light sources. The lamp housing has a porcelain enameled steel reflector for redirecting light, that would otherwise be wasted, back to the area illuminated. The housing is equipped with holders so that glass or silk diffusing screens may be used for creating, in effect, a

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

larger area source, thus softening the light. The light distribution is quite uniform over a vertical and horizontal angle of 130 to 140 degrees. The incandescent lamp broadside uses 1000- or 1500-watt pear-shaped bulb lamps, and the arc type uses two 35-ampere automatic arcs operating in series. Broadsides are mounted on a three-legged adjustable stand, which permits the lamp to be raised from about $4^1/_2$ to 8 feet, and tilted. Means are also provided for attaching the lamp house to the base when light is required near the floor.

FIG. 1. M-R Type 20. Double side lamp.

FIG. 2. M-R Type 211. Rifle lamp.

The twin arc broadside is still the conventional general illumination unit where arc lighting is employed. The incandescent broadside is being largely superseded by the more efficient "rifle" (Fig. 2) units and floodlights. The broadside is most generally employed as a floor unit for the general lighting of small and medium sized sets. More detailed information relative to its use is given in the section on lighting practice.

Rifle Unit.—The rifle unit is a product of incandescent lighting. It consists of a deep circular reflector about 18 inches in diameter, and a 1000- or 1500-watt, PS-52 bulb lamp is generally used. The reflector

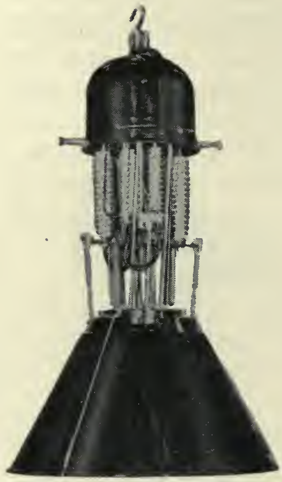

FIG. 3. Fifty-amp. arc dome with silent working mechanism and built-in resistance for 110 volts.

FIG. 5. M-R Type 125. Bowl lamp.

is made either of silvered glass or of chromium plated metal. The reflecting surface possesses spiral flutes which break up striations and irregularities in the illumination; hence the name "rifle."

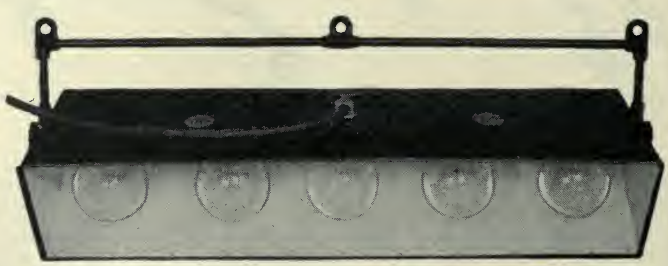

FIG. 4. M-R Type 30. Overhead strip lamp.

This lighting device is employed and mounted in a manner similar to the broadside, the greater part of the light distribution is confined to an angle of about 60 degrees. The efficiency of the unit is very high and from 50 to 70 per cent of the light output of the lamp is available at the area to be illuminated.

Scoop.—The scoop is similar in general design to the broadside except that the reflector is shaped so as to direct the greater part of the light through a vertical angle extending downward from the horizontal. Since the scoop is designed primarily to be mounted overhead it is not provided with a floor stand. It is available either with the arc lamp

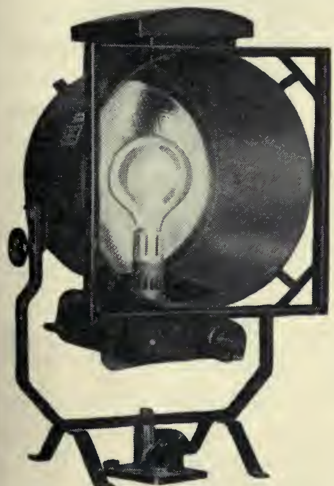

FIG. 6 (*a*). One hundred and fifty-amp. arc illuminator. (Available with facetted mirror and ground glass parabolic mirror.)

(*b*). Two- or three-kilowatt incandescent spot (available with ground glass, facetted, and stippled parabolic mirrors) on spot rail fitting. (Illustration with stippled mirror.)

or with 1000- or 1500-watt incandescent lamps. It is used relatively little in incandescent lighting since the rifle unit can be readily substituted. The greater efficiency of the rifle unit gives it a decided advantage over the older forms of scoop.

Dome Light.—This unit (Fig. 3) is designed primarily to be mounted above motion picture sets and to give a general uniform flood of light throughout the set. In arc lighting practice, domes are available having from one to four lamps. In incandescent practice, domes are used to a limited extent, and possess usually ten or twelve 1000- or 1500-watt PS-52 bulb lamps.

In incandescent lighting practice, the dome has largely been superseded by an overhead lighting unit consisting of 4 to 12 rifle reflectors mounted on a single suspension device. Since individual reflectors around each lamp are far more efficient in directing light where it is desired than a single large reflector for a group of light sources, this latter device gives far greater illumination intensities for the same wattage than the dome.

Strip Lights.—These (Fig. 4) are an outgrowth of incandescent lighting practice, and they usually consist of a long, porcelain enamel, trough-shaped reflector about 18 inches wide and 60 inches long. Five 1000-watt PS-52 bulb lamps are mounted in a row. These units are available with floor stands, and without stands but with a number of suspension rings. The strip light finds its greatest use as a substitute for the dome unit, and when used in this manner several strips are hung side by side. The strip light is also used to direct light through a doorway, behind columns, *etc.* The greater compactness of this unit over broadsides giving the same light output makes it desirable where it is necessary to use the doorway.

Backing Lights.—The backing of a motion picture set is the large curtain that often surrounds three sides of the set and is used to give the effect of sky or to produce a background. It is necessary to light this backing very uniformly and to a high intensity.

In incandescent lighting practice there are available large shallow chromium plated metal reflectors that use the 5000- and 10,000-watt incandescent lamps (Fig. 5). These reflectors are designed to give a very wide uniform distribution so that they can be used quite close to the backing.

Floodlights.—In arc lighting practice high intensity arc lamps either in their housings but without reflectors, or the bare lamps themselves, are commonly used. Where space is available large numbers of broadsides or floodlights are used, especially to give a high intensity of illumination near the floor.

There are also available a number of small miscellaneous lighting devices, some consisting of only a socket and a semi-cylindrical metal reflector. These devices usually employ the 1000-watt, 115-volt tubular bulb projection lamp. They are primarily used to secure a high intensity of illumination over a limited space, such as behind statues, clocks, vases, *etc.*

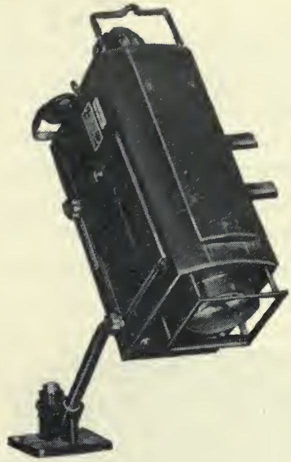

FIG. 8. Twenty-five amp. arc spot on spot rail fitting.

FIG. 7. M-R Type 324. Twenty-four inch "Integral Inkie" sun spot.

FIG. 9. M-R Type 26. Two thousand-watt "Integral Inkie" studio spot.

MODELING LIGHTING DEVICES

Reflector Spots.—The most generally used modeling lighting devices are the reflector spot lamps. For arc lighting practice they are available with 18-(Fig. 6), 24-(Fig. 7), 36-, and even 60-inch reflectors, and in incandescent practice 18-, 24-, and 36-inch reflectors are used. The reflectors are generally mirrored glass of a parabolic contour.

Mirrors employed for incandescent service usually have a shorter focal length than those of the same diameter used with arc lamps. The incandescent reflector spots operate with beam spots having spreads varying from 7 to 30 degrees. The arc spots vary from 2 to

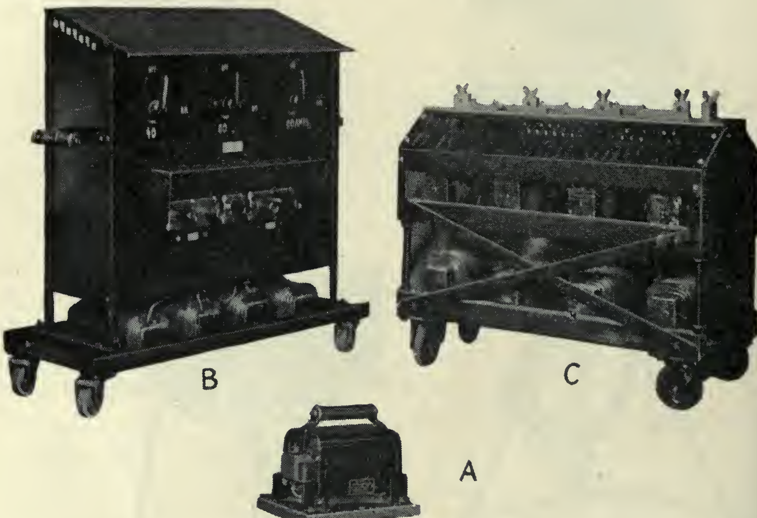

FIG. 10 (*a*). Fifty-amp. choke. (*b*) Resistance and choke combined for 150-amp. sun arc. (*c*) Three hundred amp. choke for 300-amp. arc lens. or two 150-amp. suns, or four 75-amp. arcs.

30 degrees. Practically all the arc lamp reflector spots use the 150-ampere, high intensity arc lamp with rotating electrode. For incandescent lighting, the 2000-watt, 115-volt G-48 bulb monoplane filament lamp is used with the 18-inch reflector; the 5000-watt, G-64 bulb with the 24-inch spot; and the 10,000-watt, 115-volt, G-96 bulb lamp is used with a 36-inch mirror.

Control of the beam spread is obtained by moving the light source from the focal point where maximum concentration is obtained toward the mirror. The great advantage of this type of lamp is that the mirror intercepts light through an angle of 120 to 140 degrees, thus utilizing a relatively large proportion of the available light. These reflector spot lamps are usually provided with mountings so that diffusing glass doors or prismatic lens doors, giving a horizontal beam spread, can be attached. There have recently been made available a number of metal mirrors, usually chromium plated, designed to give some diffusion so that the illuminated spot produced has a high intensity center, and the illumination gradually falls off toward the edges.

Lens Spots.—The lens spot lamp employs a plano-convex lens 6, 8, 10, and 12 inches in diameter (Figs. 8 and 9). The particular advantage of the lens spot is that all the light emitted is contained within the beam and there is no spill light; also, the beam spread can be controlled with great uniformity, through a wide range at all times. Its particular disadvantage is that the light is intercepted at the lens in a small angle, 30 to 45 degrees, and hence the volume of light contained within the beam of a lens spot is much less than that of a reflector spot of equal wattage. In arc lighting practice, lens spots are available using both open and the high intensity arc with 70-, 80-, 100-, 120-, and 150-ampere ratings. Incandescent lamp lens spots employ either the 1000- or 2000-watt, monoplane filament, 115-volt lamps. A spherical mirrored reflector placed behind the lamp is always employed with incandescent spot lamps for redirecting into the beam much of the light that would otherwise be wasted.

Soft Spot.—The soft spot is another outgrowth of incandescent lighting, and consists of a glass reflector of a modified parabolic contour, in some instances the surface of the reflector being stippled. The illumination is produced by a fairly well-defined beam having a high intensity center that tapers off at the edges. Movement of the lamp in and out of the reflector produces some control of the beam spread. The soft spot is largely used in close-up work.

CHOKE COILS

Various types of rugged induction coils have been developed for use in series with d-c. arcs for filtering out commutator hum. Three types of these are shown in Fig. 10.

DISCUSSION

PAST-PRESIDENT CRABTREE: Has any practical application been made of photometers for measuring intensity in studios?

MR. PALMER: No. We have tried to use photometers, and have spent a great deal of time in the effort to do so, but have always encountered the difficulty that photoelectric cells are not constant in their reactions, and that a reading obtained from a certain cell one day does not check with the reading obtained under the same conditions the next day.

PAST-PRESIDENT CRABTREE: A cameraman in Hollywood suggested that, if a rheostat or some means of controlling the intensity were attached to each lighting unit, it would be of great assistance to him in his work.

MR. FARNHAM: In one of the West Coast studios, a number of banks of semi-portable rheostats have been made up, that can be moved to the set and into which various lighting units can be plugged, so as to obtain various dimming effects.

MR. PALMER: Mr. Crabtree's suggestion is to apply a control unit to each individual lamp. We frequently have occasion to dim a single lamp, and find it necessary instead to put on another diffuser or, perhaps, two more diffusers, in order to soften the light. A simple, light, easily worked device for reducing the voltage of the individual lamps would certainly help in many cases, and would save a lot of time in the studio.

MR. MOLE: The banks to which Mr. Farnham referred were made only for effects; for certain sunrise effects or to dim the entire set and the like. The cameramen always wanted a control at each lamp, instead of having to apply diffusers. But a great deal of equipment would be required, and, if any more gadgets are connected to a lamp, difficulties will result. We have found that in studios the simplest equipment, having the least number of connections, is the successful equipment. The personnel is not as well trained as that in the projection room where the equipment remains in one spot and where it is not difficult to add auxiliary parts to supplement the main equipment.

MR. BARTON: Does not the actinic value of incandescent lamps change rapidly in the useful range, so that the effect of the resistors may be to decrease the actinic value considerably without decreasing greatly the apparent brilliancy?

MR. PALMER: That is one of the difficulties that would be encountered if we should dim a lamp by using a resistor. But experience quickly teaches how much dimming is necessary, and how much difference a slight change will make in the photographic value of the lamp. The new film is quite sensitive to red and yellow light, so that the introduction of a resistance into the lamp circuit would not necessarily render the lamp useless.

PAST-PRESIDENT CRABTREE: Are the studios taking advantage of the increased sensitivity of the film? Are they reducing the intensity of the lamps, or are they using the same number of lamps and simply adding a few more diffusers?

MR. MOLE: When the new film first came to Hollywood, many cameramen used it in tests and found that excellent results could be obtained with about fifty per cent of the former illumination. It appeared as though half the number of lamps would be needed, and half the wattage. The studios were very much encouraged over it, as they felt that it was going to cut down their expenses.

But actually, in a production, the cameramen do not have the time to adjust each light. They cannot take the time to fuss around with the adjustments, as the saving achieved in using less wattage or fewer units would not warrant the additional time required to shoot the picture.

After a few months, it was found that, although the wattage was reduced to about seventy-five or eighty-five per cent of the former value, the number of units was about the same. No appreciable reduction in lighting expense was noticed. However, the new film is being used in many productions; I should say that seventy per cent of the productions in Hollywood are being made with the new film.

MR. FARNHAM: I wonder if the cameramen are not stopping down the lenses more, improving the photographic quality, and thus taking advantage of the new film in that manner, instead of endeavoring to reduce the wattage?

MR. MOLE: That depends on the cameraman; some feel that sharp photography is not artistic photography and would not prefer the sharp pictures to the so-called artistic pictures that are continually being produced.

MR. MITCHELL: I think the question is not so much that of saving light, as in having a sufficient number of point sources of light to permit satisfactory adjustment of the shadows, or to obtain the requisite detail in the shadows; in many cases, and, in fact, in most cases, these requirements involve quite a number of sources of light. By using the same number of lamps they can be controlled by diffusers, reducing the over-all illumination, but keeping the general illumination unchanged—that is, the balance of the illumination. If the lens is stopped down, the desired effect is entirely lost.

PAST-PRESIDENT CRABTREE: Could not someone deal with one particular treatment? In the matter of lighting, the conception of the artist is definite. He has a picture in his mind of what he wants or at least he should have, before photographing the set. It is purely a matter of technic in getting the result, and I wonder if someone could not outline in black and white how to get it.

MR. MOLE: The same result can be obtained using various technics. The cameraman can obtain about the same results with entirely different forms of lighting. A paper written on such a subject would describe Mr. Jones' lighting; another would describe Mr. Smith's lighting; and so on. That is their stock-in-trade, and the cameraman cannot be expected really to disclose it or publish it. I dare say you could place every lamp in the same manner that he does, and shoot the picture; and you would not get the same result that he does. There is some individual touch that he has, in painting that picture with light, in being able to obtain certain effects that another cameraman would not obtain with the same set-up.

PAST-PRESIDENT CRABTREE: I disagree with Mr. Mole. If the lamps were placed in the same position, with the same intensities and at the same angles, under the same conditions the results would be identical.

MR. MITCHELL: I agree with Mr. Mole. I have seen a cameraman photograph the same scene that another cameraman had previously photographed, with lights approximately in the same position, and the results would be entirely different. They develop, through experience, an uncanny sense of light. The cameraman may put a diffuser on, or move a light back two feet, and although the change may not be noticeable to the eyes, it makes a difference in the photography of the picture.

ABSTRACTS

The Demand for Stereoscopic X-Ray Motion Pictures in Diagnosis. G. KÖGEL. *Kinotechnik* **13**, Nov. 5, 1931, p. 399. It is maintained that the stereoscopic impression of an object obtained in looking at a pair of stereograms with a suitable optical device depends largely on the observer's previous experience with similar objects, *i. e.*, on his "memory images." For this reason, in order to achieve the ability to see x-ray stereograms correctly, the student must familiarize himself with x-ray photographs. It is believed that the field for stereoscopic x-ray motion pictures lies in detecting the faulty functioning of organs before the disease has had time to alter their form, especially in those cases in which long irradiation of the patient is undesirable. M. W. S.

Thomas A. Edison and His Relations to Motion Pictures. C. FORCH. *Kinotechnik,* **13,** Nov. 5, 1931, p. 397. By autumn of 1891, Edison had constructed an operable motion picture camera in which Eastman perforated film was moved intermittently. The film was advanced by a sprocket driven by a friction belt. Suitable members served to arrest the rotation of the sprocket during the intervals when the exposure was being made. Edison is reported to have employed a Maltese cross for securing the intermittent movement but he discarded it for the mechanism described. Edison's Kinetoskop was a device enabling only one person to view a motion picture. In it, the film moved continuously; a very narrow shutter opening gave such a short view of each picture that a sharp image was obtained. In his American patent no. 493,426, applied for Aug. 24, 1891, he described another viewing device by means of which pictures were projected to a screen. The system was intended to give stereoscopic relief, but the principle was wrong, and incapable of giving a true stereoscopic effect. The apparatus was not designed, however, to project large pictures visible to more than a few persons at a time. M. W. S.

Vacuum Photoelectric Cells of High Sensitivity. M. C. TEVES. *Technique Cinemat.* **2,** Dec. 1931, p. 13. Increased sensitivity, especially to light of longer wavelengths, has been attained in Philip's caesium vacuum photoelectric cells with the purpose of increasing their usefulness with tungsten light sources. Caesium is deposited to a depth of 100 molecules on a foundation coating of a salt or oxide. Sensitivity extends to 12,000 Å. with a maximum between 6000 and 8000 Å. A response of 20 or 30 $\times$ 10^{-6} amperes per lumen for illumination by a source at 2680° Kelvin is attained regularly. Quantum efficiency is therefore as high as 1:20. After 3 hours' use the sensitivity diminishes 5 per cent, but is recovered in 20 hours' rest. Forty to fifty volts' potential is recommended. With such cells the maximum of absorption variation among colored films of a well-known manufacturer measures only 25 per cent. Two (geometric) types of cell are made. C. E. I.

The Use of the Color Filter in the Production of Photographic Images That Are True to Reality. P. LOB. *Kinotechnik,* **13,** Nov. 5, 1931, p. 400. The absorptions of five filters—red, yellow, green, bright blue, and deep blue—were measured at five different positions in the spectrum. For this purpose, a monochromator was used, the intensity of the monochromatic light before and after the insertion of the filter into the beam being measured by means of a thermocell. The sensitivity of a photographic plate for the same wavelengths was measured by first adjusting the light source so that it produced the same effect on the thermocell at each wavelength, and then exposing the plate to the monochromatic light. The sensitivity of the plate was taken as directly proportional to the density produced. Then, in order to show the difference between the absorption of a filter as determined photographically and as measured by its effect on a caesium cell, as well as to show the necessity of knowing the spectral sensitivity of a photographic plate in determining the absorption of filters, exposures were made through each of the five filters by monochromatic light of each of the five spectral regions, and the densities compared to the density produced without the filter in the beam. The absorption of each filter was then measured at each wavelength by means of a caesium cell. In general, the effect produced on the plate fails to correspond to the effect on the cell. It is concluded that for exact work with filters, the following three items must be known: (1) the spectral distribution of the light source, (2) the spectral sensitivity of the photographic emulsion, and (3) the characteristic absorption curve of the filter. M. W. S.

The Motion Picture in Rockefeller City. G. SCHUTZ. *Mot. Pict. Herald,* **106,** Feb. 13, 1932, Sect. 2, p. 13. Building No. 8 in the huge construction program in progress in New York City under the Rockefeller sponsorship is to be a motion picture theater seating 3509 persons. A topographical sketch is shown of the entire project and detailed plans of the theater. The auditorium will be 158 feet wide and 128 feet deep, from the rear wall to the curtain, with the average height of 65 feet. The stage area measures 92 by 46 feet. There will be three shallow mezzanines, each seating approximately 500 persons. Although the large overhanging balcony with its objectionable acoustic character is eliminated, the added height of three levels places the two upper levels above the normal line of the screen, and will require patrons of these sections to lean forward to see the picture, which means some physical discomfort. An excessive and objectionable screen angle for projection is also introduced, since the projection room will be located above the uppermost section. Certain other features of the theater are commented on in the light of modern knowledge of theater construction. G. E. M.

A New Type Projection Lamp. F. H. RICHARDSON. *Mot. Pict. Herald,* **106,** Feb. 13, 1932, Sect. 2, p. 40. A detailed description of an improved lamp for theater projection. Specially designed, quickly acting clamps have been introduced, both for negative and positive carbons, which permit rapid change of carbons but insure firm retention when burning. Control of the arc is intended to be accomplished chiefly by means of a thermostat. A lens projects a side view of the burning positive crater to a mirror which reflects the image to a thermostat. As the crater burns away, the image falls nearer and nearer the thermostat until a set of electrical contacts is brought together which speeds up the motor and the crater is brought forward to its normal position. Additional features are mentioned. G. E. M.

New A-C. Amplifier. *Film Daily,* **58,** Feb. 21, 1932, p. 6. This instrument has been designed especially for sound-on-film reproduction, and constitutes the entire electrical apparatus necessary between the photoelectric cells and the stage horns. The unit is equipped with a new type of transformer which is stated to supply the current to the exciter lamps without the need of filtering. The device is designed for use in theaters having about 1200 seats. G. E. M.

Sound Equipped Theaters in U. S. in 1931. *Mot. Pict. Herald,* **106,** Jan. 30, 1932, p. 9. According to figures supplied by the Film Boards of Trade, there were 13,223 sound equipped theaters in the United States at the close of the year 1931. Of these, 6434 have sound-on-film equipment; 3609 use disk only; and 4898 were equipped for both disk and film. One thousand five hundred eighty-two theaters having sound equipment were not operating. A total of 20,100 theaters, having an approximate seating capacity of 10,767,000, are listed on the books of national distributors. G. E. M.

Planning Today's Simplified Cinema. B. SCHLANGER. *Mot. Pict. Herald,* **105,** Nov. 21, 1931, Sect. 2, p. 18. Two theater plans are discussed in some detail for 300-seat and 600-seat structures, respectively, which are designed to be built within limited spaces. Both theaters are planned to occupy only a portion of a structure used also for other purposes. The reverse slope floor plan is used in each design. G. E. M.

Sound Control in Air Conditioning Installations. V. O. KNUDSEN. *Mot. Pict. Herald,* **105,** Nov. 21, 1931, Sect. 2, p. 37. Attention given to sources of extraneous noise within and without the sound picture theater has resulted in considerable study of causes of and means for elimination of noise in the ventilating system. It is important that all mechanical equipment used in air conditioning be carefully insulated from the solid structure of the building. Detailed mathematical equations are presented for the determination of suitable insulation, knowing certain measurable factors. Absorptive filters are necessary between the ventilating fan and the outlets to eliminate noises transmitted through the ducts. G. E. M.

A Radically New Studio Camera. W. STULL. *Amer. Cinemat.,* **12,** Feb., 1932, p. 12; *Internat. Phot.,* **4,** Feb., 1932, p. 4. The novel feature of this new camera, designed by T. L. Tally and T. M. de la Garde, is that the magazines are placed beneath the camera case, thereby lowering the center of gravity and providing better balance. The range of tilt is increased. Sprockets are a part of the magazine, and act as a light trap in this position. The camera has a four-lens turret, movable as a unit for focusing—a 240-degree shutter, and a view finder in which the film aperture can be observed directly. A. A. C.

New B. & H. Lens Eliminates Crane Shots in Professional Movies. *Amer. Cinemat.,* **12,** Feb., 1932, p. 31. This objective is a variable focus outfit, with mechanical shifting of the elements to maintain accurate focus and diaphragm opening throughout a range of 40 to 120 mm. focal length. It is thus possible to approach a subject or recede from it without moving either the camera or the scene. The speed of the unit ranges from $f/3.5$ for 40 mm. to $f/5.6$ at 120 mm. focus. It is made on special order only. A. A. C.

RCA Presents 16 Mm. Sound-on-Film Projector. *Amer. Cinemat.,* **12,** Feb., 1932, p. 36; *Internat. Phot.,* **4,** Feb., 1932, p. 25. This new equipment is said to show a good 4 × 6 foot picture, with excellent quality of sound reproduction. Since it is practically the first of the sound-on-film 16 mm. outfits, its performance will be noted with much interest. The projector amplifier unit weighs 43 pounds, with its case; all the equipment is readily accessible for necessary adjustment so that it need not be removed from the case during operation. The loud speaker fits in a 21-pound case, 19 × 16 × $9^1/_2$ inches. Space for eight 400-foot reels is also provided. Sound volume is sufficient for a room of 10,000 cu. ft. A. A. C.

Internationalizing Talking Pictures. A. GRADENWITZ. *Proj. Eng.*, **4**, Feb., 1932, p. 7. A new rhythmic method of recording sound effects enables directors to add the foreign text after a film has been finished in English. It is based on a new means of remote control, invented by C. R. Blum, of Berlin, by which synchronism can be attained between any number of electrical devices. It is independent of the actual speed of motion. The recording from the film is repeated on a band arranged to move in front of the operator on an electrical recorder. Text and music are accurately spaced in accordance with the rhythm of the picture so that actors have only to read or play their parts from the band in order to be sure of perfect agreement between picture and sound record.
A. A. C.

A New Zoom Lens. *Amer. Cinemat.*, **12**, March, 1932, p. 16. Describes a lens of adjustable focus announced by O. Durholz, of Paterson, New Jersey. "The lens snaps over the standard Mitchell type cup mount in a few seconds ready to focus. . . . From long shot to close-up it maintains focus automatically from 40 to 160 mm. (equivalent focal length). The effective aperture is $f/8$ at full range, $f/5.6$ at 3x, increasing as the range is limited." An outline of the problems of mechanical construction met by the designer is given in some detail.
A. A. C.

Agfa-Novopan Reversal Film. L. KUTZLEB. *Kinotechnik*, **13**, Sept. 10, 1931, p. 333. A new panchromatic 16 mm. reversal film has been placed on the market. This is said to have a speed standing in the ratio, 16:6:1, to the speeds of Agfa Pan and Ortho Reversal films by tungsten light, and in the ratio 4:2:1 to the speeds of these same films by daylight. This increased speed is stated to be the result of increased color-sensitivity, particularly for the longer wavelengths. An anti-halation layer is inserted between the emulsion and the support. The film is recommended especially for use under artificial lighting.
M. W. S.

Agfa Leica-Superpanfilm. L. KUTZLEB. *Kinotechnik*, **13**, Dec. 20, 1931, p. 466. This film is panchromatic and is said to have three times the speed of Agfa Leica-Isochromfilm by incandescent lighting, or twice the speed by daylight. The film is said to make possible the making of snapshots in well lighted rooms by the aid of high aperture objectives without a yellow filter. A double emulsion layer and an anti-halation layer are used. A fine grain developer is recommended for developing small negatives for enlargement. M. W. S.

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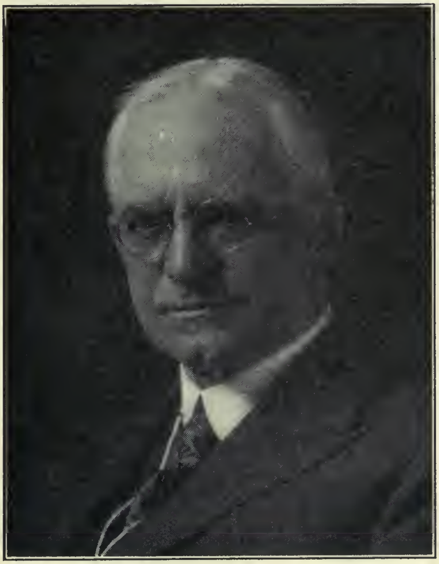
GEORGE EASTMAN

JULY 12, 1854—MARCH 14, 1932

The name, George Eastman, will always be linked inseparably with the growth of photography, particularly amateur and motion picture photography. Mr. Eastman began his career with an idea—to make photography available to every one. He lived to see the growth of a great industry built around this idea, for there are millions



George Eastman

of persons in all parts of the world who now use photography. His active interest in photography began about 1878. During his lifetime he was successful in introducing small cameras, roll film, the folding Kodak (daylight loading and daylight developing), improved photographic papers, motion pictures for the amateur, first as black and white and later in natural colors, as well as many other developments.

Almost equally significant, however, were his contributions to the growth of the motion picture industry. Within a few months after his discovery of a method of making film on a transparent support, Edison's purchase of some of the new product stimulated its manufacture. For many years this "picture ribbon," as it was called, was made only in two grades, negative and positive; but additional refinements were added as the industry grew, until in 1914 panchromatic film was introduced, making possible more accurate and pleasing tone reproduction. More than a decade elapsed, however, before the industry came to use this film extensively and, under the stimulus of greater use, further improvements were announced in 1931, both as regards speed and color-sensitivity.

Many of these developments were made possible by Mr. Eastman's life-long conviction of the value of research. Besides experimenting himself during his earlier years, he employed the services of others, until a large research organization was built up which today investigates all branches of photographic endeavor, from theoretical as well as practical standpoints.

Besides his fame as an industrial leader, he gained public distinction and satisfied his personal responsibility as a philanthropist through his gifts to the upbuilding of his native city of Rochester and other cities. These took the form of endowments for research and teaching, erection of buildings for education in engineering, a school of music, a college of medicine, dental clinics, and for other useful purposes.

Mr. Eastman was elected to honorary membership in the Society of Motion Picture Engineers on April 13, 1928; and at the banquet honoring pioneers of the industry, which was held at Swampscott, Mass., on October 7, 1931, was one of seven honorary members to whom formal scrolls were presented. On that occasion he designated J. I. Crabtree to receive his scroll for him. Concrete evidence of Mr. Eastman's respect for the work of the Society was shown recently by his donation of a fund for the establishment of a Motion Picture Engineering Fellowship, under the supervision of the Society.

Honored by many nations and international societies, George Eastman's greatest contribution was undoubtedly the development of the medium of film photography, which resulted in a worldwide hobby for the amateur and exerted an important influence in the establishment and growth of the motion picture industry.

GLENN E. MATTHEWS

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held on March 25th at New York, further details of the Spring Convention to be held at Washington, D. C., were arranged, the general scheme of which was published in the April issue of the JOURNAL. Other details concerning the Convention are given below.

Authorization was given for the formation of a "Constitutional Committee," the function of which would be to consider recommended amendments of the Constitution and By-Laws of the Society. Among other amendments proposed at this meeting of the Board of Governors, the recommendation was made that the admission fee to the grade of Active membership be reduced to ten dollars and to the grade of Associate membership, five dollars; and that the transfer fee from the Associate to the Active grade be the difference between the two admission fees, or five dollars.

It was also ruled that the Honor Roll of the Society, established at the Swampscott Convention for the purpose of perpetuating the names of distinguished pioneers in the motion picture art, who are now deceased, be published each month in the JOURNAL.

SPRING, 1932, MEETING

MAY 9 TO 12, 1932

WARDMAN PARK HOTEL, WASHINGTON, D. C.

A rather complete schedule of activities for the approaching Washington Convention was submitted to the Board of Governors at its recent meeting by Mr. W. C. Kunzmann, Chairman of the Convention Arrangements Committee, and Mr. O. M. Glunt, Chairman of the Papers Committee. The final plan adopted by the Board of Governors included, among other details, the following features:

The morning of Monday, May 9th, will be devoted to registration, committee meetings, *etc.* The Convention will be formally opened at 11:00 A.M. with a welcoming address by Hon. Congressman Sol Bloom, followed by the response of the President.

The afternoon of Monday, May 9th, will be devoted to the presentation of S. M. P. E. committee reports.

On Wednesday, May 11th, a session will be held at the Auditorium of the Department of Commerce, where addresses will be delivered by various government departmental heads. Sightseeing trips and other means of recreation will be provided for the afternoon of this day. The semi-annual banquet of the Society will be held on the evening of Thursday, May 12th, in the Gold Room of the Wardman Park Hotel.

An interesting papers program has been arranged by the Papers Committee, separate sessions being devoted to (1) the problems of theater operations; (2) problems of the release print, in production, theaters, and exchanges; (3) lectures by members of the staff of the U. S. Bureau of Standards; (4) motion picture photography, and various other interesting subjects.

An exhibition of newly developed motion picture apparatus will be held at the Wardman Park Hotel, the Convention Headquarters. Manufacturers desiring to exhibit their new apparatus should communicate with the General Office of the Society at 33 West 42nd Street, New York, N. Y.

NEW YORK SECTION

At a meeting of the New York Section held on March 23rd at the Electrical Institute in New York, N. Y., an interesting address on the subject of "Animated Cartoons in the Making" was presented by Mr. Harry Bailey, of Fables Pictures, Inc., illustrated by hand drawings and a motion picture parody of the subject of the talk.

The next meeting of the Section is scheduled for April 30th, at the Electrical Institute, at which time Mr. H. G. Tasker, of the United Research Corporation, will present a paper dealing with the problems of recording sound on sixteen millimeter film and of the corresponding problems of projection and reproduction.

CHICAGO SECTION

The March meeting of the Section was held on March 3rd at the headquarters of the Electric Association in Chicago. A paper presented by Mr. H. Shotwell, dealing with portable a-c. amplifiers, was followed by a general discussion of the problems attending the use of this type of equipment in reproducing sound from film.

At the following meeting held on April 7th at the Electric Association headquarters in Chicago, Mr. E. Cour demonstrated the Artreeves recorder and described its operation. Mr. W. A. Holtz also gave a demonstration of the new sixteen millimeter sound-on-film projector.

PROJECTION PRACTICE COMMITTEE

At a meeting held at New York, N. Y., on April 4th, a further study was made of the various problems attending the use of the release print in the theater, and a preliminary draft of that section of the Committee's report, to be presented at the Washington Convention, was drawn up. Further consideration, also, was given to a proposed method of equalizing the sound output of projectors in theaters, and of the data that are now being accumulated by the Committee with regard to the illumination of projection screens in theaters. It is probable that, on account of the magnitude of the work of collecting and analyzing all the requisite data on projector tolerances, clearances, and tensions, the description of that part of the Committee's work will be deferred until the following report, as it was felt that unless the data were reasonably complete, their great importance to the motion picture industry might not be fully appreciated and their utilization might be more limited than is desirable.

SOUND COMMITTEE

At a meeting held at New York, N. Y., on March 18th, the report of the subcommittee on frequency characteristics was considered, particularly with reference to the compensation of frequency characteristics of reproducing and recording apparatus, and as to the manner in which compensation should be made for the slit losses in recording. The report also included a recommendation on the method of adjusting the azimuth of the recorder slit.

A study was also made of the desirable volume range of reproduction, the limitations of reproducing equipment, and the overload to ground noise ratio in sound records.

Another meeting of the Committee will be held prior to the Washington Convention for the purpose of drafting the final report to be presented at that time.

STANDARDS COMMITTEE

At a meeting of the Standards Committee, held at the General Office of the Society on March 15th, further consideration was given to the establishment of dimensional standards for sixteen millimeter sound film, and to various items recommended for standardization by the Projection Screens Committee. Among these were the standardization of tolerances and methods of test for determining the acceptability of projection screens, the method of making measurements of the reflectivity of screens, the definitive names of various types of projection screens, and the relation of the size of screen to the distance of the nearest observer.

After reviewing the circumstances attending the problem of establishing dimensional standards for the apertures of 35 millimeter projectors, the Committee passed for recommendation to the Society the dimensions 0.600×0.825 inch for the projector aperture, and the dimensions 0.631×0.868 inch for the corresponding camera aperture.

Final recommendations were made concerning the layout for 16 mm. sound film to be proposed for standardization, and arrangements were made to have these final layouts ready for submission and action at the Washington Convention.

JOURNAL AND PROGRESS AWARDS

At a meeting of the Board of Governors held May 24, 1931, it was decided that the following actions of the Board, relating to the JOURNAL Award and the Progress Medal, should be published annually in the JOURNAL.

JOURNAL AWARD

The motion was made and passed that "an award of $100.00 shall be made annually, at the Fall Convention of the Society, for the most outstanding paper published in the JOURNAL of the Society during the preceding calendar year. An appropriate certificate shall accompany the presentation.

"The JOURNAL Award Committee shall consist of not less than six Active members of the Society, to be appointed by the President subject to ratification by the Board of Governors. The Chairman of the Committee shall be named by the President and a two-thirds vote is necessary for election to the award. (Proxies are permitted.)

"The Committee shall be required to make its report to the Board of Governors at least one month prior to the Fall Meeting of the Society, and the award must be ratified by the Board. A list of five papers shall also be recommended for honorable mention by the Committee. These rules, together with the titles and authors' names, shall be published annually in the JOURNAL of the Society."

PROGRESS MEDAL

"The Board of Governors may consider annually the award of a Progress Medal in recognition of any invention, research, or development, which in the opinion of the Progress Award Committee shall have resulted in a significant advance in the development of motion picture technology.

"The Committee shall consist of not less than six Active members of the Society, to be appointed by the President subject to ratification by the Board of Governors. Names of persons deemed worthy of the award may be proposed and seconded, in writing, by any two Active members of the Society and shall be considered by the Committee during the month of June; a written statement of accomplishments shall accompany each proposal.

"Notice of the meeting of the Progress Award Committee must appear in the March and April issues of the JOURNAL. All names shall reach the Chairman not later than April 20th.

"A two-thirds vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing. The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

"Recipients of the Progress Medal shall be asked to present their portraits to the Society, and, at the discretion of the Committee, the recipients may be asked to prepare a paper for publication in the JOURNAL of the Society. These regulations, the names of those who have received the medal, the year of each award, and a statement of the reason for the award shall be published annually in the JOURNAL of the Society."

Active members of the Society are invited, according to the above, to propose names of those deemed worthy of receiving the Progress Medal Award, which proposals should be seconded by another Active member and forwarded to the Chairman of the Committee, Dr. C. E. K. Mees, addressed to the General Office of the Society.

A written statement of accomplishments should accompany each proposal, which should reach the Chairman not later than April 20th.

The two committees have this year been amalgamated into a single committee known as the "Committee on Journal and Progress Medal Awards."

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Carrier Engineering Corp.
Case Research Laboratory
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN

Statement of the Ownership, Management, Circulation, *Etc.*, Required by the Act of Congress of August 24, 1912, of *Journal of the Society of Motion Picture Engineers*, published monthly at Easton, Pa., for April 1, 1932.

State of New York
County of New York } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared Sylvan Harris, who, having been duly sworn according to law, deposes and says that he is the Editor of the *Journal of the Society of Motion Picture Engineers* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), *etc.*, of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of— *Post Office Address—*

Publisher, Society of Motion Picture Engineers, 33 W. 42nd St., New York, N. Y.
Editor, Sylvan Harris, 33 W. 42nd St., New York, N. Y.
Managing Editor, Sylvan Harris, 33 W. 42nd St., New York, N. Y.
Business Manager, Sylvan Harris, 33 W. 42nd St., New York, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

Society of Motion Picture Engineers, 33 West 42nd St., New York, N. Y.
A. N. Goldsmith, President, 570 Lexington Ave., New York, N. Y.
J. H. Kurlander, Secretary, 2 Clearfield Ave., Bloomfield, N. J.
H. T. Cowling, Treasurer, 343 State St., Rochester, N. Y.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)

None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is: (This information is required from daily publications only.)

SYLVAN HARRIS, Editor-Manager.

Sworn to and subscribed before me this 14th day of March, 1932.

(Seal) KENNETH L. JEFFERY.
Notary Public, Westchester County,
Certificate filed in New York County,
Clerk's No. 48, Reg. No. 2-J-37.
(My commission expires March 30, 1932)

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Volume XVIII | JUNE, 1932 | Number 6

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

Published monthly at Easton, Pa., by the Society of Motion Picture Engineers.

Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, 33 West 42nd St., New York, N. Y.

Subscription to non-members, $12.00 per annum; to members, $9.00 per annum, included in their annual membership dues; single copies, $1.50. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or 33 W. 42nd St., New York, N. Y.

Entered as second class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

THE PRINCIPLES OF THE LIGHT VALVE*

T. E. SHEA, W. HERRIOTT, AND W. R. GOEHNER**

Summary.—*The light valve has been used very widely as the modulating device in systems of film sound recording. In this paper the principles of operation of the light valve are discussed, and those engineering factors which prescribe limitations on performance and indicate operating advantages are described in detail. The type of distortion which results when a light valve is overloaded is depicted both for single-plane and two-plane valves. Finally, a new type of light valve having advantages from the standpoints of weight, size, and stability of operation is described.*

I. Introduction

The light valve, as a sound recording instrument, has seen very wide use during the past three years. It has undoubtedly been used for more recording and re-recording in the motion picture industry during that time than have all other types of light modulating devices combined. The extensive experience acquired with its use in studio, location, and newsreel recording has shown it to be a rugged and efficient instrument capable of making sound records of excellent quality.

During this time extensive studies have been carried on to perfect the light valve. For instance, as the producers have become better acquainted with sound recording systems and have been able to utilize them more nearly to their full capabilities, the quality of sound recording has improved, and it has been necessary to improve various elements of recording systems in order to extend their range of operation and to reduce to a minimum production delays due to recording difficulties. How great a change in recording conditions has taken place during the last three years may be seen by considering, as a case in point, the early difficulties encountered with outdoor recording on location in contrast with the smoothness and regularity with which recording equipment is now operated under similar circumstances.

As often happens with an instrument which has been perfected to a

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Bell Telephone Laboratories, Inc., New York, N. Y.

high degree prior to commercial use, the improvements which have resulted from the studies mentioned above, though numerous, have not been fundamental. They represent rather an aggregation of minor improvements which, taken as a body, constitute an important advance. A new type of light valve, described later in this paper, does, however, represent fundamental advances.

Although various earlier attempts to construct light gates of variable aperture for sound recording had been made, the first

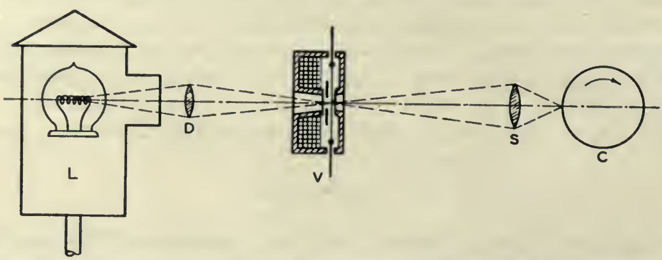

FIG. 1. The receiving end (optical system) of a picture transmission system; *V*, the light source; *D* and *S*, condensing and objective lenses; *C*, the moving film.

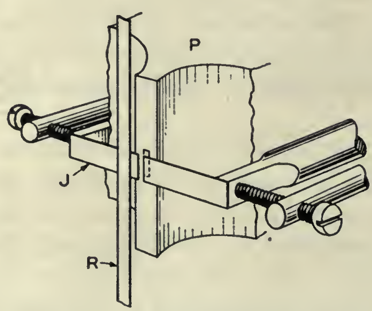

FIG. 2. The single-ribbon type of light valve; *R*, the ribbon; *J*, the aperture jaws.

practical form of light valve was developed by E. C. Wente in 1922. Subsequently, the light valve has been used in the "single-ribbon" form since 1924 for the regular commercial transmission of pictures over telephone circuits.[1]

In this development, the picture is broken into a series of long, narrow sections, similar to sound tracks, which when illuminated are scanned by a slit and photoelectric cell. The electric currents thus generated are amplified and sent over telephone wires. Processes of frequency modulation are used which need not be described here. At the receiving end these currents modulate a light valve which varies the exposure of a moving film, and provide the proper latent image for the re-creation of the transmitted picture. Fig. 1 shows the receiving end optical system of a picture transmission system, V being the light valve, L the light source, D and S the condensing and objective lenses, and C the moving film. Fig. 2

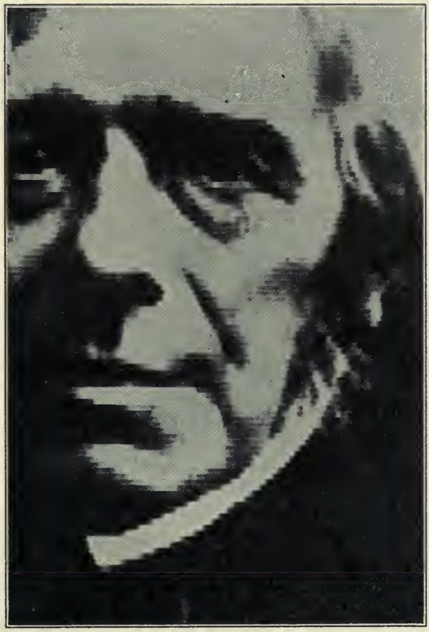

FIG. 3. Enlarged portion of a transmitted picture of the variable density type.

shows the single-ribbon type of light valve employed, the ribbon R vibrating in front of the gap between the aperture jaws J. Fig. 3 shows an enlarged portion of a transmitted picture of the variable density type; the similarity of its horizontal sections to sound tracks is obvious.

The conditions of use of light valves in sound recording are rather different from those of picture transmission, and a consideration of some of them led to the choice of the double-ribbon type of valve for this field. In general, it was recognized that in the latter field the proposed conditions of operation were more severe; and it was believed that, if the duty of modulating could be carried out by two ribbons instead of one, the sensitivity of the valve would be increased, the internal temperature rise due to conductor heating reduced, and tones freer from spurious harmonics obtained. Subsequent experience has verified these suppositions.

This is not to say that the single-ribbon valve is not suited to sound recording, but that under present conditions, at least, it will do so only at a disadvantage from several fundamental design standpoints. In what follows, where a comparison between the two types is made, an endeavor will be made to separate these factors out of any specific design and consider them on a general basis, so that the facts involved may not be clouded.

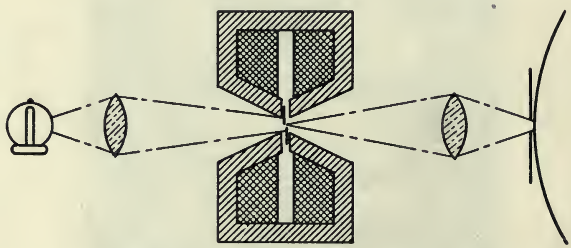

FIG. 4. An early double-ribbon valve whose moving condensers lie in different planes.

It should be kept in mind, however, in order to dissipate a prevalent but erroneous belief, that *either the single- or the double-ribbon valve may have two forms:* (*a*) *one in which light barriers or gates adjacent to the aperture are in the same plane, and* (*b*) *one in which these barriers are in different planes.* Thus, in the general form of either type of valve, excessive modulation does not lead to "light valve clash" but merely to a cutting off of the peaks of one side of the signal wave. Indeed, in one of the earliest discussions[2] of light valve operation there is described (Fig. 4) a double-ribbon valve whose moving conductors lie in different planes.

In the use of the light valve as an optical rectifier, valves of the two-plane type are requisite. In the use of a light valve as a simple modulator, the choice between the *one-plane* and *two-plane* types is to be determined by efficiency, quality, and maintenance considerations. These will be discussed later.

The general method of employing the light valve in variable density sound recording has been described at length by MacKenzie.[3] The photographic and recording technic outlined by him is sufficiently representative of present-day procedure to be assumed in what follows. The light valve itself has undergone changes in form which will be described. It is important to note in this connection, however, the specific changes in recording technic involved (1) in the use of a 1.0-mil normal aperture (instead of 2.0 mils) imaged on the film (Fig. 5) as an exposure beam 0.5 mil wide, and (2) in the use of noise reduction equipment such as that described by Silent.[4]

Either the single- or double-ribbon valve may be used not only for variable density, but for variable width recording. In the former case, the direction of the ribbons is transverse to the film; in the

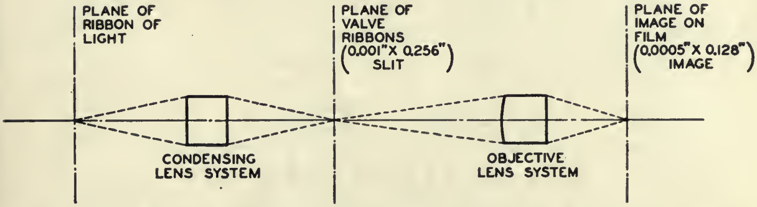

FIG. 5. Illustrating the specific changes in recording technic involved in the use of a 1-mil normal aperture (instead of 2 mils).

latter case, lengthwise with respect to it. The light valve has been used for variable width work in picture transmission. Inasmuch as all commercial light valve sound recording is of the variable density type, we shall consider only the latter.

The remainder of this paper will be divided into a consideration of theoretical aspects of light valve modulation (Part II), a discussion of practical factors important in light valve design and use (Part III), and a general description of a new type of light valve (Part IV).

II. Theoretical Aspects of the Light Valve

1. VIBRATORY ACTION OF THE LIGHT VALVE

The light valve, considered in its electromechanical aspects, is similar in operation to the Einthoven string galvanometer. Considered in a transverse section (Fig. 6), a current I flows in a conductor A in a uniform magnetic field. (A second conductor B is used in the double-ribbon valve for the return of the current and moves always in opposite direction to the first, but the individual conductors may be considered to act separately.)

The conductor (ribbon) A will move at right angles to both the direction of the magnetic field and of the current, and the force F acting upon it is

$$F = kIH$$

where H is the intensity of the magnetic field linked by the conductor, and k is a constant. Thus the force acting upon the ribbon is proportional to (1) the strength of the magnetic field and (2) the instantaneous current. If I is an alternating current, such as corre-

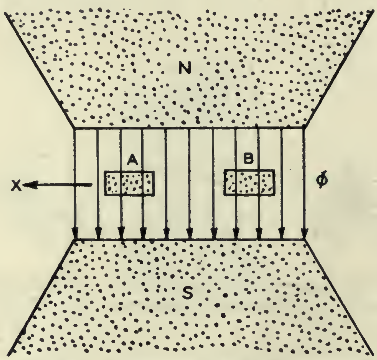

FIG. 6. Transverse section of light valve used in analyzing its action.

sponds to speech and music, the force F will be of similar character and the motion of the ribbon will alternate accordingly.

The extent of motion of the conductor per unit of current at low frequencies will depend solely on the total tensioning force exerted on the conductor as it lies stretched between its supports. That is, the force due to the current will deflect the ribbon until it is offset by an equal restoring force; the latter is a component of the tensioning force and is proportional to the displacement of the conductor from its line of support.

Under these conditions, the power input to the conductors is simply that dissipated by their resistance. The conductor, however, has uniformly distributed mass as well as elasticity, and the former becomes of increasing importance at high frequencies. The inertial force of the moving conductor tends to keep the conductor moving and to offset the effect of the restoring force. As the influence of the mass increases, an increase in the motion of the conductor for a given amount of current occurs, and the valve becomes more sensitive or responsive. At a particular high frequency, the effect of distributed mass and elastance will offset each other and light valve "resonance" will occur. For this condition, the valve is highly sensitive; and for frequencies in the vicinity of resonance, distortion of the signal takes place in that the response is excessive compared with that at low frequencies. Fig. 7 shows relative response curves

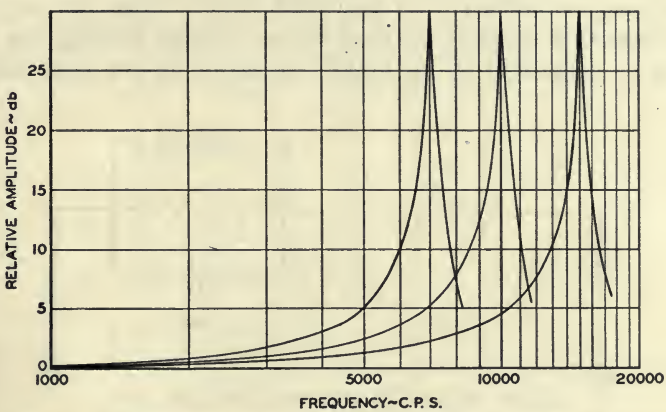

FIG. 7. Relative response curves of light valves whose resonances occur at 7000, 10,000, and 15,000 cycles.

of light valves whose resonances take place at 7000, 10,000, and 15,000 cycles, respectively.

2. LIGHT VALVE RESONANCE AND TUNING

This resonance, of course, is controllable and is generally caused to fall outside the useful range of recording. The resonance or "tuning" frequency is given[5] by

$$f = \frac{1}{2l}\sqrt{\frac{T}{M}} = \frac{1}{2l}\sqrt{\frac{T}{A\rho}}$$

where
f = resonance frequency
l = length of vibrating conductor
T = tension
M = mass per unit length
A = area of conductor in cross-section
ρ = density of conductor material'

The resonance or "tuning" frequency may be controlled, therefore, by changing the tension of the conductor, the length of its vibrating span, the cross-section of the conductor, or the density of its material. For a given design of light valve, l is fixed. For a given type of conductor ribbon, M, A, and ρ are fixed. Consequently, in practice the resonance frequency is set by adjusting the tension of the ribbon to a sufficiently high value.

3. IMPEDANCE OF THE LIGHT VALVE

The impedance characteristic of the light valve is of interest in considering the efficiency of the light valve. Since the motion of the conductors depends on the value of current flowing, the valve should be connected to its supply circuit under the most efficient

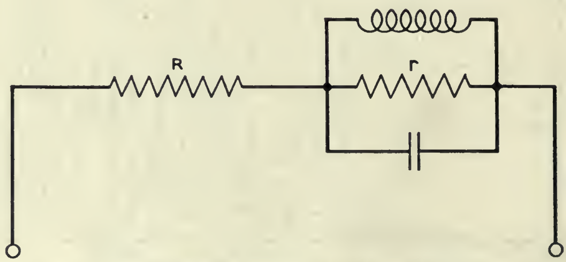

FIG. 8. Electrical equivalent of the light valve.

conditions, *i. e.*, when the impedance of the valve and the circuit are matched so that for a given emf. in the supply circuit, maximum current flows in the valve.

At low frequencies, the power delivered to the valve is entirely used in conductor heating, and yet the valve is most highly responsive when maximum current is delivered because the mechanical force set up is greatest. At high frequencies, the mass and elasticity of the conductor must be represented in the electrical impedance, for, as the conductors move, reaction emfs. are generated, which create reactive impedance in the valve circuit. At resonance, the reactances due to mass and elasticity offset each other and the impedance is controlled largely by the damping resistance (r), due to mechanical friction. Fig. 8 shows the electrical equivalent of a light valve. Fig. 9 shows a typical light valve frequency-impedance characteristic. The same data, when put in polar form (Fig. 10), display the "motional impedance characteristic" typical of the telephone receiver and other vibrating instruments.

4. SCANNING LOSSES AND HARMONIC DISTORTION

The "Ribbon Velocity" Effect.—The foregoing discussion has dealt with the movement of the ribbons in response to an alternating current and, accordingly, with the variations of light flux passed through the valve. We are interested, however, in the variations

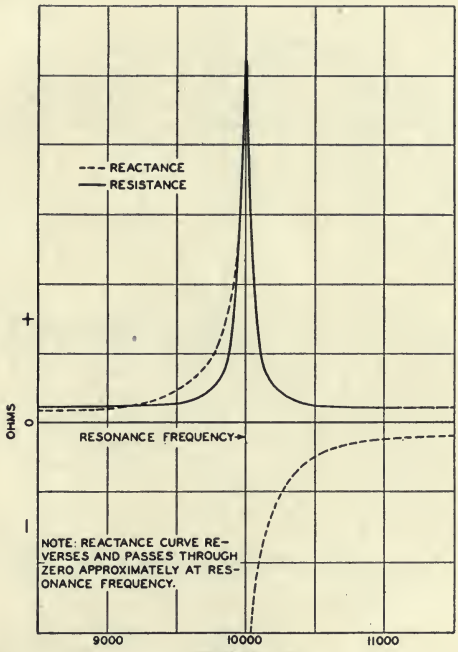

FIG. 9. The optical light valve frequency-impedance characteristic.

in point-to-point exposure of the moving film on which the light valve slit is imaged in a recording machine. The exposure given to the film, it may be readily seen, is not determined by changes in intensity of the light flux, but by the time required for any point on the film sound track to pass through the image of the light valve slit. This time, and the effective exposure of any point on the film, is therefore affected by the film velocity.

If the film moves very rapidly, the average exposure of the sound track will be low, and *vice versa*. The brilliancy of the lamp source, the condensing lens system, and the average opening of the light valve must be arranged, for any given film speed (*e. g.*, 90 ft. per min.), to give the proper average film exposure.

If the frequency being recorded is low, so that the velocity of the ribbons is small compared with the velocity of the film, the variations in film exposure will represent faithfully a pattern of the light

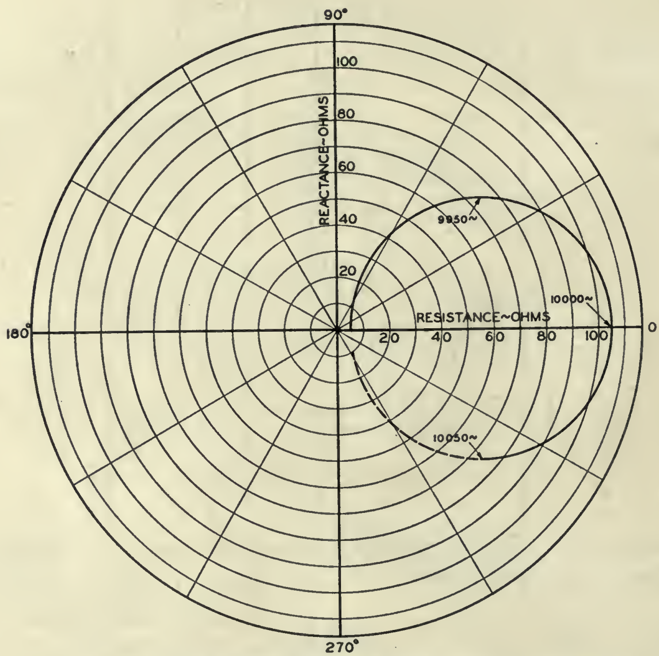

FIG. 10. Same data as in Fig. 9, plotted in polar coördinates.

valve modulation. As the frequency becomes high enough, however, the velocity of the ribbons increases, so that "the ribbon velocity effect," as it is called, comes into play. This results (1) in a loss of effective variation in exposure, which means a loss of recorded volume, and (2) in a degradation of wave-shape which includes the production of spurious harmonic frequencies.

The ribbon velocity effect is somewhat different in the cases of the single- and double-ribbon valves. It may be analyzed[6] as follows:

Double-Ribbon Case.—In Fig. 11, let a transverse line (infinitesimal striation) P of a film moving with velocity v be, at any time t, at the center of the exposure image, and let the instantaneous width of the image be $2w$. The half-width of the image is then w. Let the half-width of the image at that previous time t_1, when P just entered the image, be w_1, and let the half-width at that subsequent time t_2, when P will leave the image, be w_2. It will be assumed that the film velocity v always is greater than the rate of change of the half-image size (dw/dt).

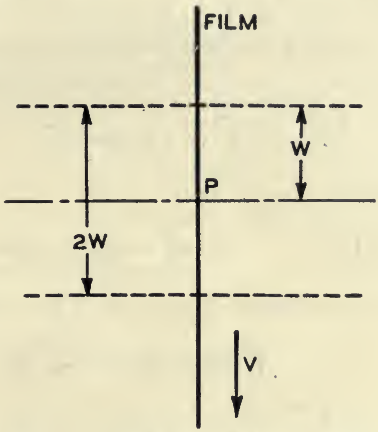

FIG. 11. "Ribbon velocity," effect diagram.

The total light received by P is proportional to

$$w_1 + w_2 = v(t_2 - t_1)$$

This must be expressed in terms of t.

Now

$$w_1 = v(t - t_1)$$

and

$$w_2 = v(t_2 - t)$$

If the image varies sinusoidally, that is,

$$w = a + b \sin \omega t$$

then

$$vt_1 = vt - a - b \sin \omega t_1$$

and

$$vt_2 = vt + a + b \sin \omega t_2$$

or, multiplying by ω/v for convenience

$$\omega t_1 = \omega(t - a/v) - (b\,\omega/v)\sin\omega t_1$$

and

$$\omega t_2 = \omega(t + a/v) + (b\,\omega/v)\sin\omega t_2$$

These equations are of the type

$$x = y + \alpha\sin x$$

so that x and y are odd functions of each other. Hence $x-y$ can be expanded into a Fourier series of y, containing only sine terms, *i. e.*,

$$x - y = \sum_{n=1}^{\infty} a_n \sin ny$$

Hence

$$A_n = \frac{2}{\pi}\int_0^{\pi}(x-y)\sin ny\,dy$$

Integrating by parts,

$$A_n = \frac{2}{n\pi}\left[-(x-y)\cos ny\Big|_0^{\pi} + \int_0^{\pi}\cos ny\,d(x-y)\right]$$

The integrated term vanishes since $x = y$ for both 0 and π; also

$$\int_0^{\pi}\cos ny\,dy = 0$$

Hence, putting

$$x - \alpha\sin x = y$$

$$A_n = \frac{2}{n\pi}\int_0^{\pi}\cos n(x - \alpha\sin x)\,dx$$

$$= \frac{2}{n}J_n(n\alpha)$$

by the Bessel integral.

Thus, we obtain the solutions

$$\omega t_1 = \omega(t - a/v) + 2\sum_{n=1}^{\infty}\frac{1}{n}J_n\left(-\frac{nb\omega}{v}\right)\sin n\omega\left(t - \frac{a}{v}\right)$$

and

$$\omega t_2 = \omega(t + a/v) + 2\sum_{n=1}^{\infty}\frac{1}{n}J_n\left(+\frac{nb\omega}{v}\right)\sin n\omega\left(t + \frac{a}{v}\right)$$

Whence

$$v(t_2 - t_1) = 2a + \frac{2v}{\omega}\frac{1}{n}\left[J_n\left(\frac{nb\omega}{v}\right)\sin n\omega\left(t + \frac{a}{v}\right) - J_n\left(-\frac{nb\omega}{v}\right)\sin n\omega\left(t - \frac{a}{v}\right)\right]$$

By expanding and regrouping,

$$v(t_2 - t_1) = 2a + \frac{4v}{\omega}\Big[J_1\left(\frac{b\omega}{v}\right)\cos\frac{a\omega}{v}\sin\omega t +$$
$$\frac{1}{2}J_2\left(\frac{2b\omega}{v}\right)\sin\frac{2a\omega}{v}\cos 2\omega t + \frac{1}{3}J_3\left(\frac{3b\omega}{v}\right)\cos\frac{3a\omega}{v}\sin 3\,\omega t + \ldots\ldots\Big]$$

where $2a$ is the normal image width and $\frac{b}{a}$ the fractional modulation.

Single-Ribbon Case.—It may readily be shown that the character of the alternating exposure is not affected by the direction of motion of the film relative to the fixed edge of the image. We shall assume that the film approaches the fixed edge of the image first. Whence, from the equation for ωt_2 above,

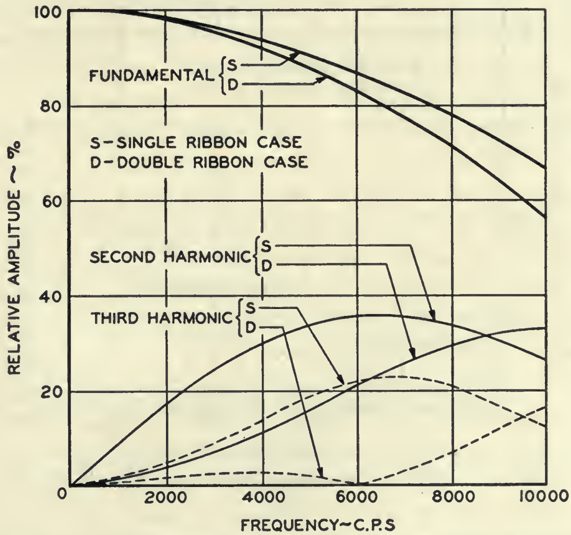

FIG. 12. "Ribbon velocity," effect for 0.5-mil normal image.

$$v(t_2 - t) = a + b\frac{2v}{b\omega}\Big[J_1\left(\frac{b\omega}{v}\right)\sin\omega\left(t + \frac{a}{v}\right) +$$
$$\frac{1}{2}J_2\left(\frac{2b\omega}{v}\right)\sin 2\omega\left(t + \frac{a}{v}\right) + \frac{1}{3}J_3\left(\frac{3b\omega}{v}\right)\sin 3\omega\left(t + \frac{a}{v}\right) + \ldots\ldots\Big]$$

From the formulas, typical curves may be drawn which show the loss of amplitude of the fundamental component of the film exposure with increasing frequency, and the magnitudes of the various harmonics.

Such curves are shown for the case of a normal 0.5-mil image for the single- and double-ribbon valve, in Fig. 12. Here it will be noted that for 100 per cent modulation, the fundamental of both types of valve suffers a loss of several decibels at 10,000 cycles, the double-ribbon valve suffering about a decibel more than the single-ribbon valve.

In the matter of harmonic distortion, however, the double-ribbon valve is markedly superior, and this is especially true for the third harmonic, which relatively is very weak in the double-ribbon valve.

At lower modulations, the frequency characteristic of the fundamental improves, in the case of the single-ribbon valve, more rapidly

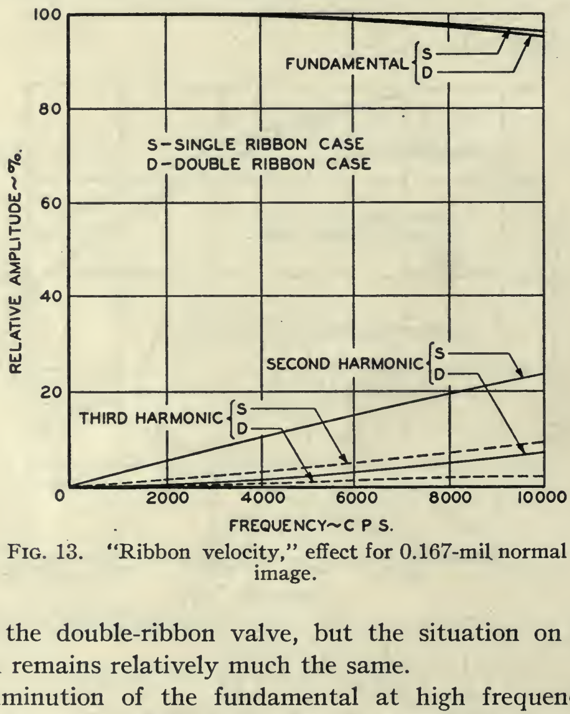

FIG. 13. "Ribbon velocity," effect for 0.167-mil normal image.

than for the double-ribbon valve, but the situation on harmonic distortion remains relatively much the same.

The diminution of the fundamental at high frequencies is of minor importance, because the influence of light valve resonance in present or future practice may be considered to offset it.

The illustration chosen (for 100 per cent modulation) is fairly typical of most recording situations where "noise reduction" apparatus is employed. It should be pointed out that, for the low valve spacings obtained on weak sounds with such apparatus, distortion of fundamental and harmonic production from the causes mentioned is greatly reduced. Fig. 13 shows curves corresponding to those of Fig. 12, except that the valve spacing is reduced to 0.3 its former value.

This latter point is especially important in comparing the light valve with other light modulating devices, such as the flashing lamp, for it indicates that by reducing the amount of the average exposure, the light valve distortion may be reduced accordingly.

III. Practical Aspects of the Light Valve

1. FACTORS GOVERNING SENSITIVITY OF VALVE

For any given normal separation of the ribbons, the sensitivity of the light valve depends on (1) the force on the ribbons per unit current, and (2) the deflection of the ribbons per unit force.

The force on the ribbons per unit current depends, as we have seen, on the strength of the field in which the ribbons move. Aside from the use of (*a*) magnetic material having high permeability and (*b*) an efficient winding, in the case of an electromagnetic field; or the use of material having high residual permeability in the case of a permanent magnet field; the principal factor influencing the magnetic field is the length of the air gap. The air gap must be wide enough to accommodate the moving ribbon or ribbons and any additional light barrier placed between the magnetic poles.

In general, then, a valve of the one-plane type is more efficient magnetically than a valve of the two-plane type, for in the latter the air gap must, in general, be somewhat longer. Although in practice the magnetic yoke is brought to a high saturation point, so long as the reluctance of the air gap forms an appreciable part of the total reluctance, the magnetic efficiency of the circuit will be greater with a narrower gap. If this is put on the basis that a definite magnetic flux is required through the gap, then, with the narrower gap generally pertaining to the one-plane type of valve, the field magnetizing current required is smaller.

In considering the sensitivity of the valve for a given strength of magnetic field the following factors are important:

(*a*) *Low Resistivity of the Conductor Material.*—Since the deflecting force of the ribbons depends on the current flowing through them, the amount of a-c. power which must be supplied to the ribbons for a given deflection is obviously proportional to the resistivity of the ribbon material. For frequencies substantially below the resonance frequency, the impedance of the valve is closely equal to its d-c. resistance. The power required to drive the ribbons is therefore similar to that dissipated in the ribbon as a conductor. It is assumed in this discussion that the valve input transformer matches closely the valve impedance. Under this condition each doubling of the resistivity means a doubling of the power supplied to the valve per unit of current in the ribbons and therefore a loss of 3 decibels in sensitivity.

(*b*) *Resonance Frequency of the Valve.*—From the formulas, given in Part II, for the resonance frequency of a light valve, it is seen that the tension which must be applied to the ribbon is proportional to the square of the resonance frequency. This means that the higher the tuning frequency the less sensitive the valve, for the amount of the tension determines the size of the restoring force which tends to prevent displacement of the ribbons. With any given ribbon material, therefore, a doubling of the tuning frequency means a loss of 12 decibels in valve sensitivity.

(*c*) *Density of the Ribbon Material.*—The density, or specific gravity, of the ribbon material has an influence on the sensitivity of the valve. If two valves be alike except for the material of which their ribbons are composed, and if each be tuned to the same frequency, it is obvious, from the formulas, that the tensioning force will be greater for the valve having ribbon material of higher density. The tension required for any given resonance frequency will be proportional to the density of the material, and, therefore, the sensitivity of the valve varies inversely as the density of its conductor material. This means that each doubling of the density of the ribbon material causes a loss of 6 decibels in sensitivity.

(*d*) *Length of Vibrating Span.*—In considering the influence upon sensitivity of the length of span of the vibrating ribbon, it is necessary to consider only the resistance of the conductor material. If the length of span be doubled, the power supplied to the ribbon must be doubled; that is, there is a loss of 3 decibels in sensitivity. While it is true that the force created in the conductor by its reaction in the magnetic field is proportional to the length of the vibrating span, this increase in force is directly offset by the fact that the force doubled must move a conductor which, for any given tuning frequency, has a total restoring force proportional to the length of the vibrating span. That is to say, doubling the length of the span quadruples the tension for a given tuning frequency, but halves the angular displacement of the ribbon. The net result, therefore, is that the sensitivity of the valve varies inversely as the square root of the length of the vibrating span.

(*e*) *Sensitivity of Single-Ribbon and Double-Ribbon Valves.*—The length of ribbon required in the double-ribbon valve is fundamentally twice that required in the single-ribbon valve. Therefore, for a given current in the vibrating ribbons, twice as much power must be supplied to the double-ribbon valve. This means an apparent loss of 3 decibels in sensitivity. However, the displacement obtained from two ribbons in the double-ribbon valve is, of course, twice that obtained with the same current in the single-ribbon valve. Therefore, for a given percentage modulation of the recording illumination, a factor of 6 decibels must be added in favor of the double-ribbon valve. The net result is that the double-ribbon valve is inherently 3 decibels more sensitive, for a given percentage of light modulation and consequent volume of reproduced sound, than the single-ribbon valve. This figure, of course, assumes valves which are alike in other design details, such as the nature of the conductor material employed, the flux density of the air gap, *etc.* This estimate of 3 decibels is conservative, for it assumes that ribbon material of the same cross-section is employed in either type of valve. Since the ribbon of the single-ribbon valve must be displaced twice as far as either of the ribbons of the double-ribbon valve, and since the width of the vibrating conductor is determined primarily by considerations of mechanical tolerances in relation to the amount of ribbon displacement required, it is more fundamentally correct to assume that in the single-ribbon light valve, for a fair comparison, the ribbon material should be twice as wide. If this assumption is made, the wider ribbon is equivalent to two of the narrower ribbons, vibrating side by side, and a further factor of 3 decibels should be allowed for the additional power required to displace the heavier ribbon. Thus, from a fundamental design standpoint the single-ribbon valve is 6 decibels lower in efficiency than the double-ribbon valve.

2. PROPERTIES OF LIGHT VALVE RIBBON

It is of major importance in the successful use of the light valve that the metal ribbon or tape used to form the vibrating light gate shall be adequate for the purpose it is to serve. In general, the ribbon should possess the following properties: (1) low resistivity,

(2) low specific gravity, (3) high tensile strength, (4) straightness of ribbon edges, (5) stability under continuous tension, (6) non-corrosiveness, and (7) non-magnetic character. The importance of (1), (2), and (3) have been discussed.

The importance of straight optical edges is apparent when it is considered that the variations from straightness cause changes from point to point in the light valve slit width and hence in average film exposure. In an average slit width of 1 mil an effort is made to keep edge straightness deviations below 0.1 mil. This represents a change of 10 per cent in average exposure for the corresponding portion of the sound track. This does not ordinarily mean a change in signal volume recorded, because the actual displacement of the ribbons is unaltered; but it means a slight shifting, from point to point along the light valve, of the exposure in relation to the straight-line part of the H & D curve. It can also affect the maximum recordable volume by altering the clash point of the valve.

Among the materials which are suitable for use duralumin has been found greatly superior and has, in addition, proved to be fairly workable material. The following table shows the more important constants of various metals which might be considered.

Constants of Various Metals Used for Light Valve Ribbons

Material	Tensile Strength	Density	Resistivity	Tensile Strength Density	Figures of Merit Sensitivity	Figures of Merit Breaking Frequency
Aluminum	27,600	2.7	3.0	10,200	1.29	0.48
Aluminum (90% Cu) Bronze (10% Al)	90,000*	8.3	2.0	10,800	0.51	0.51
Copper (hard drawn)	65,500	8.93	1.8	7,350	0.50	0.35
Duralumin	75,000*	2.8	4.6	26,800	1.00	1.27*
Duralumin (light valve ribbon)	59,000	2.8	4.6	21,000	1.00	1.00
Molybdenum	154,000†	10.0	5.7	15,400	0.25	0.73
Molybdenum (0.002 wire)	200,000*†	9.0	5.7	22,000	0.28	1.05*
Silver	42,600	10.5	1.6	4,050	0.50	0.19
Tungsten	590,000*†	18.8	5.5	31,400	0.14	1.50*
Tungsten (ribbon)	450,000†	18.8	5.5	24,000	0.14	1.14

* Probably less for ribbon form.

† Material difficult to work smoothly.

The figure of merit for sensitivity indicates directly the comparative sensitivity of valves employing the different materials, and is obtained by multiplying the ratio of the densities by the square root of the ratio of the resistivities. The figure of merit for breaking frequency indicates directly the ratio of maximum allowable tuning frequencies for light valves using the various metals. Where the figures given are not otherwise noted, they are for the metal in bar form, and it should be realized that neither the tensile strength of metal in this form nor that in drawn wire form may, as a general thing, be realized in the case of metallic ribbon of the dimensions required for light valves. It is readily seen that duralumin is the only metal listed which has a high figure of merit for both sensitivity and breaking frequency. To give specific illustrations, a light valve of any character employing molybdenum must be inherently about 12 decibels less sensitive than one employing duralumin, and a light valve employing tungsten would have a loss of sensitivity, in

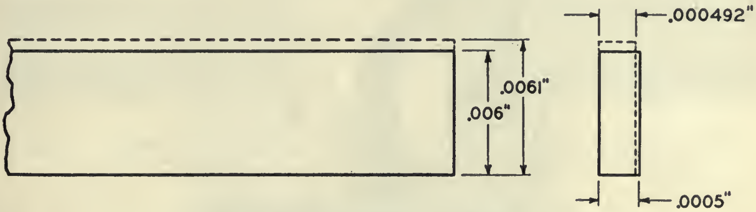

FIG. 14. Cross-section diagram of light valve ribbon.

comparison with one using duralumin, of 17 decibels. The composition of duralumin varies somewhat; the alloy at present used for light valves has the following composition:

Aluminum	94
Copper	4
Manganese	0.5
Magnesium	0.5
Silicon, iron, *etc.*	1

As is well known, heat treatment and aging have an influence on the tensile properties of duralumin, and much effort has been expended in recent years to increase the tensile strength. As a result of such efforts, the ribbon now employed has a tensile strength about 75 per cent greater than that of the earlier light valve ribbon.

There are two general methods which may be employed for the production of duralumin ribbon. In the first, wire is drawn to the proper cross-section and flattened into the ribbon form by rolling;

in the second, ribbons 0.006 inch wide are sheared directly from sheets of duralumin foil 0.0005 inch thick.

In the rolling method, the primary obstacles are the extreme accuracy required of the rolls and the uniformity throughout its length of the material. Fig. 14 represents a cross-section of ribbon 6 mils by 0.5 mil. If manufacturing tolerances hold the width to

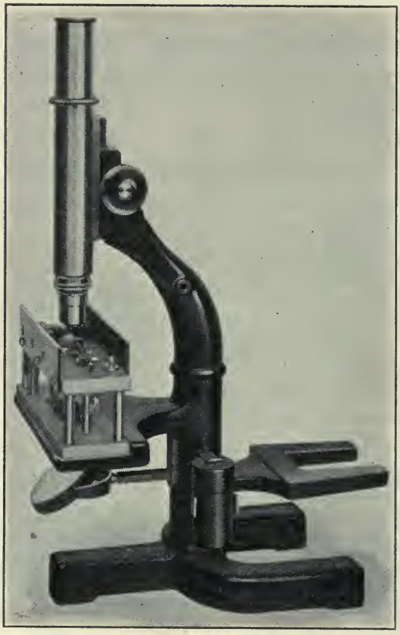

FIG. 15. Illustrating a microscope fixture attached for visual examination of ribbon edges.

$\pm$0.1 mil and the density of the material remains constant, the thickness must be held to 0.008 mil, or eight one-millionths of an inch. In the shearing process accurate alignment of cutting shears must be supplemented by a technic for producing foil of uniform thickness, free from pinholes, embedded impurities, *etc.* Because of the empirical nature of alloy processing, it is customary, as a check inspection after regular manufacturing inspection has been completed, to test a substantial portion, about 5 per cent, of all supposedly satisfactory ribbon. Valves are actually strung with this material which is then inspected for ribbon edge straightness, and the ribbons are tuned to destruction to determine their breaking point. During the past two and one-half years approximately 2500 valves have been thus strung and inspected. Fig. 15 shows a microscope fixture attached for visual examination of ribbon edges.

Fig. 16 shows an illustration of rough edges, taken from an early grade of ribbon. Fig. 17 shows a type of variation in ribbon due to undulating edges. Fig. 18 shows a sample of ribbon excellent in its quality of edge straightness.

3. LIGHT VALVE "HYSTERESIS" AND RIBBON SLIPPAGE

In much of the earlier studio recording, a phenomenon was often noticed called light valve "hysteresis." This was due to the failure

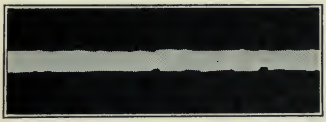

FIG. 16. Light valve ribbon having rough edges.

FIG. 17. Light valve ribbon having wavy edges.

FIG. 18. Light valve ribbon having straight edges.

of the valve ribbons to return, after a large impulsive displacement, to their original normal position. This gave the d-c. amplitude characteristic, for wide variations in current, the appearance of a magnetic hysteresis loop. Fig. 19 shows the hysteresis loops for an older type of valve for two tunings, at 7000 and 10,000 cycles, respectively. From these curves, it is seen that higher tuning reduces the magnitude of the hysteresis effect, if we judge this magnitude by the displacement (in mils) of the opposite sides of the loop. This might be expected, because the vertical component of the ribbon tension, tending to hold the ribbon in place by means of friction at the ribbon supports, is increased in proportion to the increased tension required for the higher tuning frequencies.

Improvements in recording technic required that the valve tuning frequency be raised considerably above the earlier value of 7000 cycles. This development, in combination with the availability of the recently developed stronger type of duralumin ribbon, permitted the general adoption of higher tuning frequencies, which automatically reduced the hysteresis effect. However, with the advent of noise reduction equipment to reduce film background

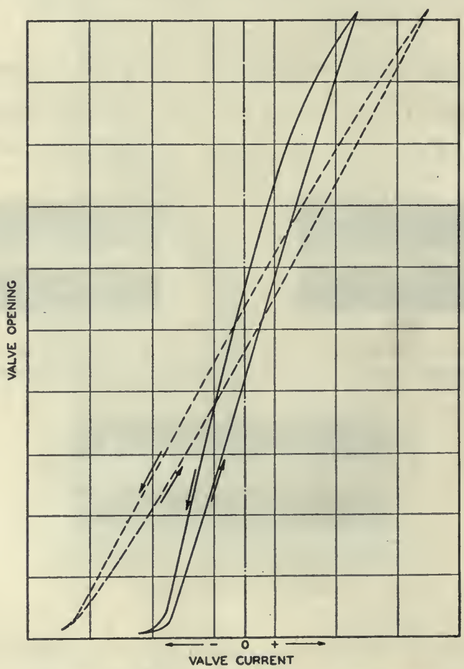

FIG. 19. Light valve hysteresis (old valve).

noise, the requirements for the exact biasing of the valve ribbons to small average slit widths made necessary the elimination of most of the hysteresis tolerated in the older equipment.

Various methods were tried experimentally to secure greater stability of average valve spacing, such as pin locating stops, metal clamps, paper spacers, cement, *etc.* The cement method was given a field trial, but did not prove satisfactory for general use.

The valve modification adopted for general field use practically eliminated the hysteresis effect and was simple enough to enable the ready conversion of available light valves; the slight modification of the bridge support and spacing pincers, shown in Fig. 20, has practically eliminated the hysteresis effect. The curves of Fig. 21 demonstrate this for 7500 and 10,500 cycles' tuning.

In interpreting the true importance of light valve "hysteresis," we must realize that it is only superficially like magnetic hysteresis. In the first place, it does not represent a loss in energy. Secondly, it is generally not present except for current cycles which exceed a critical (and large) value; thus, for the smaller displacements, frictional anchoring forces at the ribbon supports are adequate. Thirdly, if the sides of the hysteresis loop are straight and parallel, the spurious harmonics produced are small.

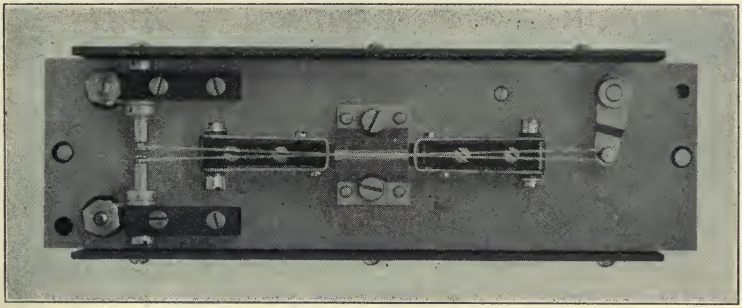

FIG. 20. Illustrating the slight modification of the bridge support and spacing pincers for eliminating hysteresis.

The principal detrimental effects of ribbon slippage were therefore (1) material variation in average exposure of the film, which interfered with exact sensitometric control, and (2) departures from normal of the load capacity of the valve, which interfered with standardization of recording technic and the securing of maximum recorded volume range. It is for both of these reasons that the introduction of noise reduction equipment required the reduction of light valve hysteresis.

4. AZIMUTH AND FOCUSING ERRORS IN RECORDING

The light valve is an electromagnetic shutter, and it translates the amplified electrical energy from the microphone into mechanical energy in such a manner that the light passing through the valve is proportional to the speech waves impinging upon the diaphragm of the microphone. It is, therefore, necessary to photograph the light valve action as accurately as possible. This is made possible by two important adjustments, the first of which is the azimuth adjustment of the light valve, and the second, the focal adjustment of the objective lens.

The azimuth adjustment of the light valve consists in locating the horizontal plane of the valve perpendicular to the direction in which the film is traveling. This adjustment also positions the

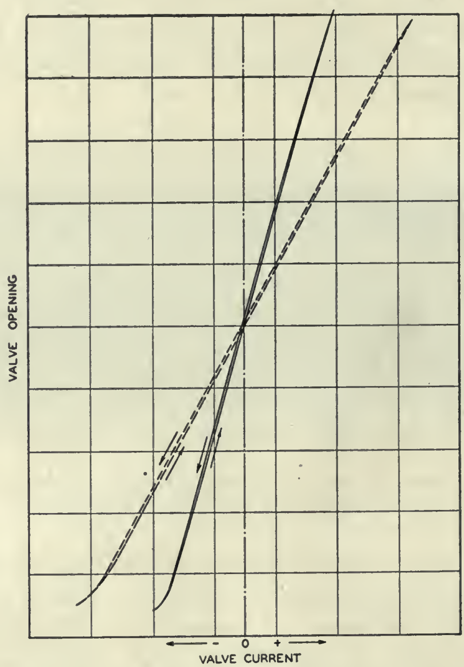

FIG 21. Light valve hysteresis (improved valve).

striations on the film so that they are perpendicular to the direction of the film travel. An error in the azimuth adjustment of the light valve produces an azimuth deviation on the recorded film.

The azimuth deviation on the recorded film must be considered in relation to the azimuth deviation of the scanning image in the reproducer. Unless these values of azimuth deviation are identical in degree and direction, the losses at the higher frequencies are greater than those for optimum conditions of adjustment. If, however, the azimuth deviation of the film varies from that present in the reproducer, we have to deal with the sums and differences in the deviation of each to obtain the effective value.

Experimental measurements of azimuth deviations in both the recorded film and the scanning image in the reproducer have indicated that the effect of an azimuth deviation on the recorded film and no azimuth deviation in the scanning image is equivalent to a similar deviation of the scanning image and no deviation in the recorded film for small values of azimuth deviation. The effect of the azimuth deviation of the scanning image has been treated both theoretically and experimentally and presented in a paper[7] before this Society.

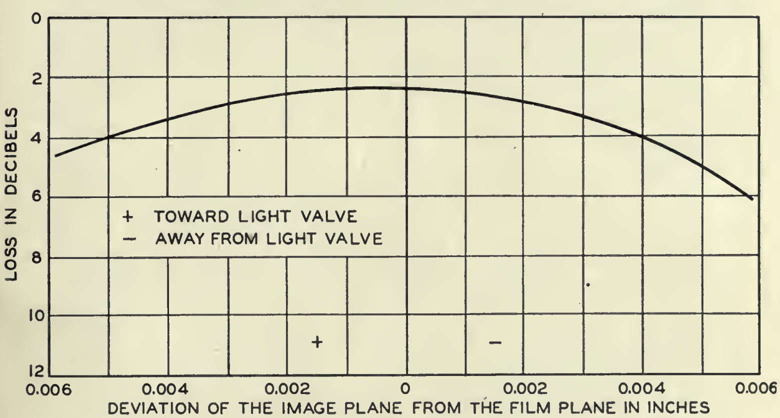

FIG. 22. Influence of improper focus on reading, *etc.*

Figs. 6 and 8 in that paper show the loss for various azimuth deviations of the 0.0005-inch light valve image.

The adjustment of the $f/1.5$ objective lens consists in the movement of the lens along the optical axis until the light valve ribbons are focused on the film emulsion at a reduction of 2:1.

As the objective lens system is moved along the optical axis, the plane of the image of the light valve ribbons also moves, but at a slower rate than that of the objective lens. Fig. 22 illustrates the influence of improper focus in the recording of a 7000-cycle sound track. A 2- and a 4-mil deviation of the image plane from the film plane results in an approximate additional loss of 1 and 3 decibels, respectively, at 7000 cycles. A more general expression of the effect of improper focus is given in Fig. 23, in which the average effective image width is shown to vary with the deviation of the image plane from the film plane. With this data, the loss at any frequency, due to an improper objective lens adjustment, may be computed. When the lens is improperly focused the average effective image width is increased and greater losses occur at high frequencies.

As shown in the paper by Stryker,[7] when the loss due to both improper focus or an increase in the average image width and the azimuth deviation occur simultaneously, as they may in practice, the total loss of reproduction due to the two of them jointly will be the sum of the individual losses produced by each separately.

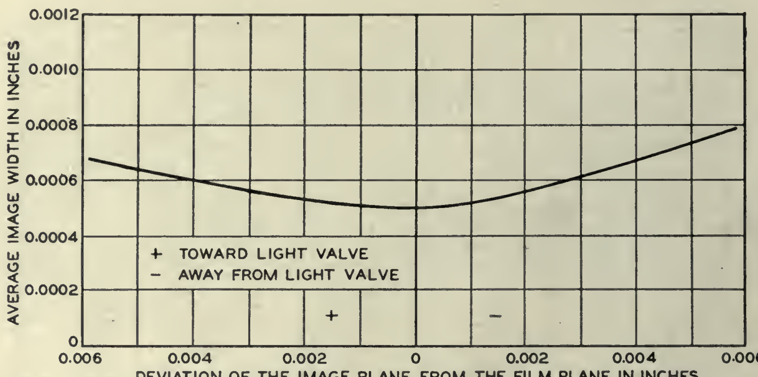

FIG. 23. Effect of improper focus on average image width.

It is, therefore, apparent that either the azimuth adjustment of the light valve or the focal adjustment of the objective lens, or both, are important factors that may seriously affect the quality of reproduced sound records. If the analysis of light valve action given in Part II is to hold, the average image width assumed must be consistent with the azimuth and focus conditions.

5. TUNING METHODS

An amplitude resonance curve for a light valve is shown by Fig. 7. The resonance peak indicates that the valve requires 30 decibels less power at the resonant frequency than at the low frequencies for the same modulation.

Several methods of measuring the resonant frequency of light valves have been employed. A visual method, used to tune the earlier telephoto and sound film valves utilized a microscope to observe the maximum deflection of the ribbons when the frequency of an oscillator connected to the ribbons was varied.

The visual method proved satisfactory until widespread use of recording equipment placed exacting limits on the resonant fre-

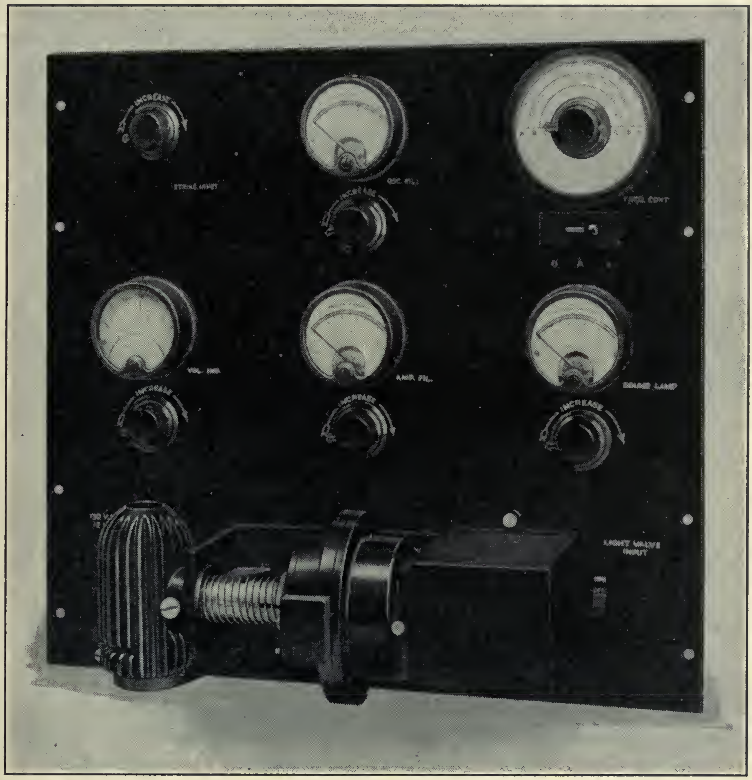

FIG. 24. Separate valve tuning unit supplied with Western Electric recording equipment.

quency, especially where it became desirable to have several valves operate at nearly the same clash point. The sound recorder itself provided ready means to determine the tuning frequency more accurately than the visual method. The procedure was to use the photoelectric cell monitoring system to measure the degree of light modulation by the valve when known current levels were supplied to the valve from a variable oscillator. An output level variation of the monitoring circuit of ±0.5 decibel could be measured with the ordinary volume indicator method and, therefore, from the resonance curve (Fig. 7) it is seen that it is possible to measure the tuning frequency to within ±50 cycles from the resonant frequency.

The use of recording equipment for tuning more than a few valves would have proved inefficient; and, therefore, separate valve tuning units were supplied with Western Electric recording equipment. This equipment is shown in Fig. 24. An oscillator, amplifier rectifier, light source, light valve field coil, and photoelectric cell are mounted on a 17- by 19-inch panel. The schematic circuit of Fig. 25 shows the

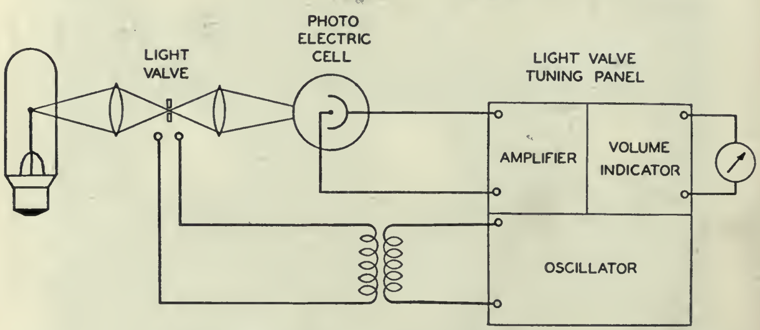

FIG. 25. A schematic circuit of the tuning unit of Fig. 24, showing the valve operation in the tuning circuit to be similar to that in an actual recording circuit.

valve operation in the tuning circuit to be similar to that in the actual recording circuit.

Another method of tuning valves, apparently due to R. D. Gibson, makes use of the motional impedance characteristic of the valve, shown in Fig. 10. The electrical impedance of the light valve with the magnetic field applied is equivalent to an anti-resonant electrical circuit as shown by Fig. 8. Many electrical methods of observing the tuning point of such circuits are familiar to the electrical art and a simple device consisting of an oscillator and a thermocouple in series with the valve has been described by Ceccarini.[8] Other arrangements employ volume indicators, thermocouples, or rectifiers to measure the voltage across the valve terminals when the valve is connected to an oscillator source supplying approximately constant current to the valve. It is evident that the series method of observing the peak will not indicate the correct peak sharpness unless the thermocouple resistance is small compared with the d-c. resistance of the light valve. Similarly, the voltage method will not indicate the correct sharpness unless the voltmeter impedance is high compared with the resonant impedance of the light valve.

6. LIGHT VALVE OVERLOAD AND CLASH

A phenomenon, concerning which little experimental evidence has been presented, is that of wave-form distortion due to light valve overload. In the two-plane type of valve the action which

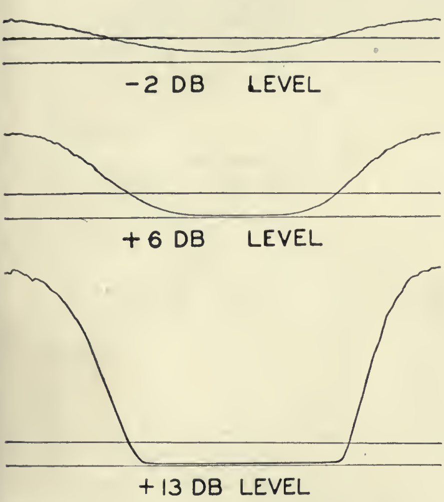

FIG. 26. Overload wave forms of single-plane valve for 100 cycles.

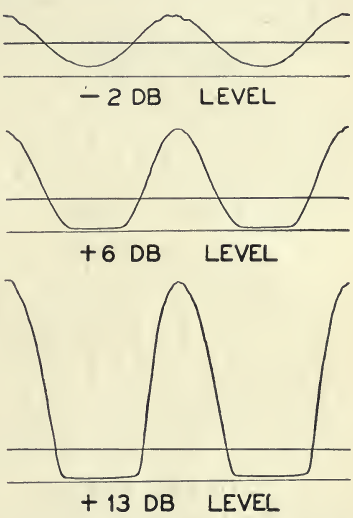

FIG. 27. Overload wave forms of single-plane valve for 250 cycles.

might be expected would be a simple cutting off of the negative troughs of the wave whenever the ribbons were sufficiently displaced so as to cut off all light. This assumes that, in the main, modification of the overload distortion, due to photographic considerations and due to non-linearity of valve displacement for excessive movements of the ribbon, might be neglected.

In the one-plane type of valve, however, it has not been clear what phenomena took place under similar conditions. Figs. 26, 27, and 28 are illuminating in this respect, as they show the relative wave-forms at frequencies of 100, 250, and 1000 cycles, respectively, which are encountered under the following conditions:

(*a*) modulation 2 db. below overload
(*b*) modulation 6 db. above overload
(*c*) modulation 13 db. above overload

It is readily seen in these cases that the type of distortion obtained is a relatively simple one, and is very much of the type that might be expected. Figs. 29, 30, and 31 show experimental wave-forms

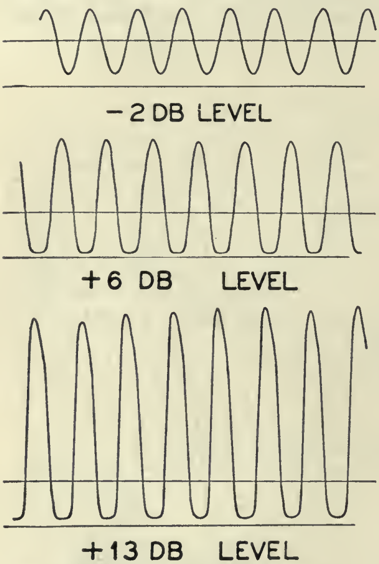

FIG. 28. Overload wave-forms for single-plane valve at 1000 cycles.

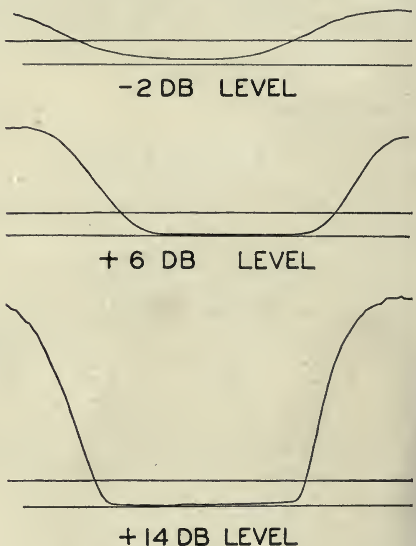

FIG. 29. Overload wave-forms of double-plane valve for 100 cycles.

obtained from a two-plane type of valve for the same frequencies, respectively, at the following levels:

(*a*) 2 db. below overload
(*b*) 6 db. above overload
(*c*) 14 db. above overload

It is quite apparent, however, from the overload wave-forms of both types of valve that distortion of this kind is highly objectionable from a sound quality standpoint, and is to be avoided in either type of valve by observing proper recording margins against overload.

Under average recording circumstances the frequency of occurrence of overload on speech and music sounds may be expected to follow the curve given by Sivian[9] for the relative distribution of instantaneous amplitudes of speech and music throughout the frequency spectrum. Thus, at very high frequencies sounds of high amplitude are seldom to be expected.

The relation of light valve overload to conductor heating and valve sensitivity should also be considered. If, for example, we

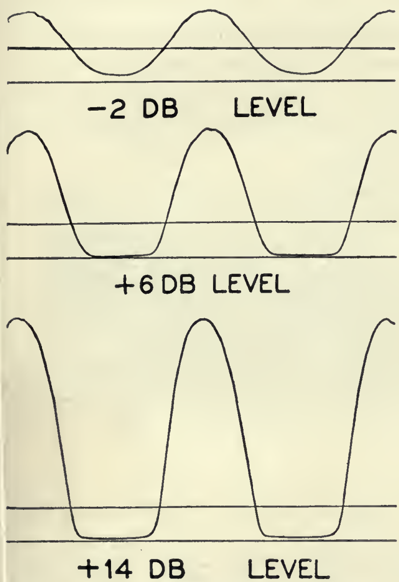

FIG. 30. Overload wave-forms of double-plane valve for 250 cycles.

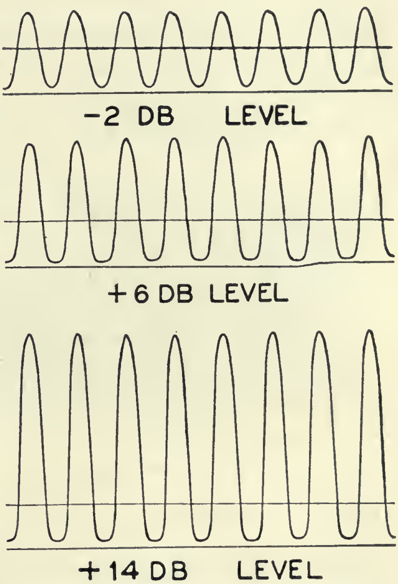

FIG. 31. Overload wave-forms of double-plane valve for 1000 cycles.

compare two types of valve differing in sensitivity by 15 decibels, it is obvious that the normal power required to bring the more efficient valve to the clash point is 15 decibels less than for the second valve. This means, of course, a much smaller internal heating of the valve since less power is dissipated. Consequently, one may expect a smaller temperature rise in relatively sensitive valves and correspondingly somewhat greater mechanical stability. One may also expect that the maximum overload level to which a valve may be subjected, from a temperature standpoint, relative to that level at which overload just takes place, will be largely dependent on the relative sensitivity of the valve.

IV. A Permanent Magnetic Type of Light Valve

A new type of light valve will now be described which represents several fundamental advances in light valve design. It is a valve which uses a minimum total ribbon length in operation so that its electrical efficiency is high. It is readily tuned to very high frequencies. It is, within experimental error, entirely free from hysteresis and ribbon slippage. It contains temperature compensation features to maintain greater constancy of spacing and tuning and, in general, is very rugged and stable. These ribbons are clamped in place in such a manner as to add to the constancy of spacing and

FIG. 32. The principal parts of a new type of light valve

tuning. Possessing a permanent magnet field, it requires no field exciting current, yet a higher flux density is secured in its air gap than was accomplished electromagnetically in the earlier light valve. Last but not least, it is especially light and compact.

Fig. 32 shows the principal parts of this valve. On the right and on the left are two permanent magnets which fasten to the central portion of the valve, the objective and condenser sides of which unit are shown in the center of the figure. The size of the units of the valve may be estimated by considering that each of the magnets is $1^1/_2$ inches in length and that the base, as shown, of the top pole-piece is $^7/_8$ by $^3/_4$ inch. The ribbon when in place lies under the glyptol clamps on the condenser side of the valve. When the condenser side and the objective side of the valve are placed together the slit in the center of the latter lies opposite the aperture between the ribbons.

The valve in an assembled form with associated condensing lens is shown in Fig. 33. The total length of the unit as assembled there is $3\,^5/_8$ inches. Fig. 33 also shows in place the terminal strip to which connections are made from the string unit of the valve.

The light valve weighs 300 grams, or about 11 ounces. The permanent magnets account for about 220 grams of this weight, so that the central unit of the light valve comprising the two components shown in the center represents a weight of 80 grams or about 2.8 ounces.

The total amount of ribbon contained in the electrical circuit of the valve as used in recording is approximately 1 inch. For the

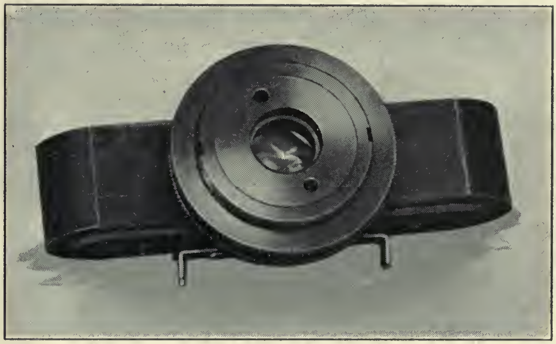

FIG. 33. The new valve in its assembled form with the associated condenser lens.

present studio light valve the corresponding length is about 8 inches. The valve can without difficulty be tuned to frequencies of the order of 12,500 cycles. Of course, as in any valve, tuning to such a high frequency can be accomplished only by a corresponding sacrifice in sensitivity. But the electrical and magnetic efficiency of the valve permit the use of relatively high tuning with a corresponding sensitivity equal to or greater than the present studio light valve when a considerably lower tuning frequency is used.

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DISCUSSION

MR. KELLOGG: Has it been found necessary or desirable to try to introduce more damping than what naturally comes from friction at the support?

MR. SHEA: There was described before the Hollywood Convention an oil-damped type of light valve used at one of the studios on the West Coast. Generally speaking, we prefer to move the resonance out of the recording range, so that the resonance does not influence the recording.

MR. PALMER: Is the fact that this light valve is a more efficient and better piece of apparatus shown in the results obtained in the theater, when the sound is taken off the film?

MR. SHEA: There are many causes of loss of quality in reproduction, and of those, the leakage due to the light valve is among the smallest, and it has been made yet smaller in this valve. I am quite sure that such losses in quality are negligible compared with other losses encountered commercially.

The improvement in size and weight, the stability of the valve, and its ability to retain its spacing and tuning, mean a great deal either in portable or studio work. The advantages of the new valve are chiefly its operating advantages; our extensive laboratory tests convinced us that the old valve, with proper care, gave excellent quality. But with the new valve less care will be required.

MR. OLSON: Is there any tendency for ribbons to turn out of their normal plane?

MR. SHEA: Not if one can judge by the oscillograms of the modulated light. They do not apparently turn to such an extent that any amount of light gets through gaps that might be so created.

MR. EVANS: We use both types of valves in our studio, and our experience to date with the baby light valve is a favorable one. It has one advantage and one disadvantage—with a compensation available for the latter. The advantage is that a higher tuning frequency reduces the frequency at which overloading occurs. If the valve is tuned to 8600 cycles, as the old ones are, sounds of that frequency, of which there are many, may, when added to the other frequencies existing, cause the valve to clash. When it is tuned to 11,000 cycles, as are the baby light valves, we avoid clashing at 8600 cycles, and 11,000 cycle sounds are less frequent and generally weaker.

On the other hand, the disadvantage is that there are frequency losses at 5000 and 6000 cycles in film processing and other places that cause quite a considerable drop in the reproduction at those frequencies. If the light valve is tuned to 8600 cycles, the resonance of the light valve tends to compensate for these losses, so that a loss is incurred at frequencies of 5000 to 7000 cycles by going to the baby light valve. This loss can be compensated for, however, by equalization in the electrical circuit. So the net result, I think, is that the baby light valve is quite a bit better than the other. Certainly it is more stable.

MR. SHEA: I believe that such a comparison should be made, not between one design of valve and another, but rather on the basis that the higher the tuning frequency, the greater the sacrifice to be made at the present time in eliminating the equalizing action of the light valve. With the old valve the same difference exists as between six or eight thousand cycle tuning, and ten thousand cycle tuning. We have employed experimentally many of the old light valves, some with the shorter bridge length, at quite high tuning frequencies, exceeding those that you mentioned for the small light valve; and I think we ought to make the comparison rather on the basis that the choice of tuning frequencies for certain reasons leads to a sacrifice in another direction at the present time.

MR. KURLANDER: Is there any effect on recording? Do the two legs of the ribbons cut each other's magnetic field, or is that field neutralized?

MR. SHEA: The ribbons act independently as far as any one can tell. There must be minor effects, such as that due to skin effect, at the high frequencies, but they appear to be very minor.

VARIATION OF PHOTOGRAPHIC SENSITIVITY WITH DIFFERENT LIGHT SOURCES*

RAYMOND DAVIS AND GERALD K. NEELAND**

Summary.—*The variation of photographic sensitivity (as measured by the index $10/E_m$) with different sources of light of equal visual intensity, but having different distributions of energy, was experimentally obtained. Ordinary, orthochromatic, and three new fast panchromatic plates were investigated. Distinction was made between two types of sensitivity comparisons. Thus it was found that: first, the ratio of the sensitivity of any one of the panchromatic plates to that of the ordinary plate was greater with incandescent lighting than when "sunlight" was used, and second, in all cases the panchromatic plates were less sensitive to incandescent lighting than to "sunlight." Approximate factors are included (for the particular emulsions studied) by which visual exposure meter readings should be multiplied when certain types of illuminants are encountered.*

I. INTRODUCTION

The sensitivity of photographic emulsions to light from various sources having different spectral energy distributions has recently become of considerable interest. This is due, in part, to the discovery of new dyes which make possible an increased sensitivity to light in the red end of the spectrum.

Artificial illuminants, particularly incandescent lamps, have a relatively large amount of energy in the longer wavelengths. With such illumination, therefore, it is natural to expect the increase in red sensitivity would make the new emulsions more efficient than former ones, *i. e.*, less exposure would be required to obtain the same photographic effect.

Comparisons of sensitivity may be made in one of two ways. First, one may compare the sensitivity of two different emulsions using the same source of light. Second, the sensitivity of an emulsion to light from one source may be compared with its sensitivity to light from another source of equal "intensity" but having a different relative spectral energy distribution.*

* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Publication approved by the Director, Bureau of Standards, U. S. Department of Commerce.

** U. S. Bureau of Standards, Department of Commerce, Washington, D. C.

The question arises as to whether the expression "equal intensity" should be taken to mean equal energy or equal visual intensity. That the two would not be necessarily the same is obvious. In certain problems, such as determining what type of illuminant is most efficient with a given emulsion, it is desirable to have the sources under comparison arranged to deliver to the plate the same amount of energy per unit time. With this arrangement, the source to which the emulsion has the higher sensitivity would be the most efficient, *i. e.*, a greater photographic effect is obtained with a given amount of energy.

However, in carrying out the experimental work described in this paper, the expression "equal intensity" has been taken to mean "equal visual intensity." That this condition for comparisons of sensitivity has practical significance may be seen from consideration of a "visual photometer" type of exposure meter in common use. With this instrument, the exposures for two objects are indicated as being the same when the light reflected from each object appears equally bright, regardless of its energy distribution.** Therefore, to use this type of meter properly, it is necessary to know how the sensitivity of the emulsion varies with different types of illuminants.

In this paper are given several examples showing the variation in sensitivity (of panchromatic, orthochromatic, and ordinary plates) with the energy distribution of the light where the visual intensity of the light incident on the emulsion is kept constant. This information is of interest, not only with regard to the use of an exposure meter, but particularly because it furnishes actual data on the performance of new panchromatic emulsions as compared with ordinary emulsions.

II. PROCEDURE AND RESULTS

The emulsions were exposed to three sources, each having a different energy distribution. These were: (1) an incandescent lamp operating at a color temperature* of 2360°K., (2) an incandescent lamp operating at a color temperature of 2810°K., and (3) an incan-

* The terms "relative spectral energy distribution" and "energy distribution" have the same meaning in this paper.

** It is assumed here that the photometer employs no blue, or other "correction" filter. However, the mere inclusion of such a filter would not, necessarily, correct for the different energy distributions of various sources. Thus, only with ordinary plates, could reliable readings be obtained with a blue filter.

descent lamp operating at 2360°K. in combination with a Davis-Gibson filter such that the resulting light closely approximates the chromaticity and the energy distribution of mean noon sunlight.**

Energy distribution curves for these three sources, together with the visibility curve V, are given in Fig. 1.

These sources were chosen because it was desired to approximate, as far as possible with available equipment, light conditions, both

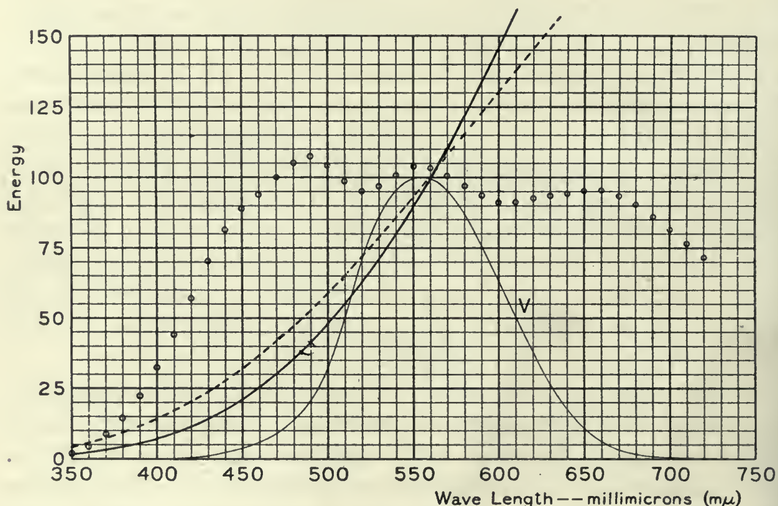

FIG. 1. Relative spectral energy distributions of the light sources used. The circles represent the spectral energy distribution of the lamp and filter combination producing artificial sunlight. The Eighth International Congress of Photography adopted this combination as standard for the sensitometry of negative materials. The dashed line represents the spectral energy distribution of the 2810°K. source and the solid line that of 2360°K., both arbitrarily adjusted to 100 at 560 $m\mu$. The visibility curve is marked V.

out of doors in sunlight and inside with artificial illuminants. Thus, a 60-watt, gas-filled incandescent lamp approximates a color temperature of 2800°K., while the old vacuum tungsten lamp approximates a

* By a color temperature of 2360°K., is meant that the chromaticity of the light approximates that of a Planckian radiator at an absolute temperature of 2360°. In the case of an incandescent lamp, the relative spectral energy distribution, as well as the chromaticity, is also very close to that of the Planckian radiator at the specified temperature.

** The chromaticity of mean noon sunlight is approximately that of a Planckian radiator at 5400°K.

color temperature of 2400°K. The incandescent lamps, such as are used for studio work in motion pictures, are close to a color temperature of 3000°K.

The sources were placed in a non-intermittent sector-wheel sensitometer[1] at such distances from the plane of the emulsions that the visual intensity at this plane was 1 meter candle.

As pointed out in a previous paper,[2] we believe that the most adequate representation of the sensitivity of an emulsion is given by a curve showing the relation between sensitivity and the time of development. It was thought best to use the index of sensitivity $10/E_m$[2,3], where E_m is the exposure of that point in the "toe" region of the characteristic curve of the emulsion where the gradient is 0.2

In each test, 24 sensitometric strips, backed by a black shellac mixture for preventing halation, were exposed, 8 to each of the three sources of light. In several instances, the tests were repeated a number of times. The 24 exposed strips were placed in eight racks, each containing 3 strips, one exposed to each source. The racks were then placed together in a single tray of developer which was kept at a temperature of 20°C. by a water bath. They were removed, one rack at a time, after periods giving a series of times of development from 2 to 22 minutes. Thus the usual range of times of development was more than covered. The developer was agitated by brushing the plates with a camel's-hair brush.

Pyrogallol developer, compounded according to the following formula, was employed:

(*A*)	Water	1000 cc.
	Potassium metabisulphite	12 g.
	Pyrogallol	60 g.
(*B*)	Water	1000 cc.
	Sodium sulphite (anhydrous)	90 g.
(*C*)	Water	1000 cc.
	Sodium carbonate (anhydrous)	75 g.

(To develop, one part each of *A*, *B*, and *C* was mixed with seven parts of water.)

The densities of the developed strips were measured in diffuse light with a Martens polarization photometer. A family of eight characteristic curves (total density *vs.* log exposure) was obtained for each source. From each curve a value of the index $10/E_m$ was derived. Thus, a measure of the variation of sensitivity with the time of development was obtained for each source. From these data the sensitivity *vs.* development-time curves were drawn.

TABLE 1

Photographic Plates Investigated

Description of plate	Identification	Figure
American "medium speed" ordinary	*A*	2
American "high speed" orthochromatic	*B*	3
American "high speed" panchromatic	*C*	4
English "high speed" panchromatic	*D*	5
German "high speed" panchromatic	*E*	6

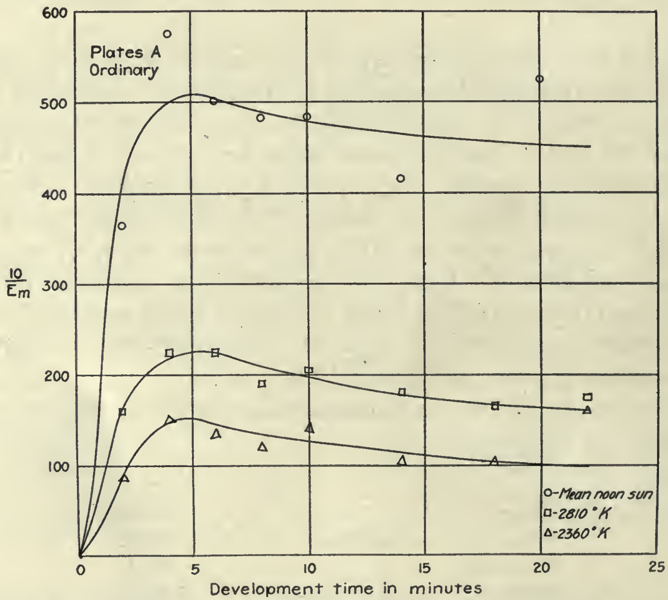

FIG. 2. Sensitivity *vs.* development-time curves for plates *A* under three conditions of illumination.

In Table 1 are listed the plates included in the study, the types of emulsions, and the identifying letters used in the figures and tables. The selection is intended to be representative of the most sensitive emulsions now available, and to include an example of each of the three common types of emulsions—ordinary, orthochromatic, and panchromatic.

III. DISCUSSION OF RESULTS

Curves representing the change in sensitivity (as measured by the index $10/E_m$) with the time of development for each of the three sources are given in Figs. 2 to 6, inclusive.

In Fig. 2, the sensitivity *vs.* development-time curves are given for plates *A*. The three curves are similar in shape, as would be expected, and show the usual[3] optimum time of development (in this instance 5 minutes). Since these plates are "ordinary" (not "color-sensitive"), the drop in sensitivity to the light from sources of lower color temperature is large compared with that of the panchromatic plates.

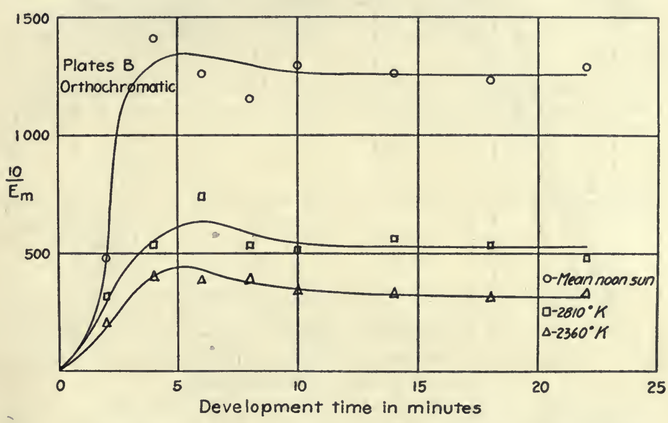

FIG. 3. Sensitivity *vs.* development-time curves for plates *B* under three conditions of illumination.

In Fig. 3, similar curves are given for plates *B*. Although these plates are orthochromatic, the drop in sensitivity is nearly as great as with the ordinary plates.

In Fig. 4, the curves for the panchromatic plates (*C*) indicate a drop in sensitivity that is, for practical purposes, negligible. Although these are not as sensitive as plates *D*, their sensitivity is less diminished by the incandescent type of illumination.

Fig. 5 presents the curves for plates *D*, the most sensitive of the five brands studied. Even though their loss in sensitivity with incandescent illumination is greater than with plates *C*, the plates *D** are more sensitive with all three sources.

* It is interesting to note that these plates, *D*, advertised to have a higher H & D speed to "half-watt" light than to daylight, do not appear to justify the claim.

In Fig. 6, plates E,* we have an example of a panchromatic plate in which the maximum sensitivity is reached at a long time of development.

Table 2 gives the data on the sensitivity (as measured by $10/E_m$)

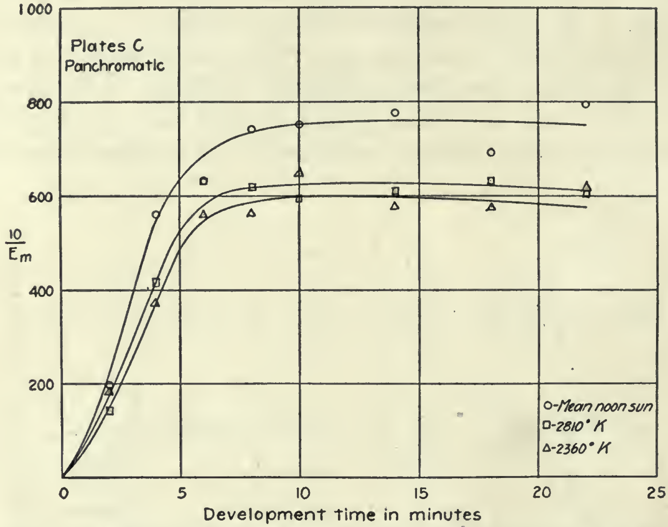

FIG. 4. Sensitivity *vs.* development-time curves for plates C under three conditions of illumination.

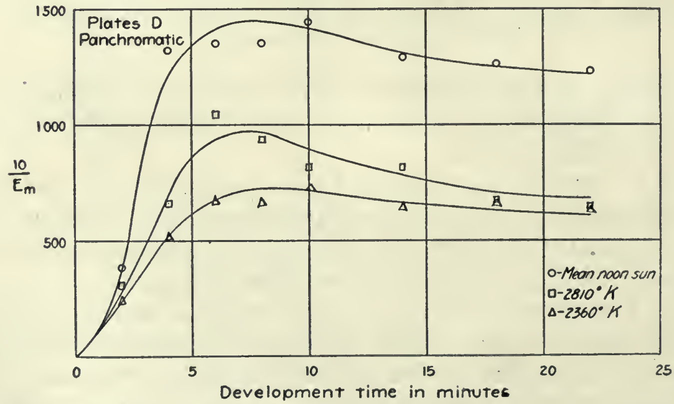

FIG. 5. Sensitivity *vs.* development-time curves for plates D under three conditions of illumination.

* Although advertised as "special rapid," these plates are considerably slower than the other two brands of panchromatic plates.

of the five brands of plates in a more easily visualized form. To obtain these values, each sensitivity *vs.* development-time curve is represented by its maximum value.* The resulting number is thus

TABLE 2

Maximum Values of $10/E_m$ Taken from the Sensitivity vs. Development-Time Curves

Plate	Maximum Value of the Sensitivity Index 2360°K.	2810°K.	Mean Sun
A (Ordinary)	150	225	505
B (Orthochromatic)	450	620	1350
C (Panchromatic)	600	625	755
D (Panchromatic)	725	975	1450
E (Panchromatic)	240	300	380

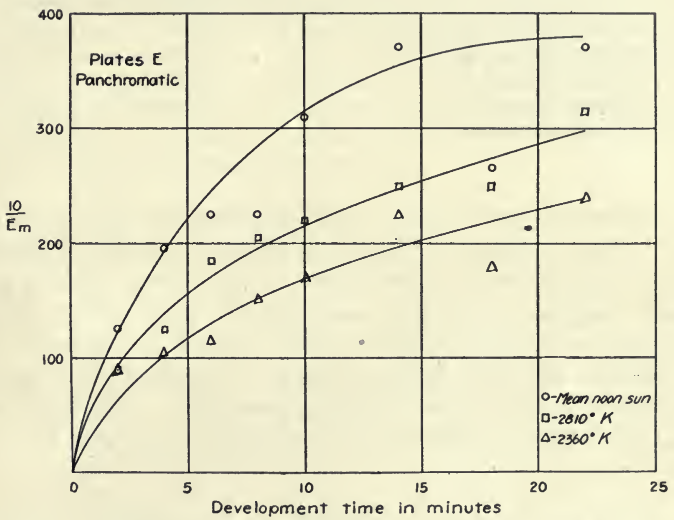

FIG. 6. Sensitivity *vs.* development-time curves for plates *E* under three conditions of illumination.

more accurately representative than any of the experimentally obtained values of the index. The table shows that: (1) the ratio of the sensitivity of the panchromatic to the ordinary plates is greater with incandescent lighting than with "sunlight," and (2) with every

* The representation of the panchromatic plates *E* by a single number is not strictly comparable with the others, since the maximum value of the index occurs at a development time exceeding 22 minutes and was, therefore, unobtainable.

brand of plate the sensitivity decreases with decreasing color temperature of the source.

The values of Table 3 were obtained from the data in Table 2. This table gives the correct exposure for a given plate to a given source, that of the ordinary plates to sunlight being taken as unity.

TABLE 3

Factors Indicating the Exposure Necessary to Obtain Similar Results with Each of the Five Plates under the Three Conditions of Illumination, That for the Ordinary Plates to Sunlight Being Taken as Unity

	Exposure Factor		
	Indoors		
Plate	Vacuum Lamps	Gas-Filled Lamps	Sunlight
A (Ordinary)	3.4	2.2	1.0
B (Orthochromatic)	1.1	0.81	0.37
C (Panchromatic)	0.84	0.81	0.67
D (Panchromatic)	0.70	0.52	0.35
E (Panchromatic)	2.1	1.7	1.3

At present the use of the "visual photometer" type of exposure meter is fairly common. Usually with such a device provision is made for the difference in sensitivity of the several types of photographic materials. However, assuming that the correct exposure to sunlight for a certain brand of plates is known, it is important to know further how the exposure should be modified when using the meter under "incandescent" lighting conditions. This information, for the five brands of plates studied, is supplied by Table 4.

TABLE 4

Factors Indicating the Exposure Necessary to Obtain a Similar Result with the Two "Incandescent" Illuminants, That with Sunlight Being Taken as Unity

	Exposure Factor		
	Indoors		
Plate	Vacuum Lamps	Gas-Filled Lamps	Sunlight*
A (Ordinary)	3.4	2.2	1.0
B (Orthochromatic)	3.0	2.2	1.0
C (Panchromatic)	1.3	1.2	1.0
D (Panchromatic)	2.0	1.5	1.0
E (Panchromatic)	1.6	1.3	1.0

* These values do *not* indicate that the plates are equally sensitive to sunlight.

REFERENCES

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[2] DAVIS, RAYMOND, AND NEELAND, G. K.: "An Experimental Study of Several Methods of Representing Photographic Sensitivity," Bureau of Standards Research Paper No. 355.

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DISCUSSION

MR. HARDY: The specification of the speed of a photographic material to different light sources may be misleading if it is forgotten that one seldom, in practice, photographs the light source. In other words, the only time these data apply directly is when one takes a picture, in one case of the sun, or, in the other case, of the tungsten lamp. Actually, the scenes photographed are, of course, colored, and may represent practically any distribution of energy throughout the spectrum. It is difficult to suggest any better answer than the one the author has given to this question, but it is nevertheless necessary to recognize the fact that if the subject happens to be colored, a different factor applies.

PAST-PRESIDENT CRABTREE: I might add to what Mr. Hardy says that the only way in which to measure speed is to measure it under the actual conditions that obtain when using photographic material.

VARIATION OF PHOTOGRAPHIC SENSITIVITY WITH DEVELOPMENT TIME*

RAYMOND DAVIS AND GERALD K. NEELAND**

Summary.—*The relation between photographic sensitivity and the time of development has been studied. Three modifications of Hurter and Driffield's method of measuring plate speeds have been used as indexes of sensitivity. The results are generally in accord with those of Bullock, who investigated the relation of "threshold speed" to development time. An optimum time of development is indicated, which varies with the type of emulsion.*

The differences between the three indexes have been brought out. Just which index is most satisfactory depends somewhat on the nature of the individual problem. It is concluded that, in many cases, a single value of any index is inadequate to represent the sensitivity of a given emulsion. The clearest representation may be had by a curve plotted between a sensitivity index and development time.

I. INTRODUCTION

Several methods of representing the sensitivity of photographic emulsions have been proposed from time to time. At first, the sensitivity, or "speed," was taken as inversely proportional to the exposure required to produce (on development) a just perceptible density. This has been called threshold speed. The difficulty in specifying accurately a "just perceptible" density has discouraged the use of this method, although the method and its modifications are still employed to some extent.

Hurter and Driffield's system was based on a characteristic curve representing density as a function of the logarithm of the exposure. The exposure at the intersection of an extension of the straight-line portion of this curve with the base line was called the "inertia" of the plate. The "speed" of the plate was taken as proportional to the reciprocal of the inertia. It was found that, in the absence of soluble bromides, the speed of a given plate was constant regardless of the time of development. Later it was shown that the H & D speed of a

* Presented at the Fall, 1931, Meeting at Swampscott, Mass. Publication approved by the Director, Bureau of Standards, U. S. Department of Commerce.

** U. S. Bureau of Standards, Department of Commerce, Washington, D. C.

plate varies somewhat with development. The nature of this variation has not, to our knowledge, been systematically investigated. The discrepancy between the results of Hurter and Driffield and those of later workers is probably due to changes in the methods of manufacturing emulsions.

Bullock[1] investigated the relation between threshold speed and development time (using a Chapman-Jones plate tester), and obtained curves indicating an optimum time of development.

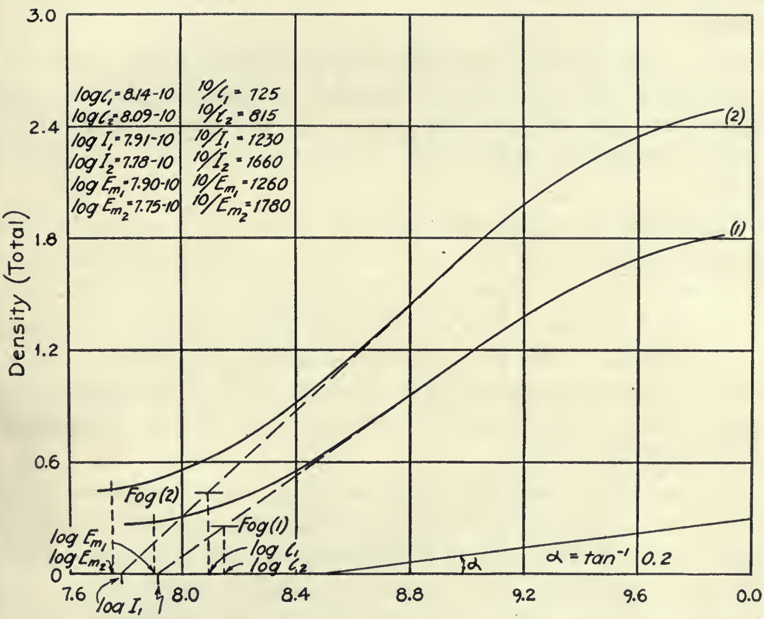

FIG. 1. Illustrating the methods of obtaining the three indexes of sensitivity from each of two characteristic curves.

We have investigated the relation between sensitivity and time of development, using three modifications of Hurter and Driffield's system as indexes of sensitivity. We shall, first, show the nature of the relation; second, indicate the relative merits of the three indexes; and third, show that a single value of any index is, in many cases, inadequate to represent the sensitivity of an emulsion.

The first method substitutes the tangent of the curve at the point of maximum gradient for the extended straight-line portion. The value of the exposure at the intersection of this tangent with a horizontal line representing the fog density is designated as ι. The sensitivity index on this basis is $10/\iota$.

An index of sensitivity, that has frequently been used, is derived in a manner similar to that adopted by Hurter and Driffield. That is, the sensitivity is taken as inversely proportional to the value of the exposure at the intersection of an extension of the straight-line portion of the characteristic curve with the exposure axis, where total density is plotted against log exposure. The exposure at this point of intersection is sometimes erroneously called the inertia.

In the second method employed in the present work, a quantity I is defined as the value of the exposure at the intersection of the tangent of the characteristic curve, at the point of maximum gradient, with the exposure axis. The sensitivity index on this basis is $10/I$.

Note that, when the characteristic curve has a central straight portion, ι will be equal to the inertia, and I will be equal to the above-mentioned quantity, erroneously called "inertia."

The third method is that of Jones and Russell,[3] who take "speed" as proportional to the reciprocal of a quantity E_m, which is defined as the exposure corresponding to the point in the "toe" region of the characteristic curve where the gradient is 0.2. The sensitivity index on this basis is $10/E_m$.

This method is applicable in those cases where the characteristic curve is not straight over an appreciable length, or where an exposure range that more than covers the straight-line portion is encountered. The latter condition often occurs in practical photography. The expression of sensitivity in terms of inertia is obviously unsatisfactory under either condition.

II. PROCEDURE

In order to determine for each emulsion the nature of the relation between the sensitivity and the time of development, sets of 11 test strips each, backed with a black shellac mixture for preventing halation, were exposed in a non-intermittent sector wheel sensitometer. The source of light, having a visual intensity of one meter candle and the quality of sunlight, was produced by an incandescent lamp operated at a color temperature of 2360°K., in combination with a Davis-Gibson filter.[2] The 11 exposed test strips were developed together in total darkness in a tray of pyro* at 20°C. The strips were removed, one at a time, giving development times ranging from 1 to 22 minutes. The developer was agitated by brushing the plates with a camel's-hair brush. The resulting densities were measured in diffuse light with a Martens polarization photometer.

The characteristic curve corresponding to each test strip was plotted, and from it values of the indexes $10/\iota$, $10/I$, and $10/E_m$

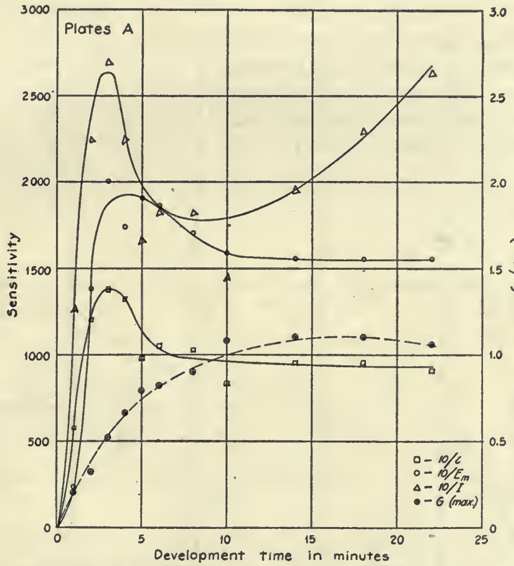

FIG. 2. Sensitivity *vs.* development-time curves for plates A. The solid curves show the variation in each of the indexes with the time of development. The dashed curve shows the change in the maximum gradient, G (max.), with the time of development.

were obtained. From this data three curves were drawn for each emulsion, showing the variation of the indexes with the time of de-

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* Pyrogallol developer, compounded according to the following formula, was employed:

(A)	Water	1000 cc.
	Potassium metabisulfite	12 g.
	Pyrogallol	60 g.
(B)	Water	1000 cc.
	Sodium sulfite (anhydrous)	90 g.
(C)	Water	1000 cc.
	Sodium carbonate (anhydrous)	75 g.

(To develop, one part each of A, B, and C was mixed with seven parts of water.)

velopment. The curves are given in Figs. 2 to 6, inclusive. In each figure a curve is included which shows the relation of the maximum gradient to the time of development for that particular emulsion. In Table 1 are listed the plates included in this study, the types of emulsions, and the identifying letters used in the figures.

TABLE 1

Photographic Plates Investigated

Description of plate	Identification	Figure
American "high speed" orthochromatic	*A*	2
American "medium speed" ordinary	*B*	3
German "high speed" orthochromatic	*C*	4
English "high speed" panchromatic	*D*	5
American "process" ordinary	*E*	6

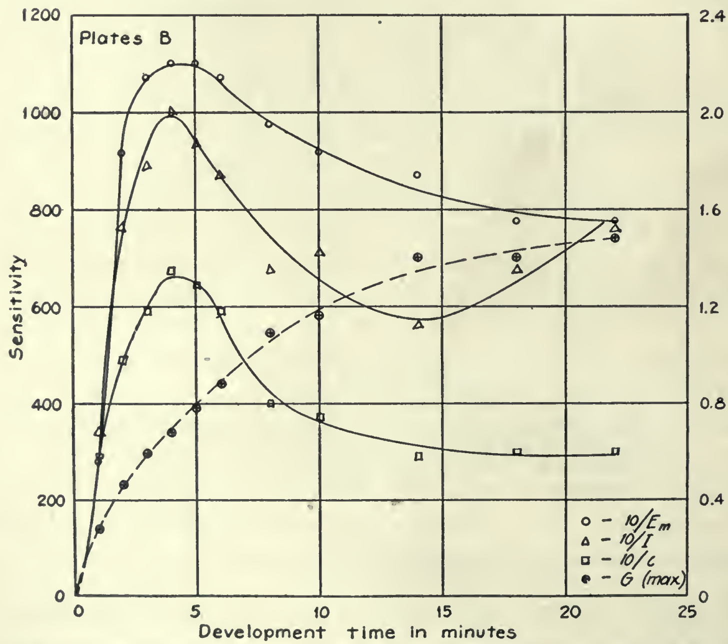

FIG. 3. Sensitivity *vs.* development-time curves for plates *B*. The solid curves show the variation in each of the three indexes with the time of development. The dashed curve shows the change in the maximum gradient, *G* (max.), with the time of development.

III. DISCUSSION OF RESULTS

1. Characteristics of the Three Indexes.—Figs. 2 to 6 show the variation of sensitivity, as measured by the three indexes, with the time of development. For plates A, Fig. 2, all three indexes show a pronounced maximum in the neighborhood of 3 to 4 minutes' development. However, it is to be seen that the curve for $10/I$ is distinctly different in shape from the other two, showing a second upward trend after 8 minutes' development. Note that, with these plates, the curve for $10/I$ lies above that for $10/E_m$.

For plates B, Fig. 3, we again have all indexes a maximum at

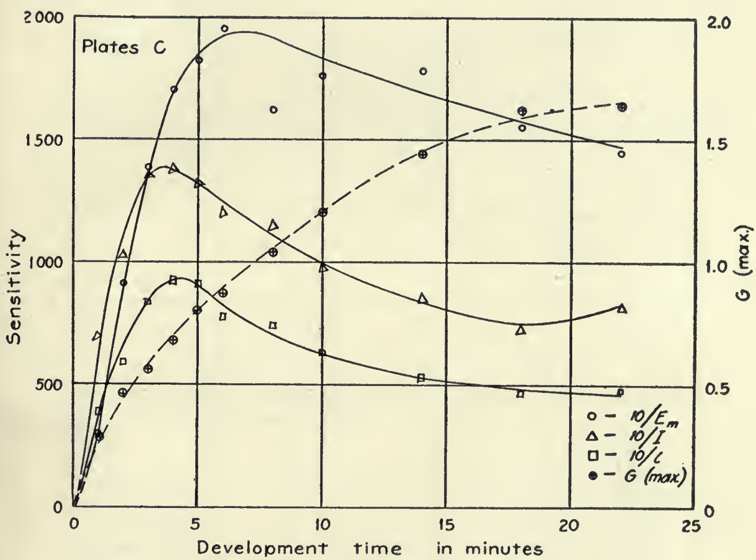

FIG. 4. Sensitivity *vs.* development-time curves for plates C. The solid curves show the variation in each of the three indexes with the time of development. The dashed curve shows the change in the maximum gradient, G (max.), with the time of development.

about 3 to 4 minutes' development. As before, the curve for $10/I$ differs in shape from the other two.

For plates C, Fig. 4, similar results are obtained. The curve for $10/I$ differs less from the other two than in the two preceding cases, but the beginning of the second upward trend is indicated at about 18 minutes' development.

For plates D, Fig. 5, the curves for both $10/\iota$ and $10/I$ indicate an early maximum not shown by the curve for $10/E_m$. Here the second upward trend of the $10/I$ curve begins at about 14 minutes' development.

For plates E (Fig. 6) the curves for both $10/\iota$ and $10/I$ again indicate an early maximum sensitivity. Note that the G (max.) curve does not flatten out here as with the other plates. As with plates D, the curve for $10/E_m$ indicates maximum sensitivity at time of development in excess of 22 minutes.

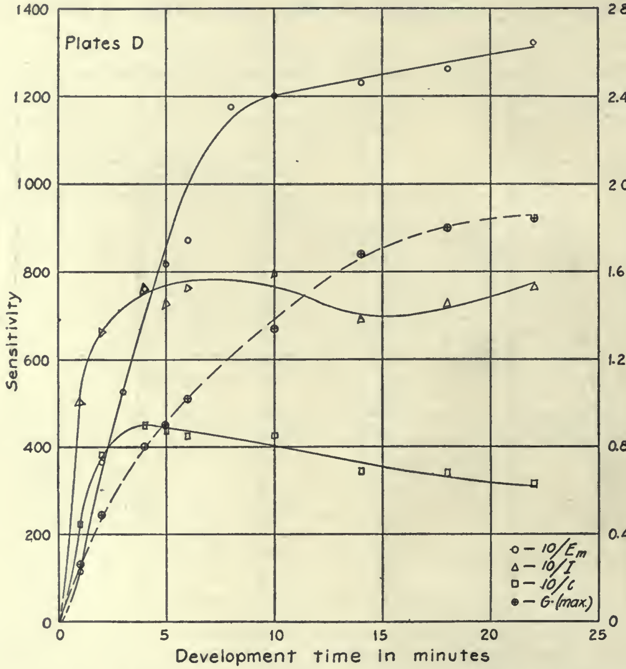

FIG. 5. Sensitivity *vs.* development-time curves for plates D. The solid curves show the variation in each of the three indexes with the time of development. The dashed curves show the change in the maximum gradient, G (max.), with the time of development.

Figs. 2 to 6, inclusive, show that the second upward trend in the $10/I$ curve usually occurs in the region where the rate of increase of maximum gradient has fallen off.* That is, after this point is reached, the maximum gradient line tends to shift so as to remain parallel to itself, resulting in an increase in the values of $10/I$. That

* On all except the process plates, the rate of growth of fog was practically constant over the entire range of development times.

this rise does not necessarily signify an actual increase in sensitivity, has been shown by the "hypothetical" case discussed in a note[4] by the authors. In this "hypothetical" case, we have two characteristic curves identical in form but one raised above the other. (Total density is here plotted against log exposure.) The tangents at the points of maximum gradient are, of course, parallel, and intersect the zero density line so that the upper curve gives the higher value of

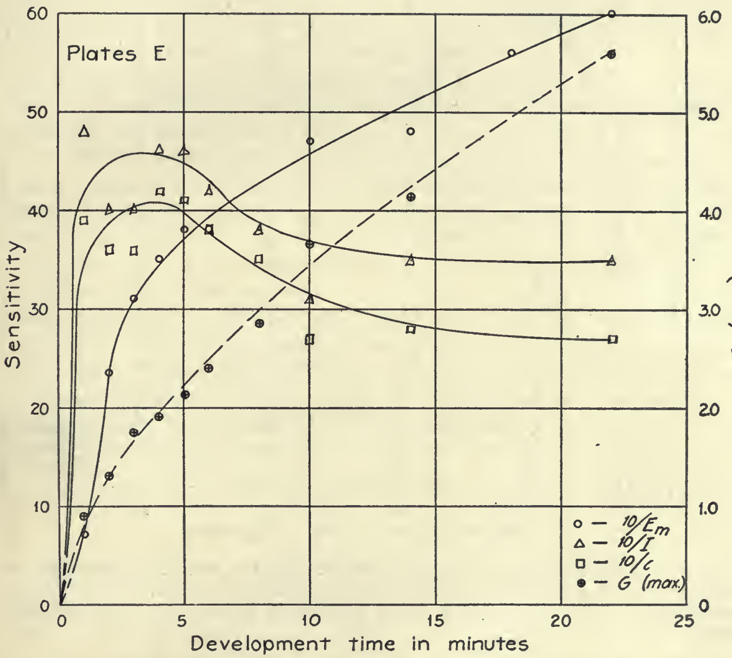

FIG. 6. Sensitivity *vs.* development-time curves for plates E. The solid curves show the variation in each of the three indexes with the time of development. The dashed curve shows the change in the maximum gradient, G (max.), with the time of development.

$10/I$. It is obvious that the two emulsions represented by these curves should be considered equally sensitive since, if two negatives were made under the same conditions, one with each emulsion, they could be made to yield identical positives by properly adjusting the printing exposure.

2. *Method of Expressing Relative Sensitivity.*—In Fig. 7, the $10/E_m$ curves are plotted for plates A, B, C, and D. The superiority

of such a curve over a single quantity for expressing sensitivity is obvious from this figure. The sensitivity of an emulsion having a comparatively flat curve can be satisfactorily represented by a single value; an emulsion having a curve with a pronounced maximum obviously can not. The procedure, followed by some workers, of giving values at 3 times of development is sufficient in some cases

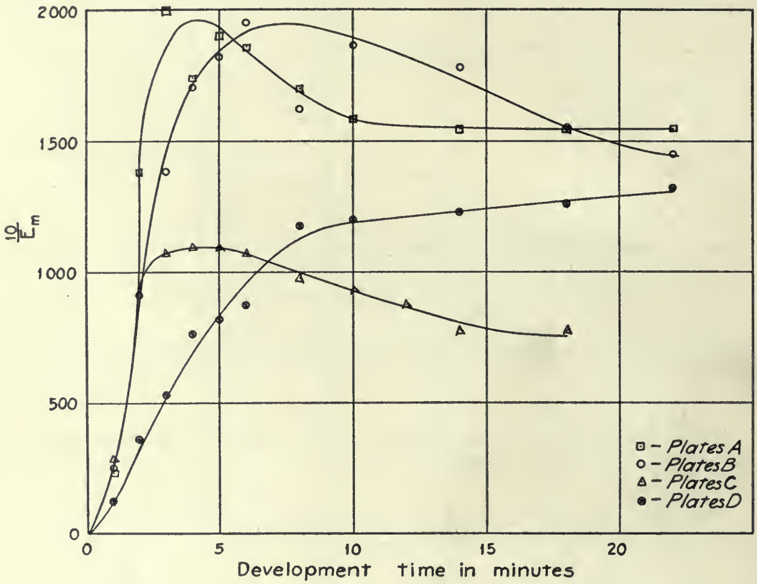

FIG. 7. Illustrating the manner of expressing the relative sensitivity of emulsions. All curves are plotted to the same scale. The curve for the process plate E is not included, as its sensitivity is too low to show to advantage.

provided that the times are properly chosen. However, an adequate representation of the sensitivity of emulsions seems to require their sensitivity *vs.* development-time curves.

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[2] DAVIS, RAYMOND, AND GIBSON, K. S.: "Filters for the Reproduction of Sunlight and Daylight and the Determination of Color Temperature," Bureau of Standards, *Mis. Pub.*, No. 114.

[3] JONES, L. A., AND RUSSELL, M. E.: "The Expression of Plate Speed in Terms of Minimum Useful Gradient," *Proc. 7th International Congress of Photography* (1928), p. 130.

[4] DAVIS, RAYMOND, AND NEELAND, G. K.: "A Note on the Speed of Photographic Emulsions," *J. Opt. Soc. of America*, **21** (July, 1931), No. 7, p. 416.

DISCUSSION

PAST-PRESIDENT CRABTREE: The variation in the speed was not more than twenty-five per cent, which, from a practical standpoint, is not very serious.

MR. NEELAND: In other cases the variation is greater than fifty per cent. We have plates where the sensitivity is reduced to one-half its maximum value after eighteen or twenty minutes of development.

MR. SEASE: What fog levels did you reach?

MR. NEELAND: Fog values of 1 to 1.5 might be reached in certain cases, but usually they are not greater than 1.

PAST-PRESIDENT CRABTREE: Gammas in practice are much lower than those limits to which you have been developing. Furthermore, the solutions that you used were absolutely fresh and new. Do the results apply to solutions that are partially exhausted?

MR. NEELAND: Solutions that are not fresh would have a maximum, at least at a higher time of development.

PAST-PRESIDENT CRABTREE: We rarely use a solution that is absolutely fresh. As soon as a certain number of feet of film are developed the stock solution in the system of the developing machine is partially contaminated by exhaustion products that cut down the fog values, and would change that data materially.

MR. CARROLL: With regard to the lower gammas in practice, the change in sensitivity number was greatest at about seven-tenths gamma, a fact which indicates the practical importance of the thing.

A REFLECTOR ARC LAMP FOR PORTABLE PROJECTORS*

HARRY H. STRONG**

Summary.—*A description of a portable reflector arc lamp and current rectifying device designed especially for use with portable sound projection equipment. The lamp is small, is adapted to portable projectors, is well proportioned, and of exceptional power. The rectifier is of the familiar Tungar type and gives full-wave rectification. It is compact and portable in design, and the whole equipment is of an efficiency high enough so that ample screen illumination may be secured with current drawn from the 110-volt lamp socket.*

A new field for motion picture projection has been created by the perfecting of portable sound equipment. This type of equipment is finding extensive application for educational and advertising purposes, as well as for entertainment in small theaters and in auditoriums of moderate size.

In all of these uses, however, the audience is composed of individuals accustomed to the large projected image and brilliant screen illumination characteristic of the motion picture theater today. They are no longer satisfied with a picture three or four feet wide, a low intensity of screen illumination, and sound coming from a position at one side of the picture.

The attainment of satisfactory results in the use of portable sound equipment requires a picture eight to twelve feet wide, a porous screen permitting the sound to come from the screen itself, and a light source of sufficient power to afford a screen illumination and brilliancy comparable with that seen in the popular theaters.

The d-c. carbon arc is the only available source of light possessing sufficient power and concentration to satisfy the requirements of this newly created condition. Adaptation of the d-c. carbon arc to portable equipment, however, presents certain problems, the solution of which has required careful study and extensive experimentation.

Portability places definite restrictions on the weight and bulk of equipment, and these factors must be given careful consideration in

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Strong Electric Co., Toledo, Ohio.

working out details of design. Direct current is no longer available in most localities, except in central urban districts. This condition makes it necessary to provide some means of converting the alternating current of the power supply to direct current suitable for use at the arc.

Simplicity of operation is a requisite of prime importance in portable equipment, since the equipment is more likely to be used by an operator of little experience than by one having extensive knowledge of motion picture equipment. Finally, results must be attained in a manner to afford efficient use of electrical power so that connections may be made to any available light socket.

It is the purpose of this paper to describe a portable, reflector type, carbon arc lamp and rectifier, developed to meet the difficult conditions outlined in the preceding paragraphs.

The remarkable success of the reflector type of arc lamp in standard theater projection has led to the adoption of the reflector principle in the development of the portable unit. The superiority of d-c. reflector arcs is due basically to the interception of a large angle of radiated light emanating from the crater of the positive carbon and the reflection of this light, as a converging beam, to the film aperture. The adaptation of these principles has resulted in the development of a compact unit only 18 inches long, 12 inches high, and 10 inches wide, well proportioned and having exceptional power. Fig. 1 shows this lamp adapted to the modern portable projector.

The urgency of reliable performance in the hands of the lay operator requires the elimination of hand control of the arc. This is accomplished by means of a fully enclosed control motor, which is mounted as an integral part of the lamp house, and which automatically feeds the carbons at exactly the same rate at which they are consumed, thus maintaining the proper arc length throughout the entire burning of the carbons.

The automatic arc control system operates upon the principle that certain electrical characteristics of an arc are changed as the carbons are consumed. Use is made of these changes to control directly the speed and direction of rotation of a differentially compounded motor. A wiring diagram of this motor is shown in Fig. 2.

The armature of the control motor is geared to the carbon carriages in such a manner that the rotation of the armature will cause the carbons to move closer together, or farther apart, depending upon the direction of rotation of the armature. Since the armature is so connected that it is electrically energized at all times, its speed and direction of rotation, and hence the movement of the carbon carriages, will depend upon the direction and strength of the magnetic field passing through the armature.

The field of the motor consists of two windings which are differentially connected—a shunt or potential winding, and a series or current

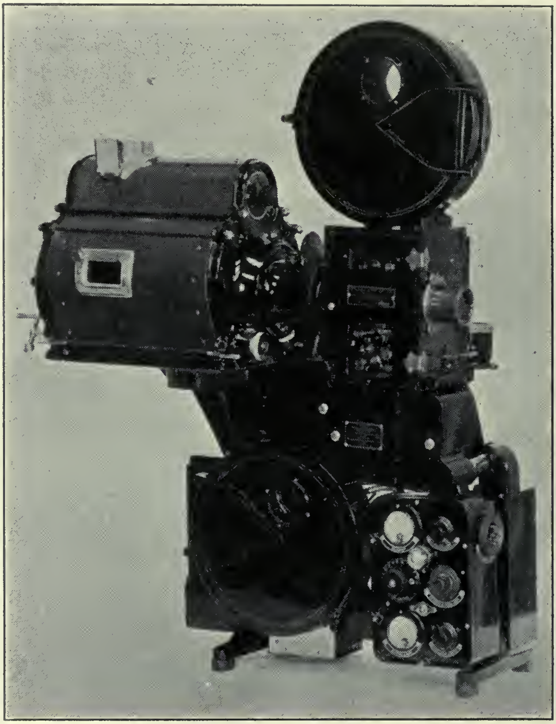

FIG. 1. Portable reflector arc lamp, adapted to Western Electric portable sound projector.

winding. The shunt winding, comprising many turns of fine wire, is connected through a rheostat across the arc. This sets up a magnetic field which tends to rotate the armature in a direction that feeds the carbons toward each other. The series winding, comprising a few turns of heavy wire, is connected in series with the arc, and sets up a magnetic field opposed to that of the shunt winding, thus causing the armature to rotate in a direction that separates the carbons.

When the arc is burning properly, and the rheostat which controls the strength of the shunt winding is adjusted so that both the series and shunt windings are of equal strength, the two field windings neutralize each other and the armature does not rotate. As the arc gap increases, due to the normal burning of the carbons, the potential across the arc is increased and the current through the arc decreased. An unbalanced condition is thus created in the field windings, and the resultant magnetic flux through the armature is equal to the difference in strength between the shunt and series field windings. Under these

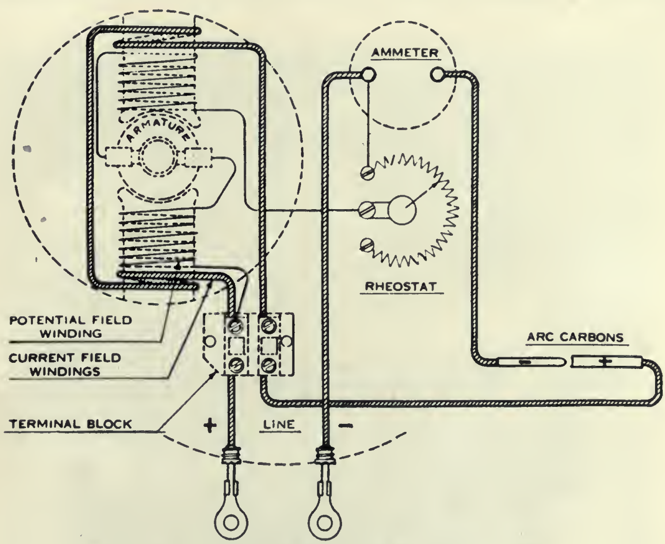

FIG. 2. Wiring diagram of arc control system.

conditions the armature will rotate in a direction to bring the carbons closer together and compensate for the burning loss.

The rheostat, in series with the potential field windings, permits adjustment of the strength of the potential field in relation to that of the series field, so that proper motor speed may be established and the proper arc length maintained for any given operating current. The rheostat is provided with an adjusting knob and indicating dial at the top of the lamp house, as shown in Fig. 3.

The operation of the arc control is entirely automatic and continuous. Once the arc has been struck and the carbons separated to the proper arc length, the control motor rotates slowly and continuously, feeding the carbons toward each other at a rate that exactly equals their consumption. A uniform arc gap is thus maintained without manual control.

An arc imager is mounted on the side door of the lamp house adjacent to the window. The imager projects an image of the arc and the incandescent carbon tips to a small screen secured to the side of the vent stack. This device can be seen in Fig. 4. While the lamp is in operation, the lines on the imager screen will indicate the proper position of the positive crater in its relation to the focus of the reflector. as well as the correct position of the negative carbon in relation to the positive.

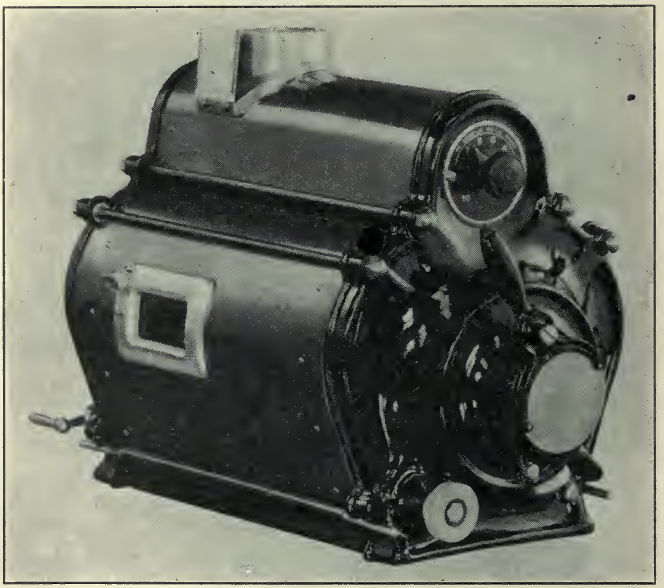

FIG. 3. Portable arc lamp showing knurled knob for adjusting focus and motor control rheostat with dial.

The operator may adjust the position of the positive crater to the exact focus of the mirror by turning the knurled knob at the lower left-hand corner of the lamp house, as shown in Fig. 3.

"Striking the arc" is accomplished by turning the ball crank at the rear of the lamp house. This crank is clearly shown in Fig. 4. The ball crank further permits manual adjustment of the arc length, *i. e.*, adjustment of the negative carbon in relation to the positive. Once this relation has been set, the carbons seldom require further manual adjustment. The automatic control, under normal conditions, will maintain the proper arc length and position of the positive crater for the entire burning period of one complete trim.

The optical system comprises an elliptical mirror 6 $^5/_8$ inches in diameter, having a working distance of 4 inches from the arc crater to the vertex of the mirror and 19 inches from the mirror to the film aperture. This gives a working speed to the optical system slightly faster than $f/3$, which is sufficient for the quarter-size lenses regularly supplied with portable projectors.

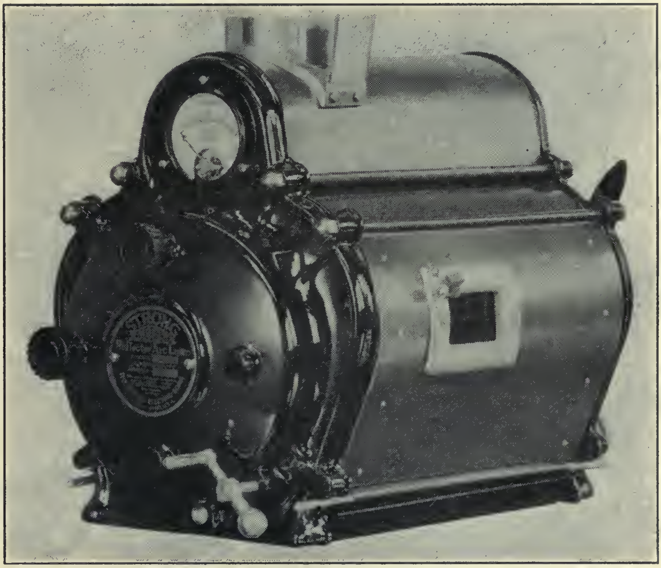

FIG. 4. Portable arc lamp showing ammeter, arc imager, and manual controls for mirror and carbon feeds.

The mirror is adjusted for horizontal and vertical alignment of the spot at the film aperture by means of two knurled knobs projecting from the back of the lamp house, as shown in Fig. 4.

This lamp is designed for use with either standard 35 mm. or with 16 mm. film. The arc current required will vary with the width of the film used and the size of the projected image.

The diameter of the carbons is determined by the arc current. The following table indicates the correct carbon trims for different conditions of operation.

Positive Carbon	Negative Carbon	Arc Current	Film Width
7 mm.	5 mm.	9 amp.	16 mm.
9 "	6.4 "	13 "	35 "
10 "	7 "	15–16 "	35 "

Under the operating conditions indicated in this table, the lamp will produce a screen brilliancy comparable with that produced by standard theater equipment at equal current. Ample illumination is provided for the projection on perforated screens of an 8- to 12-foot picture from standard 35 mm. film. On a solid screen the intensity of illumination is ample for a picture 14 feet or more wide.

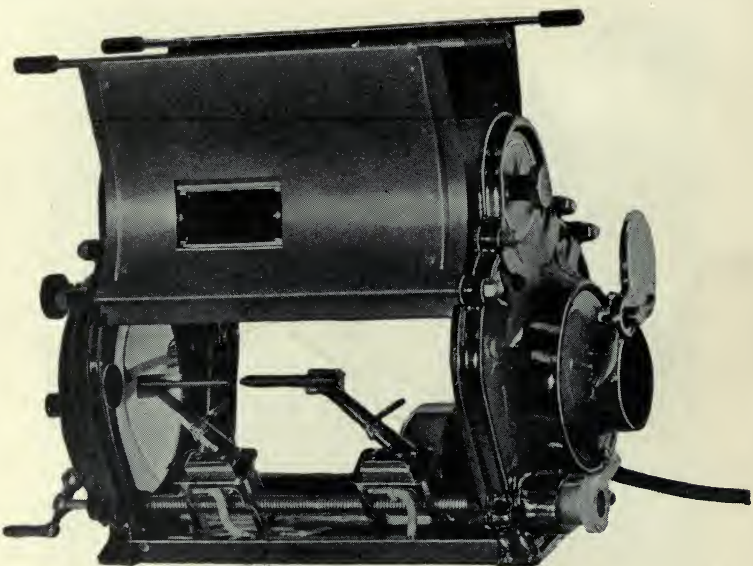

FIG. 5. Interior view of portable arc lamp.

To avoid the possibility of trimming improperly, the lamp has been designed to accommodate carbons 4 inches long, when clamped at their extreme ends. This arrangement eliminates any necessity of adjusting the carbons in the holders during the burning period of slightly more than an hour.

In trimming the lamp, the spring clutch is released, the carbon is placed against a stop at the back of the holder, and the clutch is then allowed to engage the carbon. By confining the carbon length to 4 inches, a perfect alignment of positive and negative carbons is assured without any necessity of adjustment.

The interior mechanism of the lamp is shown in Fig. 5. It should be noted that the parts are few in number, as well as simple and sturdy in construction.

To avoid the necessity of purchasing carbons of special length, and so as to permit the use of standard 8-inch carbons, a cutter is provided at the rear of the lamp house. By using this cutter, standard 8-inch carbons may be scored and broken to exactly 4 inches in length.

Should an experienced operator, who understands the readjustment of carbons in the holders, desire to use the full 8-inch carbons, the stops can easily be removed from the back of the carbon holders,

FIG. 6. Exterior view of full-wave rectifier for use with portable arc lamp.

and a tubular guard can be attached to the rear of the lamp. This arrangement will prevent contact of the end of the negative carbon which extends through the mirror.

An opening is provided in the bottom of the lamp house for connection to the ventilating system provided with some makes of portable sound equipment. The exhaust from the lamp house is carried out through a chimney at the top.

An ammeter is mounted on the rear of the lamp house (Fig. 4). This is surrounded by a ventilating duct that connects to an annular passage around the main ventilating flue. In this manner an induced draft of cool air is drawn in around the ammeter, to maintain the instrument at normal temperature and prevent any disturbance of its calibration.

The rectifier has been chosen as a means of converting alternating current to direct current because of its light weight for the required capacity, its freedom from moving parts and intricate mechanism, and its simplicity and safety of operation.

The rectifier, herein described and shown in Fig. 6, was developed particularly for use with the lamp described above. Its elements comprise a special transformer for changing the alternating line voltage to the correct potential for operation of an arc; a radial switch for regulating the current to the desired value; two Tungar tubes for rectifying the current; a substantial housing; and necessary sockets and lead wires.

The transformer is of a special design in which the output possesses constant current characteristics, thus allowing commercial fluctuations of line voltage without affecting the stability of the arc. The primary and secondary coils are separate and are effectively insulated from each other, which construction allows only the low voltage necessary for operating the arc to enter the lamp house, thus avoiding any possibility of the operator's sustaining an electric shock.

The rectifier tubes are of the familiar Tungar type, *i. e.*, thermionic tubes filled with argon at low pressure. These tubes provide a valve action, permitting the alternating current to pass in one direction only. Connection is made in such a way that full-wave rectification is secured without the use of moving parts, relays, or other intricate devices.

A radial switch, placed within convenient reach, gives eight points of current adjustment. This permits the arc current to be adjusted to values ranging from 8 to 16 amperes when the rectifier is connected to a 115-volt supply.

The electrical efficiency of the rectifier unit is 80 per cent. From this fact, it is evident that the lamp may be operated at an arc current of 15 amperes with a line consumption of only 1000 watts.

VACUUM TUBE AND PHOTOELECTRIC TUBE DEVELOPMENTS FOR SOUND PICTURE SYSTEMS*

M. J. KELLY**

Summary.—*This paper reviews some recent vacuum tube and photoelectric cell developments which are of interest in sound recording and reproduction systems. An indirectly heated cathode triode is described, in the output circuit of which the current components due to the a-c. power supply of the heater have been reduced approximately 20 decibels below previously obtained levels. This tube makes it possible to use an a-c. supply in amplifiers having flat frequency characteristics with over-all gains of the order of 100 decibels. The microphonic disturbances in vacuum tubes are discussed. A measuring system for evaluating the microphonic noise currents is described, and the characteristics of a filamentary cathode tube of low microphonic noise level are given. The characteristics of a double anode, thermionic, gas-filled, rectifier tube for use in a d-c. power supply unit for the sound lamp and vacuum tube filaments of reproducing systems are given. A photoelectric cell of high sensitivity for use in sound reproduction work is described.*

Since the standardization of sound recording and reproducing systems many technical developments have been made resulting in less distortion in reproduction, in a decrease of extraneous (background) noise, and in systems having improved operation and maintenance characteristics. The thermionic vacuum tubes used in the recording and reproducing systems and the photoelectric cell used in reproduction are important elements in determining the quality of reproduction, the level of background noise, and the operation and maintenance characteristics of the systems. A review of the vacuum tube and photoelectric cell developments at the Bell Telephone Laboratories during the past year that have contributed toward such improvements in sound recording and reproducing systems will be given, and the characteristics of the new devices described.

1. A LOW "HUM LEVEL" AMPLIFYING TUBE

The advantages of obtaining the filament supply of vacuum tubes directly from a-c. lighting circuits have long been recognized. Prior to the time when the indirectly heated cathode vacuum tube became

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Bell Telephone Laboratories, Inc., New York, N. Y.

available, much consideration was given to the use of "raw" alternating current for heating the filamentary type of cathode. Due to the magnitude of the 60 and 120 cycle disturbances introduced into the plate current even under the most favorable cathode design conditions, it has not been possible to make at all general the application of alternating current to the heating of filamentary cathodes. In audio frequency amplifiers the 60 and 120 cycle disturbances generally restrict the use of alternating current for heating the filamentary cathodes to the final stage of amplification.

The introduction of the indirectly heated cathode into the vacuum triode made immediately possible a further extension of the use of "raw" alternating current as the source of the cathode energy. A heater and cathode unit consisting of a hairpin of tungsten wire imbedded in a cylindrical insulator of magnesia or similar material, with a tightly fitting nickel sleeve surrounding the insulator upon which is deposited the active cathode material, has been generally standardized in triodes for broadcast radio receiver use. The heater element of such a tube can be lighted by alternating current without introducing 60 and 120 cycle disturbances in radio frequency stages. However, its use in audio frequency circuits having flat frequency characteristics above 60 cycles is, in general, limited to circuits having gains less than 50 decibels ahead of the first tube heated by alternating current. If such a tube, employing alternating current for the heater supply, is used in amplifiers having flat frequency characteristics and appreciably greater gain, the 60 and 120 cycle disturbances from the heater supply are too great to be tolerated.

The amplifying units of sound recording and reproducing systems have over-all gains of the order of 100 decibels. In systems having such great gain, it is possible to use alternating current for heating the filaments of all the tubes only by suffering a reduced response at frequencies lower than 120 cycles, or by tolerating in the output a high level of extraneous noise arising from the 60 and 120 cycle disturbances in the tubes of the preceding stages.

The advantages of using alternating current for the filament supply in high-quality amplifiers used for sound reproduction as well as for public address systems, radio broadcast pick-up systems, and other high-gain audio frequency amplifiers, made desirable the study of 60 and 120 cycle disturbance levels in the plate circuits of the indirectly heated cathode tubes and an investigation of means of making these disturbances sufficiently small to permit the use of alternating current for heating the cathodes of all the tubes in such systems. In order that alternating current might be generally used for such purposes, the disturbances in the plate circuit of the first tube should not be greater, in order of magnitude, than the resistance and thermionic emission noises. Alternating current could be then used for heating all the cathodes in any amplifier whose gain was not limited by these fundamental causes of noise.

As the first step in these studies, a measuring system was developed with which one could measure a 60 or 120 cycle current to 120 decibels below a level of 1 milliampere. This system is shown schematically in Fig. 1.

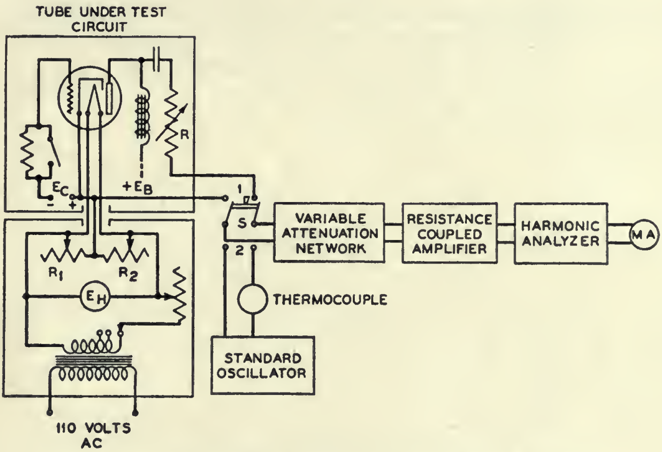

FIG. 1. Circuit used for measuring disturbance current.

The tube under test is placed in a single-stage amplifier circuit, and its heater supply is so arranged that there is no 60 and 120 cycle disturbance in the plate circuit except that produced by pick-up in the tube itself. The output from this circuit passes through a variable attenuation network to the input of a resistance coupled amplifier. The output of the resistance coupled amplifier is fed into a harmonic analyzer which permits the separation and measurement of the 60 and 120 cycle currents. In order to calibrate the analyzer, an oscillator is provided whose 60 or 120 cycle output can be fed into the variable attenuation network, amplifier, and analyzer.

Two variable 100 ohm resistances of the dial box type are connected in series across the heater terminals of the tube under test. The equipotential cathode is connected to their common point. By keeping the sum of the two resistances equal to 100 ohms, a potentiometer is provided, by means of which the cathode may be maintained at any potential varying from that of one end of the heater to that of the other. It is then possible to determine the value of the disturbance currents as a function of the potential of the cathode with respect to the heater.

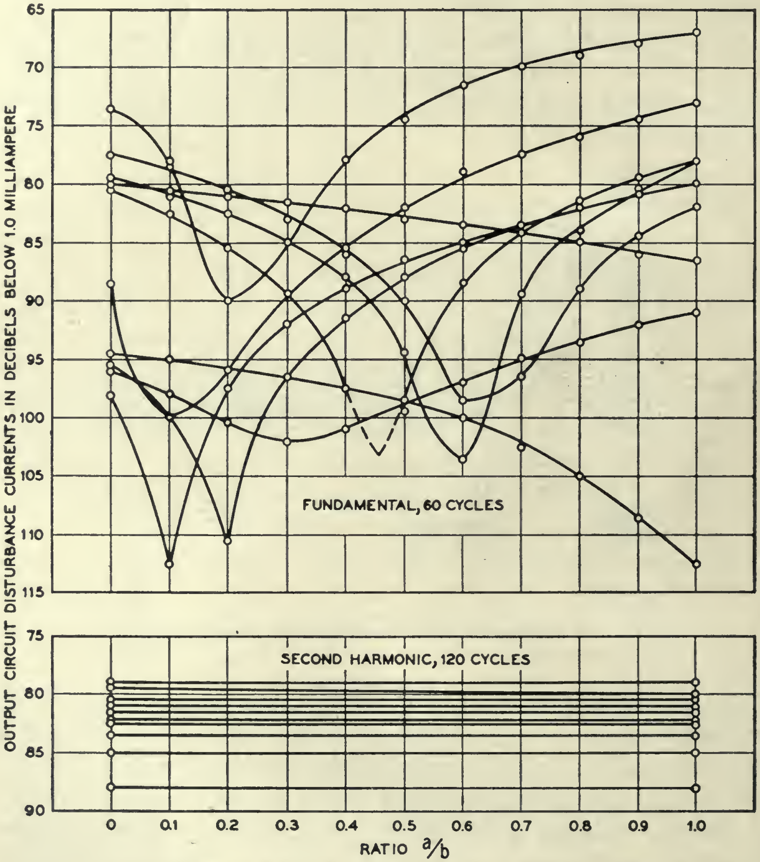

FIG. 2. Disturbance currents in typical indirectly heated cathode triodes.

Measurements of the disturbance currents in the plate circuits of typical standard indirectly heated cathode triodes were made with the measuring equipment described above. The curves of Fig. 2 exhibit representative results. The levels of the disturbance currents in the output circuit are shown as functions of the position of the common point of the heater and cathode. For a/b equal to 0, the common point is at one end of the heater; for a/b equal to 1, it is at the opposite end of the heater. The measurements were made at the rated plate, grid, and heater voltages of the tube, with an output impedance equal to that of the tube and with an input resistance from 100 to 200 ohms.

The disturbance currents resulting from the a-c. supply used for the heaters of indirectly heated cathode triodes are introduced into the output circuits by the:

(1) Electric field of the heater,
(2) Magnetic field of the heater,
(3) Resistance between heater and grid and between heater and plate, and capacitance between heater and grid and between heater and plate.

The electric field of the heater element in the space between the cathode and anode will affect the electron current to the plate in precisely the same manner as does the electric field of the control grid. With one point of the heater circuit connected to the cathode, the electric field of the heater at each point in the cathode-anode space will be the sum of the fields due to each segment of the heater element. As the common point of the heater and cathode is shifted along the heater wire, the value of the field will change. It would be expected that, when the common point was located at the mid-point of symmetry of the heater circuit, the electric field would have its minimum value.

The results given in Fig. 2 confirm this expectation for the fundamental disturbance current. A definite minimum is shown in most cases. However, since in the tubes under test the 60 cycle disturbance current is due to factors in addition to the electric field, the expected characteristic variation of the disturbance currrent due to shift of the common point is masked in varying degrees in the different tubes.

The second harmonic disturbance current does not vary with the position of the common point for the tubes of Fig. 2. From this it might be assumed that there was no second harmonic component due to the electric field. In general, this is not the case. The grid action of the heater circuit varies non-linearly as the effective voltage of the heater system changes with respect to the cathode. This non-linearity of the grid action would be expected to produce second harmonic components in precisely the same manner as they are produced in the familiar case of "mu" modulation with the standard control grid. The second harmonic disturbance current due to the electric field is, in general, very much smaller than that due to the magnetic field, and is masked by it. This is the case with the data of Fig. 2. Experiments have been arranged where the magnetic effects were eliminated and the presence of second harmonic current due to the electric field demonstrated.*

The magnetic field of the heater in the space between the anode and the cathode will affect the electron current to the plate. The electrons

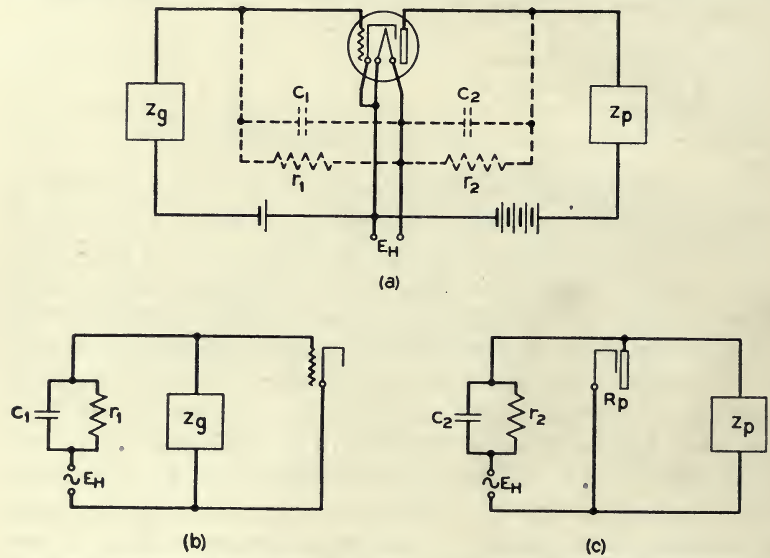

FIG. 3. Equivalent circuits of tube, used for analyzing disturbance currents: *a*, complete circuit; *b*, input circuit; *c*, output circuit.

will be deflected by the magnetic field according to force relations of the magnetic field. The deflection of electrons by this field causes a double frequency change in the electron space charge which results in a second harmonic component of the disturbance current in the anode circuit. Due to asymmetries in the space charge system, the two changes in space charge per cycle of the heater current are not equal. The inequality in the two changes will produce a disturbance current in the plate circuit of the same frequency as that of the heater current.

* To be described in a forthcoming paper by J. O. McNally on "Disturbance Currents in the Output Circuit of an Indirectly Heated Cathode Triode," *Proc. I. R. E.*

Heater circuit voltages are introduced into the grid circuit and into the plate circuit through resistance and capacitance between the heater and each of these elements. The circuit diagram shown in Fig. 3 indicates the paths. For simplicity, one side of the heater is shown connected to the cathode, and the resistance and capacitance from the heater to the other elements are connected to the opposite side of the heater.

Experimental tubes of special construction were made in order to evaluate the contribution to the disturbance current of the factors described above. The various means of decreasing the disturbance currents were considered, and experimental models were made in order to check the relative effectiveness of the different means. From these data the best tube, from a manufacturing view-point, that would give a sufficiently low level of disturbance current, was designed.

In order to decrease the electric field effect, the heater circuit was electrically shielded. The cathode itself acts as a shield over a portion of the heater circuit. In order to make the shielding more complete, the upper end of the cathode sheath was completely enclosed and the sheath was lengthened so as to extend well below the lower ends of the plate and grid. A drawn metal thimble was then placed around the heater leads below the end of the cathode, extending to the stem press.

In order to reduce the disturbance currents due to the magnetic field, the magnetic field of the heater in the space between the cathode and the anode must be made as small as possible. There are several ways in which this may be done. The heater circuit may be completely enclosed by a sheath of material that will act as a magnetic shield; the heater unit may be so designed that the field outside its surface is substantially zero; or the heater can be made of high resistance so that the heater current is small and its voltage drop is large.

It was found that the most practicable solution lay in combining the last two methods. The heater current was adjusted to 0.32 ampere and the voltage drop to 10 volts. The heater is a closely wound spiral of tungsten wire, mounted in the form of a hairpin in a twin bore magnesia insulator. The geometry of the hairpin is such that the magnetic field in the cathode-anode space is as small as can be realized in a commercial mounting; and the reduction of the heater current to 0.32 ampere, which is approximately one-fifth the value normally used, gives an adequate reduction of disturbance current from the magnetic effect. By reducing the heater current to this extent the potential drop across the heater is increased from four to five times the value normally used. This increase in voltage increases the electrostatic effect of the heater, increasing the 60 cycle disturbance current. However, it is possible in a commercial structure to shield the structure sufficiently so that even with the increased potential drop the contribution to the disturbance current by the electric field is adequately small.

In order to decrease the disturbance currents due to resistance leakage, the tube elements are held together at the two ends by means

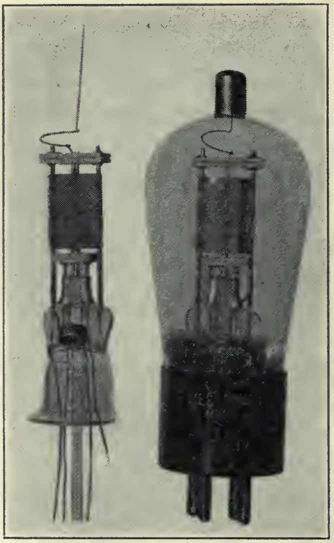

FIG. 4. Type 262A mounting and completed tube.

of a specially designed insulator. The insulator is so designed that there is not a continuous path between any two of the tube elements on the side of the insulator facing the tube elements. This makes impossible the formation of leakage paths of metal vaporized in the pumping process or of active material vaporized from the cathode. With the tube elements at operating temperature, the leakage between the tube elements, or between the heater and the tube elements, is maintained at a value greater than 100,000 megohms throughout the life of the tube.

For general services the normal values of capacity between heater

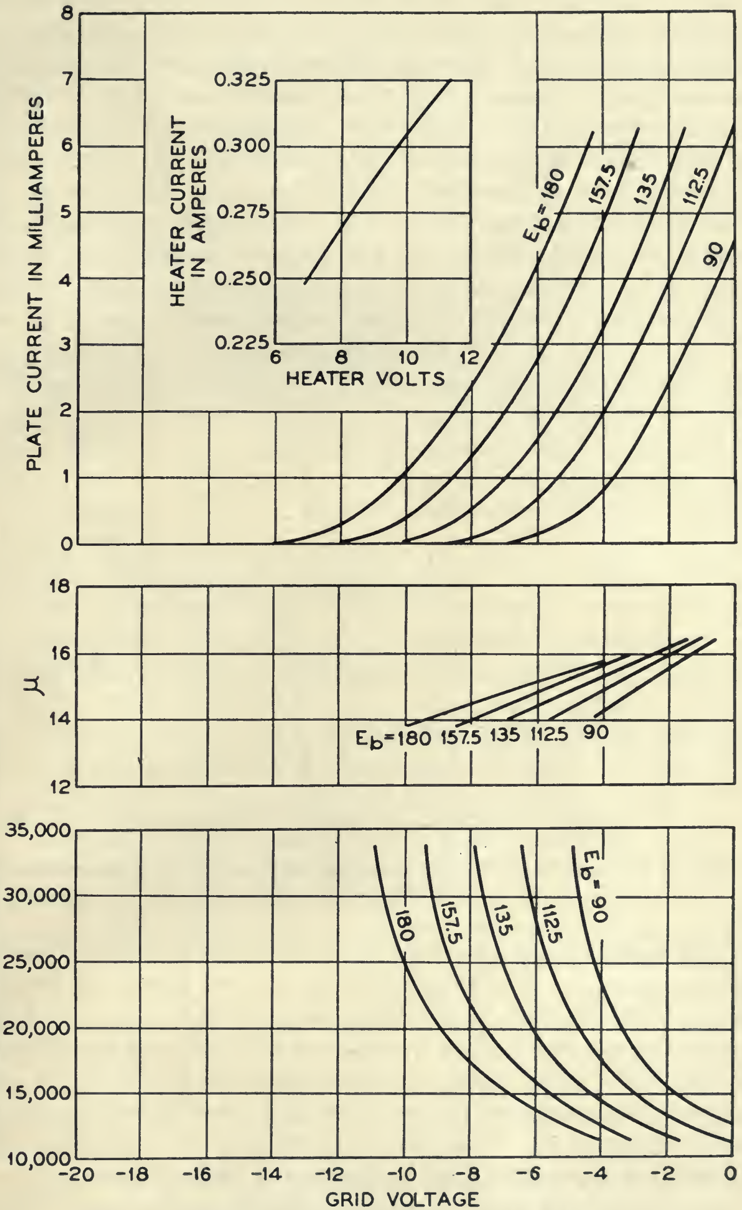

FIG. 5. Electrical characteristics of the 262A tube.

and grid and between heater and plate, that are obtained with standard mechanical designs, are of sufficiently low value that the disturbance currents introduced through them are not important. However, in such cases as when a tube works directly from the output of a photoelectric cell, it is desirable that the heater-grid capacitance be lower than that obtainable by standard design. In order to reduce this capacitance to a sufficiently low value, the grid lead for the tube has been brought out at the top of the tube through a cap of the type used in screen grid tubes. No grid supports are placed in the stem press of the tube and all the constructional details of the grid are in keeping with the minimum capacity requirements.

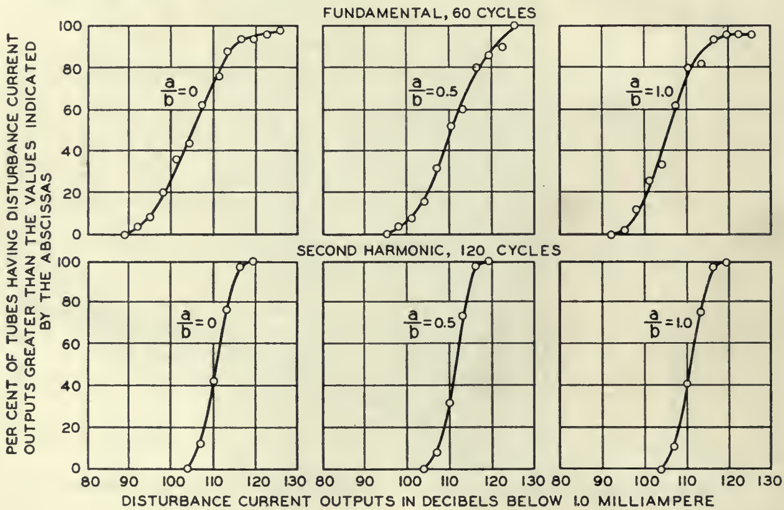

FIG. 6. Distribution of disturbance output currents in a representative number of 262A tubes.

This tube has been standardized by the Western Electric Company and coded 262A. The completed tube and its mount are shown in Fig. 4. Its electrical characteristics are given in Fig. 5. The tube is normally used with a plate potential of 135 volts and a grid bias of -4.5 volts. Under these conditions the plate current is 3.0 milliamperes, the output impedance 15,000 ohms, and the voltage amplification factor is 15. The tube is satisfactory for use with a plate potential of 180 volts and a plate current of 10.0 milliamperes.

Distribution curves of disturbance currents in the output circuits of typical tubes, taken under normal conditions of operation with an input resistance of less than 1000 ohms, are shown in Fig. 6. These data indicate that for $a/b = 0.5$, the level of fundamental disturbance current for all tubes is less than 95 decibels below 1.0 milliampere, and the level of the second harmonic disturbance current is less than 105 decibels below 1.0 milliampere.

The level of the output noise derived from sources other than the a-c. supply used for heating is of interest. The noise level in representative tubes was measured in a voice frequency amplifier that had a flat frequency characteristic. The heater was operated on direct current. With an input resistance of less than 100 ohms, the noise level of the output circuit varied between 118 and 127 decibels below 1.0 milliampere. This noise is principally due to the Schott effect from the cathode. With 2 megohms in the grid circuit the noise level in the output circuit is approximately 105 decibels below 1.0 milliampere. This noise is almost entirely due to the resistance noise of the grid circuit.

It is necessary to have the disturbance currents due to acoustic pick-up or mechanical shock sufficiently low that they will not place a limitation on the fields of application of the tube. The mechanical structure of the tube has been determined with these requirements in view. The tube has a sufficiently low response to acoustic or mechanical stimulus so that, when mounted in a suitably cushioned and shielded socket, the disturbance currents from acoustic and mechanical sources will not be of greater magnitude than the resistance noise and heater current disturbance noise.

2. AGITATION NOISE IN AMPLIFIER TUBES

When a vacuum tube in an amplifying circuit is subjected to mechanical agitation the resulting motion of the elements of the tube relative to each other gives rise to small transient changes in the electrical characteristics of the tube, which produce transient changes in its plate current. The plate current changes are usually of the form of complex damped oscillations, corresponding in their general character to the damped vibration of the tube elements. When these plate current changes are amplified and reproduced by a loud speaker they produce the unpleasant, usually discordant, ringing sound generally designated as microphonic noise.

There is another kind of disturbance whose existence has not been generally recognized, which also arises from mechanical agitation. It is often as much of a limiting factor in noiseless reproduction as is the microphonic noise. It manifests itself in the loud speaker as an irregular scratching or sputtering as contrasted with the more or less sustained ringing sound of the microphonic noise. This sputtering is caused less directly by the relative motion of the elements in the tube, in that it depends on the making and breaking of electrical contacts between metallic parts, which are not otherwise electrically connected, or by the discontinuous change in a relatively high resistance between tube elements.

One of the most common causes of the sputtering noise in the filamentary type of tube lies at the center point of a filament "V," which is ordinarily supported by a small hook attached to a spring imbedded in an insulating support. If this hook is in contact with the filament, its potential will, of course, be the same as the potential of the filament at the point of contact. If, however, it is not in electrical contact with the filament, it will assume some potential, depending upon its degree of insulation from the other elements which, in general, will not be the same as that of the contact point on the filament. If the contact between the filament and hook is alternately made and broken, as easily happens when the filament is suspended loosely on the hook and mechanical agitation occurs, the potential of the hook changes discontinuously; and, by a grid-like action, produces corresponding discontinuous changes in the plate current. These plate current changes when amplified, produce the disturbance designated as the sputtering noise. This type of noise is also due to the imperfect welding of the parts constituting the grid or plate structure. It has also been traced to discontinuous changes in the resistance of thin films of conducting material covering the insulating materials between tube elements.

The level of agitation noise currents in the initial stages of amplifying systems having over-all gains of the order of 100 decibels is sufficiently great to produce an objectionable level of background noise in recording and reproducing systems using such amplifiers.

As the first step toward decreasing these agitation noises, a measuring system was developed in which the microphonic and sputtering noise currents could be separated and quantitatively measured when the tube under test was subjected to a reproducible agitation stimulus.

Although the aural demonstration of microphonic and sputtering noises requires nothing more than a high-gain amplifier and loud speaker, the measurement of these quantities presents a number of difficulties. Instead of applying an arbitrary thump with the finger or pencil to the tube under test, it is necessary to provide a constant and reliable agitating agent. If the test is to form a part of a factory acceptance test, the agitation should be continuous, since ballistic readings are slow and unsatisfactory. The agitation and mounting of the tube should be such that a periodic excitation is applied; otherwise, mechanical resonances may occur between certain tubes in the testing apparatus. Such resonances give rise to misleading results, since a tube with a resonant point at a predominant frequency of excitation will respond much more strongly than other tubes, which on the whole may have very similar microphonic characteristics.

The chief problem in measuring the sputtering noise is not the agitation of the tube under test, although this is important, but rather the separation of the sputtering noise from the microphonic noise.

Sputtering is often more disagreeable to the ear than microphonic noise, and although the intensity of the noise may sometimes be much higher than the intensity of the microphonic noise, the total energy of the sputtering noise over an interval of time is usually considerably less than that of the microphonic noise for the same interval. This is due to the discontinuous character of the sputtering noise. Since microphonic noise is always present and varies in magnitude from tube to tube and from one operating condition to another, it is practically impossible to measure the sputtering noise by taking differences between measurements of total noise.

Advantage, therefore, has been taken of the fact that a discontinuous impulse may be resolved into a continuous spectrum of frequencies. The frequency spectrum of the sputtering noise extends even into the radio frequency band, and has given trouble in radio frequency amplifiers. The microphonic noise spectrum, on the other hand, lies largely in the audio frequency band, and no components of microphonic noise of measurable intensity have been observed above 15,000 cycles per second. If a high-pass filter which cuts off below 15,000 cycles is included in an amplifier having a flat frequency characteristic, the microphonic disturbance currents will be effectively suppressed, while the components of the sputtering noise above 15,000 cycles are transmitted with only slight attenuation. The sputtering noise currents of frequencies greater than 15,000 cycles may then be measured by ordinary means. If it be assumed that the distribution of energy over the entire spectrum is the same for all sputtering noises, then such measurements may be taken as an indication of sputtering noise intensities. While this assumption is certainly not exactly true, it has been found to be approximately so, and the measurements of the components of the sputtering noise at frequencies greater than 15,000 cycles has proved of much value in conducting investigations of tube noises.

On the basis of these considerations, a measuring system was developed which comprised four essential parts: a tube mounting and agitating system, a flat-frequency amplifier, a high-pass filter, and an indicator. These units are arranged as shown in the schematic diagram of Fig. 7.

The agitator consists of a thick slate base on which is rigidly mounted at one end an uncushioned tube socket, and at the other end

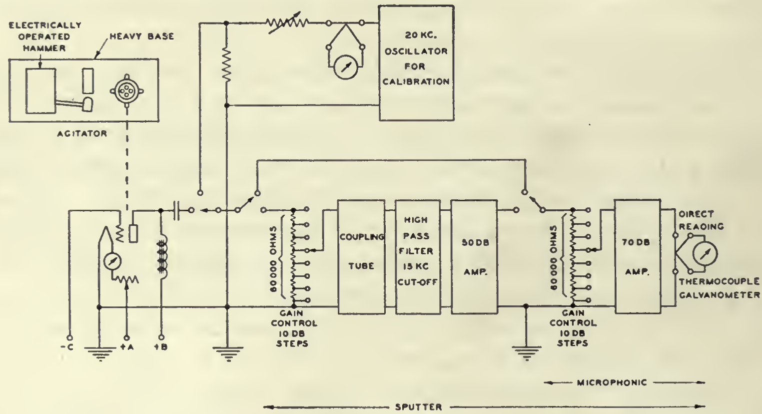

FIG. 7. Circuit for measuring agitation noise.

a vibrating hammer which directs horizontal blows against a steel block firmly mounted on the base near its center of gravity. The hammer consists of a good vibrating electric bell, the gong of which has been replaced by the steel block just mentioned and whose clapper has been weighted by the steel hammer. This hammer strikes eight times per second; and because of the rigidity of the base mounting, for all practical purposes, it causes shock excitation of the tube under test. The frequency of the blows is so low that there is little likelihood of encountering resonance in tubes under test.

The tube under test is mounted in the socket of the agitator, and is operated under its standard plate, grid, and filament voltages, with a resistance of 60,000 ohms in the plate circuit. By means of taps brought out from this resistance the input to a coupling tube is controlled. A high-pass filter with a cut-off at 15,000 cycles follows the coupling tube. The filter is followed by a two-stage, 50 decibel amplifier, a gain control unit, and, finally, a two-stage, 70 decibel amplifier. The output of this amplifier is measured by means of a suitable thermocouple galvanometer. The amplifying system has substantially a flat frequency characteristic over a range from 50 to 30,000 cycles. It is down 3 decibels at 30,000 cycles and 2 decibels at 100 cycles, and is calibrated by means of a 20,000 cycle oscillator.

When the total agitation noise of the tube is measured, the 50 decibel amplifier, the high-pass filter, and the coupling tube are not included in the circuit, the output of the tube under test working directly into the 70 decibel amplifier. For separately examining the discontinuous noise, which has been designated as sputtering noise, the 50 decibel amplifier, the high-pass filter, and the coupling tube are inserted. A measurement is then made of the components of the sputtering noise having frequencies greater than 15,000 cycles. The variable potential drop produced across a fixed resistance of 1000 ohms in the output circuit of the tube by the standard agitator is taken as a measure of the microphonic noise level of the tube. This potential drop is expressed in terms of decibels below 1.0 volt.

This measuring system has been of great value in studying the agitation noise levels during the development of sufficiently quiet tubes for high-gain amplifiers. It has also been of service in making comparisons of the cushioning action of different types of tube sockets and mountings. For this purpose the agitation noise characteristics of a group of tubes of a given type are determined with the rigid mounting described above. The noise characteristics of the same tubes are again determined with the tube mounted in the socket under examination, or, if cushioning material is under investigation, with the cushioning material inserted between the agitator slate base and the socket. A comparison of the two sets of readings gives a measure of the effectiveness of the cushioning material.

A set of this type has been found satisfactory for use in acceptance tests for agitation noise in vacuum tubes. The manufacturing department's sets are kept in calibration with respect to a master set in the laboratory by means of a group of reference tubes.

The detailed mechanical design of the low hum level tube, the 262A, described in Section 1, has been based on agitation noise level studies made in this system. Both its microphonic and sputtering noise levels are sufficiently low that with standard cushioning and shielding, the agitation noise currents in its plate circuit, when used as the first tube of a 100 decibel amplifier, will be no greater than that of the emission noise currents.

There are many applications in which a cathode that consumes less energy than that of the indirectly heated cathode of the 262A tube is desirable. A tube having such a filamentary cathode has been developed for those services demanding microphonic noise levels much lower than those of tubes previously standardized for such systems.

In Western Electric systems the 239A tube has been used in the past for preliminary stages of high-gain amplifiers. The new filamentary cathode tube, which has been coded 264A, has been made identical with the 239A in mechanical dimensions and in electrical characteristics, except for a slight change in the filament characteristics. With a plate potential of 100 volts and a grid potential of -8 volts, its average output impedance is 12,500 ohms. The average amplification factor is 7, and the average plate current is 2.0 milliamperes. The filament current is 0.30 ampere and the nominal filament potential drop is 1.5 volts.

The microphonic noise level of a 239A tube measured in the equipment described above has an average level of 28 decibels below 1.0 volt. The corresponding value for the 264A tube is 45 decibels below 1.0 volt, while it is 50 decibels below 1.0 volt for the 262A tube. It is again pointed out that these measurements were made in uncushioned sockets, and with direct transmission of mechanical disturbance from a relatively high level source. Significance should, therefore, be attached only to the relative values of noise levels and not to absolute values. The sputtering noise level of the 239A tube under the same conditions of measurement has an average value of 80 decibels below 1.0 volt, while the 264A tube has an average value of 95 decibels below 1.0 volt, the corresponding value of the emission noises of both tubes being approximately 95 decibels below 1.0 volt.

The improvements in microphonic noise level have followed an analysis of the resonances occurring among the various elements of the tube structure, and have been made by designing structures that avoid such resonances. It was found that a rigid structure built as close to the stem press as possible exhibited very little tendency to resonate. A structure in which the three elements were bound together as rigidly as possible and mounted as close to the glass stem as practicable was, therefore, adopted. For reasons of interchangeability, it was necessary to limit the size of the parts to dimensions suitable to the over-all dimensions of the 239A tube, which it was replacing, and also to permit the use of the small push type base.

With these limitations it was possible to obtain a more rigid and lower mounted structure by using a special means of constructing the glass stem press. Due to the dimensional limitations, it would not have been possible to use glass tubing for the stem press of greater average inside diameter than 0.53 inch. With such tubing, and with standard methods of stem construction, the maximum distance between the two plate supports would be approximately 0.53 inch. With new means of stem construction it was possible to use the same size of tubing and to make a stem press in which the distance between the plate supports was 0.64 inch. In order to obtain this plate support spacing with standard methods of stem construction, it would have been necessary to have used a stem tubing whose mean inside diameter was 0.66 inch. It would not have been possible to have sealed a stem made from such tubing into a bulb that could have been used with the small push type base.

Fig. 8 shows, in solid lines, an outline of the stem press for the tube using the 0.53 inch tubing and, in dotted lines, the stem press that could be made with this size of tubing with standard stem construction practice.

It is evident that the base of the mounting has been increased from 0.53 to 0.64 inch, adding considerably to the rigidity of the structure and making possible the use of straight plate support wires. By using the straight plate support wires, the assembly can be mounted closer to the stem press with greater facility than when the plate support wires are bent outward. The increased distance between the plate supports makes possible a greater separation between the leads and permits the insertion of adequate shields above the stem press to maintain insulation paths free from thin films of vaporized material. The thin films of vaporized material on the glass produce variable resistances which contribute to the sputtering noise as described above.

The filament and its mounting contribute materially to the agitation noise. If the filament is placed under considerable tension so that the contact between the filament hook and the filament is maintained at all times, the production of sputtering noise at this point is eliminated. However, the degree of tension to which the filament is subjected materially affects the level of the microphonic noise deriving from the filament unit. In general, the higher the tension, the greater the microphonic noise level. It is, therefore, necessary to balance the two requirements. With zero tension a considerable number of the tubes will give evidence of sputtering noise originating at the filament hook, whereas a minimum of microphonic noise will result from the filament unit. As the tension is applied and is gradually increased, the microphonic noise deriving from the filament unit will also increase. A spring and hook unit has, therefore, been adopted which will place the filament under a

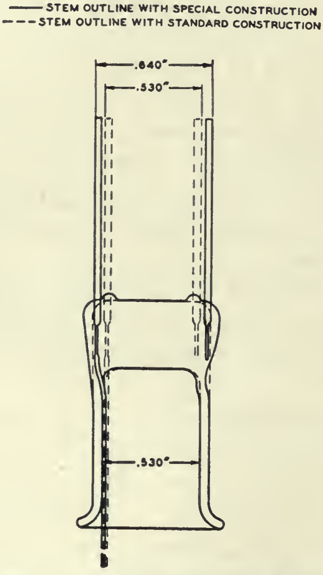

FIG. 8. Vacuum tube stem of 264A tube.

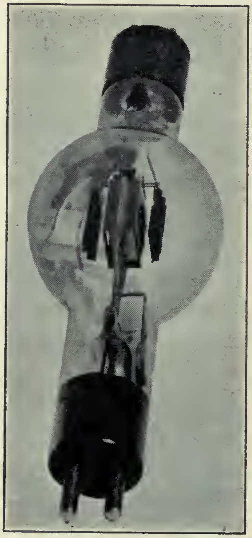

FIG. 9. Rectifier tube, type 263A.

tension of a few tenths of a gram, and will have adequate displacement to keep the hook and filament in contact. In this way both the microphonic and sputtering noise of the filament unit are kept at the lowest practicable level.

All welds in the structure which are a part of the electrical circuit are made with special care to assure the elimination of variable resistances. As described above, the stem press is shielded against the deposition of material from the filament or from the metallic parts during pumping. This shield prevents throughout life the formation on the stem press of thin film resistances that are variable and produce the sputtering noise. The glass insulator tying the parts together at the top of the structure is located at the back of the plate so that no material from the filament can be deposited across insulating paths during the life of the tube.

3. A DOUBLE ANODE THERMIONIC GAS-FILLED RECTIFYING TUBE

By operating the vacuum tubes of sound reproducing amplifiers on alternating current, only a portion of the storage battery equipment that is necessary in the projection of sound films is eliminated. The sound lamp is heated by direct current, and because of its high current rating requires considerable storage battery capacity.

A rectifier tube, which has been coded "Western Electric 263A," has been developed to supply the direct current for the sound lamp and thus completely to eliminate the storage batteries from reproducing equipment. It is shown in Fig. 9. The rectifier tube has two anodes and a filamentary cathode of the oxide-coated type. The filamentary cathode is mounted between the two anodes, with its housing so arranged that the necessary peak potential can be obtained between anodes without voltage breakdown. The tube is filled with argon at a sufficiently high pressure to give the minimum anode-cathode potential drop during the conducting half of the cycle. The characteristics of the rectifier tube are as follows:

Filament potential	2.50	volts
Filament current	16	amperes
Anode-cathode potential	5 to 10	volts
Maximum value of peak space current	6	amperes
Maximum peak potential between anodes	100	volts

With a suitable filter system this tube will supply a direct current of 4.0 amperes. The available d-c. potential will, of course, depend upon the voltage drop in the filter system. With a filter system designed to give direct current with a ripple small enough to permit the output to be used for heating the filaments of vacuum tubes, a voltage of 15 to 20 volts should be available when the peak voltage between the anodes does not exceed 100 volts.

4. A PHOTOELECTRIC CELL OF HIGH SENSITIVITY

The photoelectric cells initially used in sound picture reproducing systems were filled with gas and were of the potassium hydride cathode type. They were operated with an anode potential of 90 volts. The average cathode sensitivity of the potassium hydride surface was 1.0 microampere per lumen for a light source having a color temperature of 2710°K. The gas was maintained at such a pressure that a gas amplification of approximately 4 was obtained at 90 volts, giving an output current of 4 microamperes per lumen for the light source described above.

It was recognized from the beginning that a photoelectric cell of higher sensitivity would be of material assistance in reducing background noise. Any increase in the level of the photoelectric cell output would proportionately decrease the necessary amplification by vacuum tubes and thus increase the ratio of the signal to the noise deriving from the amplifier tubes in the output.

FIG. 10. Photoelectric cell, type 3A.

The potassium hydride photoelectric cell, in addition to having a lower sensitivity than was desirable, had other inherent properties that were not ideal for a commercial device. A potassium hydride surface, even when made under the most favorable conditions, exhibits on standing a gradual decay in surface activity. This decay is due to the covering of the hydride surface by a film of potassium. This coverage is accelerated by an increase in temperature. In commercial parlance, this type of cell has a shelf life which is a function of the temperature.

Searches were instituted for cathode surfaces of greater sensitivity and, if possible, free from shelf life characteristics. The work of Langmuir and Kingdon and of Becker on the effect of oxygen films in lowering the thermionic work function of thin films of caesium on tungsten gave a valuable indication of the most fruitful direction of investigation. The use of oxygen as well as of sulfur in connection with thin films of sodium and caesium was found to be effective in lowering the electronic work function of cathode surfaces.

Manufacturing considerations, such as the cost and the control of quality, led to the standardization of a thin film surface of the caesium type rather than of other surfaces of substantially the same sensitivity. The cathode of the cell so standardized is a silver sheet upon which there is formed during exhaustion, by irreversible chemical processes, a matrix of caesium oxide, silver oxide, and finely divided silver. Upon this matrix there is placed by reversible processes a thin film (of atomic thickness) of caesium.

This cathode surface has a long-wave limit beyond 12,000 Å and a maximum of sensitivity at about 8000 Å. This spectral sensitivity makes the surface unusually suitable for use with light from a tungsten filament. With a light source having a color temperature of 2710°K., the stabilized sensitivity of this surface is approximately 35 microamperes per lumen. The surface exhibits no shelf life characteristics, even at temperatures of the order of 65°C., which is well above normal storing and operating temperatures.

The cell employing this cathode was filled with argon at a pressure suitable for operation at 90 volts' plate potential with the light flux normally employed. At this pressure the gas amplification factor at 90 volts is approximately 3.

Late in 1929, this cell was placed in service trials in equipment previously using the potassium hydride cell. The trials indicated a considerable improvement over the hydride cell in all operating characteristics. It was coded 3A in the Western Electric series, and has been made available as a replacement of the hydride cells in existing equipment. It is shown in Fig. 10. While its substitution for the hydride cell in existing equipment is fully justified by the improved service and the lowering of operating costs, the full advantage of its improved characteristics is realized only in equipment designed to take full advantage of them.

PROCESS PHOTOGRAPHY*

GORDON A. CHAMBERS**

Summary.—*The several methods used in process photography are briefly described, in the beginning, from the historical point of view. The various methods of applying these processes, and the technics involved in applying them, are discussed.*

Marked advances have been made in recent years in the technic of process photography, particularly in the field of application of the so-called traveling matte. Many of these advances have come about as a result of the limitations placed upon the cinematographer by the addition of sound recording to his medium. It is the purpose of this paper to bring to the attention of those who are unfamiliar with process work a general survey of the methods in use, rather than to attempt to give an intimate description of those methods in the form of a text.

Process photography has as its objective two kinds of effects, those that are recognized by the audience as a deception or illusion, and those which, unrecognized as "trick" shots, are inserted in a picture to lend production value. These latter effects are obtained by means of process methods because mechanical or economic reasons make it impossible or impractical to secure them by ordinary photography.

While the results obtained by high-speed and trick crank photography fall properly in the field of special effects, it is intended to limit this discussion only to those forms of process work that employ mattes. Two forms of the latter are used, known as still and traveling mattes.

The earliest and certainly the simplest of still mattes is the so-called "split" matte, used immediately in front of the focal plane in the camera to facilitate the making of multiple exposures. Peters[1] mentions a ninety-foot production available in 1902 entitled *The Inexhaustible Cab* in which "...thirty-two persons enter the carriage built to hold but four, but none are seen to get out." This kind of effect was extensively employed in the earlier days of photography,

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* Presented before the Pacific Coast Section, S. M. P. E.

** West Coast Division, Eastman Kodak Co., Hollywood, Calif.

especially to obtain ludicrous or comical effects such as that mentioned above.

At the present time the form of still matte commonly referred to as a "glass" is very often employed. This form of photography is mentioned by C. L. Gregory[2] and by A. B. Hitchins[3] who illustrate the method of use. This process is very versatile in its ability to introduce into the picture detail that did not exist in the actual set just so long as the action on the set does not overlap that portion of the frame to be exposed to the "glass." While glass is often used as the medium on which the painting is made, many of the paintings so introduced into a motion picture are made on an opaque support. This is usually done when the film is subsequently doubly exposed to the painting on that portion of the frame that was suitably masked in the camera. The latter method is finding more general use than is the method of painting on glass and shooting through this glass on the set. The painting can be prepared after the set action is photographed without tying up the space or set for the length of time necessary to prepare a painting on glass. One expert worker in this field has found that the use of chalk in various shades from black to white makes it easier to prepare the background, as the final matching of tones at the point where the two exposures join on the frame is more easily accomplished with chalk than with oil colors. Also, the quality of the image obtained is different from that obtained from a brushed-on oil paint, and it is felt by this particular worker that the resulting composite is more uniform in quality.

While a glass is in every sense a miniature, even though confined to two dimensions, three-dimensional miniatures in the form of models are often employed to great advantage. With these also, it is possible to employ either single or multiple exposure to obtain the composite negative. For some effects it is desirable to employ both "glasses" and models. Some very realistic effects have been obtained by using model airplanes and dirigibles moving before the camera with one or more glasses interposed, on which the clouds are painted. The resulting shot of a dirigible moving through beautiful cloud banks would be difficult to obtain by natural means without expending a great deal of time and money.

In using miniatures or models, it is extremely important that not only the perspective of space be maintained but also what might be termed the "perspective of time." Attention has been called to the importance of this by several writers. Both J. A. Ball[4] and G. F.

Hutchins[5] have discussed this subject from the theoretical standpoint, and have stressed the relation that must exist between time and linear magnification for a perfect illusion. Several interesting applications of the use of models for creating special effects have been described by F. Waller.[6]

With increased development in the application of process photography has come the creation in the various studios of a "special effects department," which devotes its time entirely to the creation of these illusions.

One of the most useful tools of the specialists who comprise these departments is the optical printer. Such an instrument has been described by C. L. Gregory.[7] Essentially, it consists of a camera so mounted as to be able to copy one or more negatives moving in synchronism with the raw stock in the copying camera. One of the well-known results to be obtained with the optical printer is the kaleidoscopic effect used to convey to the audience a train of thought in a character's mind. Such an example is cited in the paper by Waller, mentioned above. The optical printer is also used extensively for the routine production of duplicate negatives from master positives, because of the fact that the duplicate image is an optical one rather than one secured from a contact printer. Greater sharpness is thus obtained. The motor-driven cameras of today can not be used easily for making fades and lap dissolves, and it is common practice to produce these on an optical printer. Mere fades are often made chemically, however, because of the ease and rapidity of this process.

Various applications have been found for prisms and other reflecting surfaces in the production of effects. These may be used on the camera itself, or subsequently in making a dupe in the optical printer. Sequences showing a ballet have been made to appear as though the dance were performed on a glass floor, whereas the reflected image was obtained by using a prism or sheet of optical glass in front of the taking lens. In the optical printer, several images from as many different negatives may be superimposed in a single composite by optical means, involving prisms for reflecting the respective images into the same plane.

It must not be imagined that these processes are used only singly, as often two or more are used to obtain the desired effect. The major problems encountered in this work are those of obtaining accuracy of registration of the images, and equal accuracy of timing of the action of multiple exposures, so that the events take place in their proper sequence without overlapping. Fig. 1 in the paper by Waller[6] is a chart illustrating the intricate attention to detail requisite to the proper timing of the events in such a sequence of multiple exposures.

The developing of traveling matte processes into their present state of perfection has opened a large field for the producer. In the generic term "traveling matte" is included that form of image-carrying film used before an unexposed negative in the camera. This image is usually of a dye that has replaced a silver image. This film has been called a "transparency" and is also sometimes referred to as a "key." It might be mentioned at this time that a complete picture, *The Subway Express*, made by Columbia was produced entirely by such a transparency process. Two traveling matte processes are available at the present time. One of these, known as the Williams Process, has been described by its inventor, F. Williams.[8] In this process, the action is photographed against a black background. From the negative of this, a duplicate negative is made which is intensified in order to produce a silhouette of the action. This silhoutte is then used as a traveling matte in a projection printer during the printing of the background negative, as it covers and leaves unexposed the space that is later to be used by the foreground action, which is doubly printed from the original negative with a print from this negative as a matte. Several variations of this process are possible; either black or white backgrounds, or colored ones in connection with filters, may be used to obtain contrast. Inasmuch as it has been found that a spreading of the image occurs on the silhouette because of the full exposure and the subsequent intensification, and further, because of the increase in graininess incidental to the multiplicity of duplicating processes employed, Mr. Williams has been engaged in a method of simplifying his process to overcome these difficulties. No information is publicly available at the present time as to the solution of these in the new process.

Another traveling matte process that has enjoyed a great deal of favor is the one commonly known as the Dunning Process. This process is the result of work by C. Dunning and R. Pomeroy. The original Dunning Process has been described previously.[9] The procedure has been modified somewhat so that at the present time the methods used by the Dunning Process Company and the special effects department of the Paramount Publix organization are essentially identical.

From the background negative is made a positive transparency from which the silver is bleached, a yellow-orange dye being substituted for the silver. This transparency is run through the camera together with the panchromatic film on which the foreground action is being photographed against a blue backdrop. The foreground action is illuminated by tungsten lamps screened by filters having a spectral transmission comparable with that of the dye in the transparency. The blue backdrop is illuminated by white light. This drop is painted with a special blue complementary to the yellow-orange dye.

Suppose for the moment that no foreground is present. The running of the transparency through the camera in contact with the emulsion of the panchromatic film would result in an exposure due solely to the blue light reflected by the backdrop. This exposure would be so regulated that the selective transmission of the dye in its various depths would result in exposing on the panchromatic film a duplicate negative of the transparency.

Suppose now that the entire field of view of the camera is occupied by action. This portion would be photographed through the transparency as though the latter did not exist by virtue of the color of the light in the foreground. The composite obtained is a combination of the two exposures, the background being a duplicate negative and the foreground an original exposed directly through the transparency.

Just as great care is taken in making shots involving the use of still mattes in order to have the shadows match, as these indicate the direction of lighting, so care is taken to simulate the lighting of the original background in the lighting of the foreground during the making of a transparency shot. The timing, where the background is moving, such as in the case of a traveling shot showing a car moving along a road, is another item that requires great care. The perspectives of the background and foreground must be the same, and the depth of focus of lenses ordinarily used must be used when making the background in order that the composite will have the appearance of reality. The results that are possible with traveling matte processes are so diverse and amazing, and at the same time invisible to the audience, that the extreme care necessary is well worth the trouble.

There has been a recent revival in several of the special effects departments of one process of making shots of the traveling matte type which was employed nearly ten years ago. The advent of higher speed negative emulsions has made the process practicable. The process referred to is the one in which the foreground action is performed in front of a translucent screen on which the background is projected by a standard projector. It is possible by this method to obtain effects similar to those obtained by using a traveling matte, that is, the superposition of action on a moving background.

At the present time a great deal of study is being given to the desired nature of the screen, the type of projection print to be used as far as general density and contrast are concerned, and other problems that have arisen in the course of trial of the process.

The variety of effects possible, and the ability of the workers in this field to realize the possibilities of the various processes, have contributed to making process photography a very useful and economical branch of the motion picture industry.

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A SHRINKAGE-COMPENSATING SOUND PRINTER*

R. V. WOOD**

Summary.—*The shrinkage-compensating sound printer described is designed on the principle of bending the shrunken negative film so that its emulsion surface will temporarily regain the exact length that matches the positive. A means of achieving this automatically is described and the advantages are noted.*

When designing machines for printing sound on film the first point to consider is the shrinkage of the negative. In general, some arbitrary value of shrinkage is chosen, say, one-third of one per cent, the machine being designed on this basis, so that for a negative of this shrinkage no creeping between negative and positive will occur. For a negative of a different shrinkage, creeping will occur, and the attempt is made to make the creeping uniform. The possibility of creeping necessitates a design that will make the creeping as uniform as possible. This is generally attempted by exercising extreme care in the workmanship, by using a very accurately cut sprocket, and by extending the printing area over a length sufficient to blur out creeping noises. The extension of the printing area, combined with the creeping, results in a loss of sound at the higher frequencies. The higher frequencies also suffer a loss due to the difficulty of establishing contact between the films over an extended area.

In the printer described here, the problem of design is approached from a different view-point. No arbitrary figure is chosen for the shrinkage, but the negative is stretched until it is of the same length as the positive, thereby entirely eliminating creeping. The negative is stretched until it exactly fits the positive; more accurately, the emulsion surface of the negative is stretched by bending the film until its emulsion surface exactly fits the emulsion surface of the positive. In previous designs the matching of the emulsion surfaces was only approximate; and it has been found that an approximate match does not eliminate the creeping.

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* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Rochester, New York.

In Fig. 1, S is a sprocket that feeds and takes up the negative and positive films (negative inside, positive outside, emulsions facing each other). R is a freely rotating drum of large diameter D driven by contact with the positive film through tension at T and T_1.

R_1 is a freely rotating roller of small diameter held by its own weight and the weight of its mounting against the roller R. R_1 is rotated by contact with the negative film, which is moved by contact with the positive film.

The negative approaches the point of contact C through an arc of diameter D_1, which is determined approximately in threading the

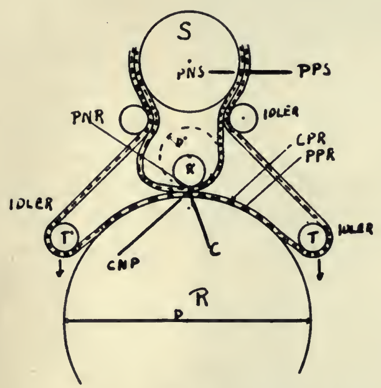

FIG. 1. A sprocket for feeding and taking up the negative and positive films (negative inside, positive outside, emulsions facing each other).

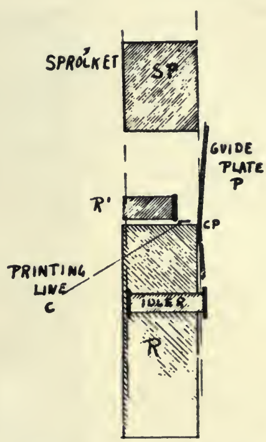

FIG. 2. Polished plate made of Allegheny metal, against which the edges of the films are brought, in order to keep them in line.

machine, and accurately by the movement of the films when the machine is in motion.

It will be seen from the following analysis that D_1 is adjusted automatically to its exact value for any condition of shrinkage as the machine runs.

In feet per minute:

Speed of PPS for unshrunken positive = 90

Speed of PPR = 90 (assuming the pitch line is the middle of the film, which moves at the speed of the film)

Speed of $CPR = 90\,\dfrac{D + \text{thickness of film}}{D} = 90.108$ (taking D as 4.5 inches and the film as 0.0055)

Speed of CNP = 90.108

$$\text{Speed of } PNR = 90.108 \times \frac{D_1}{D_1 + .0055}$$
Speed of PNS = $90 - 90s$ (where s is the per cent of shrinkage)

Now if the

Speed of PNR = speed of PNS

then

$$90.108 \frac{D_1}{D_1 + .0055} = 90 - 90s$$

In other words, there is one value of D_1 for any shrinkage.

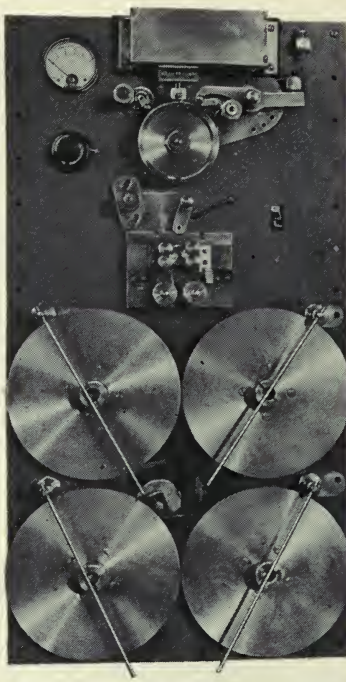

FIG. 3. View of complete printer.

Now if D_1 is larger than this value, then the speed of PNR is greater than the speed of PNS, and the loop PNR to PNS will shorten until the correct value of D_1 is reached. Now if D_1 is smaller than the correct value, then the speed of PNR is less than the speed of PNS, and the loop PNR to PNS will increase until the correct value of D_1 is reached.

So, at the point or line C, both emulsions move at the same speed and there is no tendency to creep. C is the printing point, an area of approximately 10 by 100 mils.

The films are kept in line laterally by bringing their edges against the polished Allegheny metal plate P (refer to Fig. 2). This plate is raised slightly at the point CP.

CP is slightly out of line with SP, causing the negative film to guide against it. This also assures a downward pressure at the printing line. The roller R_1 is slightly out of perpendicular with the plate P, which forces the film to guide against the plate.

The positive film is brought against the roller R at a point slightly back of the plate P so that it guides against the plate P which lines it with the negative and also causes a tendency to buckle up slightly at the printing line, insuring perfect contact.

The advantages to be expected from this design are: (*a*) Better definition; this is particularly important in printing 16 mm. film. (*b*) A considerable saving in printer cost. (*c*) All degrees of shrinkage within the intention of the design are printed with equally good definition. (*d*) Narrow width negative may be printed on larger stock; this is because at the printing point the films are driven and guided entirely by their surfaces and one edge, without regard to the other edge or the perforations.

DISCUSSION

MR. JENKINS: Do you know the difference in shrinkage of the positives and negatives before you adjust the tension?

MR. WOOD: The tension adjusts itself as the machine runs; the loop takes its own natural course and adjusts itself.

MR. KELLOGG: The film is rather slippery, and yet the adhesion between the two films that are being pressed together must be depended upon to determine the motion of one of the films—the negative, in this case. In view of the slight tendency of the film to bend more at one point than at another, has not some difficulty been experienced in this respect?

Also, how much does the length of the loop have to change in order to compensate for a given difference in thickness? It would seem, from the general layout, that it would be necessary to produce quite a change in the amount of film in the loop in order to give the necessary change in curvature. That might be somewhat of a problem in maintaining synchronism.

MR. WOOD: Regarding the amount of friction between the two films, if a screw-driver is inserted in an attempt to displace the loop one way or the other while it is running, it seems to resist, unbelievably, any pressure.

As regards the lack of synchronism, it is true that there is a variation of two sprocket holes, at most. The sound track goes either one way or the other. But as a variation in synchronism of the sound can not be detected within, say, two frames, that point is not important.

COMMITTEE REPORTS

COLOR COMMITTEE REPORT*

The producing organizations working on color motion picture processes in the United States may be grouped conveniently into two classes, according as their process is of the additive or subtractive type. In the additive method, the image to be projected is an original black and white image, the color being obtained by interposing the proper color filters in the light beam during projection. Kodacolor (16 mm.) and its "parent," the Kellor-Dorian method, are representative additive processes.

In the subtractive method, which has enjoyed considerable favor for several years, the original positive silver images are converted wholly or in part to colored images composed of inorganic salts or dyes, so that the final picture may be projected under normal conditions on a standard projector. Typical examples of the subtractive process are: Technicolor, Multicolor, Sennettcolor, Colorcraft, Photocolor, Brewster Color, and Kodachrome.

It is not certain that any of the systems mentioned meet the desires of the producers. Lower print costs are the immediate requirement. Ability to make prompt deliveries is the second important requirement. Producers also resent the presence of strange cameramen on the lots, and the wait for "rushes." Nothing will satisfy the producer other than to make his own picture in his own way, on his own lot, with his own men and equipment. This applies to the Class A producers, while the independent will always welcome the independent color print maker.

The question as to how much the theaters will stand for in making changes of or addition to projectors in order to accommodate the "additive processes" is a pertinent question for the Committee to investigate. The trend in color picture projection appears to be toward additive systems,** which require some changes in the projectors. Additive color prints are usually in black and white, making

* Presented at the Fall, 1931, Meeting at Swampscott, Mass.

** Some members of the Committee do not agree with this statement.

the rental cost of prints nearly equal to what exhibitors are accustomed to pay.

It is not believed, however, that color pictures will ever be produced and released at the same cost as a similar subject in black and white. That this is so follows from the fact that by whatever color process pictures are produced on the screen, there must be present, in the observer's mind, pictures that are made up of two or three separate components, *each photographed individually by light of different colors and each group of two or three representing only a single frame in black and white.* Such a multiplication of images must be more expensive at some part of the process, whether it be in studio technic, negative or positive materials, in projection, or in all four.

The definite trend toward the additive processes seems to be a step in the right direction, since it appears to be directed toward the type of process that will give the best *color*, and so be the most likely to make colored pictures a necessity to the theater manager. It brings with it, however, the problem of somehow increasing the amount of light available for projection, since all pictures using the additive process in projection must *of necessity* use as many times more light as there are picture units and as much more as is required by the fact that the colors employed do not transmit 100 per cent of the light of the wavelengths used. That this brings up a rather serious problem for large theaters goes without saying. If it can be solved, however, the way appears to lie open for better color than has ever before been shown in production, and at a relatively low cost.

It might be added that there has been an equally definite trend toward the belief that the public will be won only by a process using three fundamental colors, rather than the two now available by commercial methods. The Kodacolor film has already been commercially released by Eastman Kodak as 16 mm. and it is understood that it is being constantly improved. Technicolor, Brewster Color, and others are also examples of concerns working to this end. The last two concerns are reported to be working on subtractive methods. Any three-color subtractive methods as yet available have appeared to be rather costly as regards sensitive materials and equipment necessary. If these items could be cut down, it is quite possible that a subtractive method having nearly, if not equally, as good color as any additive one, would be the most satisfactory, since no changes of importance in the projectors would be necessary.

In any case, those who have been fortunate enough, in the privacy of their laboratories, to see how beautiful the most ordinary sets can be made by the use of color photography will never give up the belief that, in the not too distant future, a process will be developed that will make the movies so attractive that, if people will not pay more, at least more people will pay as much to be entertained by them.

NEW COLOR PROCESSES

Vocolor.—This process uses color wheel projection which draws down one picture at a time, but which by optical means shows two pictures superimposed on the projection screen. Black-and-white films may be shown on the same projector without affecting the sound, as the speed of the film through the projector is standard.

The negatives are made in the usual Kinemacolor manner, one exposure at a time, and fringing is noticed.

Colorfilm.—This method uses double-coated film for the positives. The film is first printed and developed in the usual way. Both sides are toned red with uranium. All treatments so far are done by immersion. The side that is to be blue-green is then passed over wicks that feed a solution of iron and acid to one side of the film, converting the red tone to blue (U. S. Patent No. 1,633,652).

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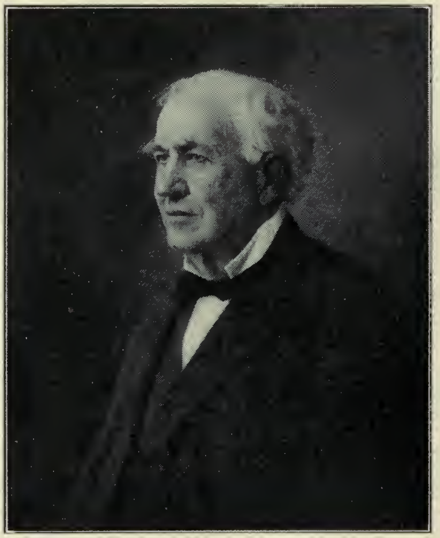
THOMAS A. EDISON

Thomas Alva Edison was the first motion picture engineer. Before him there were many who thought of motion pictures and who made endeavors toward producing them. After him came many who labored on improvements and elaborations of the motion picture. None have had for the motion picture, or have brought to it, a broader concept than did Mr. Edison.



Thomas A. Edison

He viewed the problem of the motion picture as the making of a machine, a machine tool in the service of the art of expression. He was personally interested in it chiefly as a maker of a mechanism, which he delivered to the world to do with as it might.

The motion picture was a set of dawdling experiments and a haze of day-dreams when Edison assigned himself the problem of bringing it into a practical working existence, sometime in the year 1887. The motion picture is in a very real sense the offspring of the Edison phonograph. It was in 1887, in a bit of a lull in the laboratory work, and in a day, too, when the commercial affairs of the phonograph were annoying, that Edison took a bit of playtime to spend casually on a machine "that should do for the eye what the phonograph did for the ear."

Edison set a staff to work on his preliminary drawings, locked up in the secrecy of room five at the West Orange (N. J.) works. His first picture machine was a spiral record of microscopic pictures photographed on a cylinder like a phonograph, actuated with an intermittent motion and viewed under a microscope. He had filled a room with sound from a needle in a tiny groove and he was out to fill it with pictures in a somewhat similar manner. In time, he decided upon a machine that would feed pictures the size of postage stamps upon a flexible tape moving past a lens, for viewing them either directly by magnification, or by projection. By the mid-summer of 1889, he had achieved such a machine, but had no satisfactory tape. He demonstrated the machine with strips of collodion varnish that went to bits and failed immediately. In the autumn he heard of the coming of George Eastman's flexible medium for roller photography in the Kodak. He sent to Rochester for a sample and put a trial strip fifty feet long through his machine. It worked, and the motion picture was an accomplished fact.

Interestingly enough, Edison's concept was a talking picture, and in 1889–90 he built a talking picture machine, a twin phonograph peep-show device.

It was not until late in 1892 that a promoter chanced upon the motion picture machine in a corner of the West Orange plant and prevailed upon Edison to let him put it on the market. The machine in its peep-show form went out into the world, and all over the world, beginning April, 1894. That was the Edison Kinetoscope. It presented film of the same dimensions, using the same sprocket holes and other physical characteristics as the motion picture film of today. The very size, which remains the same today, despite many experiments then and since aimed at greater areas, was determined by the covering power of the objective of a microscope that happened to be about the plant in 1887 when the experimentation began.

For a complexity of commercial reasons which we, as engineers, are not concerned about here, Edison wanted to keep the motion picture in the peep-show for a while. But all over the world showmen were demanding a machine that would show pictures to a whole room full of paying patrons at one time, and so a score of inventors took the Kinetoscope and set about the task of wedding it to the magic lantern. Most of the technical tangles and patent wars of the industry since have resulted from these parallel efforts. The history of the motion picture industry in every nation in the world, and of every motion picture corporation now in existence, can be traced to an Edison Kinetoscope, be it in London, Paris, Berlin, Stockholm, or Shanghai.

It is of incidental interest in this day of the talking picture to recall that it also was Edison's exploration of the properties of the double-filament incandescent lamp that led to the radio valve of today with all its sound-picture functions and applications. It is coincidental that William Kennedy Laurie Dickson, the same laboratory assistant who worked on the motion picture job for Edison in room five, was also the assistant who made the galvanometer tests of the "Edison effect" in the twin filament lamps. They had sound and the radio there, too, filed away in the notes of an unexplored region. One lifetime was not enough in which to cover all that vast world of technology that came within the range of Edison's vision.

Mr. Edison's records and correspondence of the day reflect a recognition that the motion picture should present the sound, the color, and the perspective of reality; and that it was destined to serve as a major successor of all the prior arts of expression, in entertainment, in advertising, in education, and as an instrument of record. He made it a tool, and left it largely to others to use and apply it.

Edison was concerned with what he deemed the great important work of the world and the mechanisms with which to do it. He was a maker of machines that worked. He brought processes and methods across the dim borderland from the dreamers and the experimental laboratories into the factories of modern, working fact.

TERRY RAMSAYE

SOCIETY ANNOUNCEMENTS

SPRING, 1932, CONVENTION

The program of the Washington Convention followed substantially the Tentative Program mailed to the membership a month or so ago, with some alterations in the order of presentation of the papers. The attendance was unexpectedly large, particularly in view of existing conditions, and the interest shown in the proceedings was indeed very gratifying. Great credit is to be given Mr. W. C. Kunzmann, Chairman of the Convention Arrangements Committee; Mr. O. M. Glunt, Chairman of the Papers Committee; Mr. N. D. Golden, Chairman of the Local (Washington) Arrangements Committee; Mr. H. Griffin, Chairman in Charge of Projection, assisted by Mr. J. Frank, Jr.; Mr. J. I. Crabtree, who arranged the motion picture exhibitions; Mr. W. Whitmore, Chairman of the Publicity Committee; and all those who assisted in arranging the details of the Convention.

Interesting features of the Convention were the sessions devoted to sixteen millimeter sound-on-film and to the problems of the release print.

The proceedings of the Convention were divided into the following sessions: General Session; Committee Reports and Society Business; Photographic Session; Symposium at the new building of the Department of Commerce; Projection Session; Release Print Session; and Theater Operation Session. Of particular interest among these were the sessions on projection, the release print, and theater operation, the attention being paid to these subjects indicating the rapid broadening of the interest of the Society in the field of the theater. The General Session, held on the first day of the Convention, included a symposium on sixteen millimeter sound-on-film, a subject of outstanding interest at the present moment.

On Wednesday, May 11th, the Society was entertained by the Department of Commerce in the auditorium of the new Department Building, Mr. C. J. North presiding. Very interesting addresses were given by Dr. Julius Klein, Assistant Director of the Department of Commerce; Mr. F. M. Feiker, Director of the Bureau of Foreign and Domestic Commerce; Mr. T. E. Robertson, Commissioner of the Patent Office; and Mr. W. M. Steuart, Director of the Bureau of the Census. Thanks are due the Department of Commerce for a highly interesting session, and particularly Messrs. North and Golden for arranging the session.

The semi-annual banquet of the Society was held on Thursday, May 12th, at the Wardman Park Hotel, the Hon. W. P. Connery, Jr., Congressman from Massachusetts, acting as Master of Ceremonies. Addresses were delivered by Mr. J. M. Gibbs, of the U. S. George Washington Bicentennial Committee, and by the Hon. Robert Ramspeck, Representative from the Fifth Georgia District.

Acknowledgment is to be made of the courtesies extended to the Society during the Spring Convention by the following organizations: Bausch & Lomb Optical Company, du Pont Film Mfg. Corp., Greater National Capital Convention Bureau, International Projector Corp., National Carbon Co., National Theater Supply Co., (Washington Branch), Raven Screen Co., RCA Photophone, Inc., Strong Electric Co., and Washington Projectionists Local No. 224.

The following Washington theater circuits are to be thanked for honoring in their theaters the identification cards of members of the Society: Fox Theater Corp., Loews Theaters, Inc., Radio-Keith-Orpheum, and Warner Bros.

Thanks are also due to the following exchanges for supplying films for the entertainment of the members: Paramount Publix Corp., Metro-Goldwyn-Mayer Pictures, Warner Bros. Pictures, RKO Exchange, First National, United Artists, Universal Pictures Corp., Educational Film Exchange, Columbia Pictures, Pathé Exchange, and the Motion Picture Division of the U. S. Department of Commerce.

BOARD OF GOVERNORS

At the meeting of the Board of Governors held at Washington on May 8th, prior to the opening of the Spring Convention, final arrangements for the Convention were completed, and action was taken upon a number of amendments of the By-Laws of the Society, to be presented for voting at the open meeting on May 9th. Revised forms of the Constitution and By-Laws, in accordance with these alterations, will be available shortly to all members upon request. Among the matters of immediate interest that were acted upon favorably by the Board and subsequently by the membership at large, were the following:

Reduction of Admission Fees.—Acting upon the recommendations of the Ways and Means Committee and of the Board of Governors, a reduction of the admission and transfer fees was effected at the open meeting of the Society on May 9th by unanimous approval of the following amendment of the By-Laws of the Society:

By-Law VII. Dues and Indebtedness.

Section 1. The admission fee for applicants to the grade of Active membership shall be ten dollars, and to the grade of Associate membership, five dollars.

Section 2. The transfer fee from the Associate grade to the Active grade shall be the difference between the above-mentioned fees, or five dollars.

The complete schedule of membership fees is therefore as follows:

Admission fee to Active membership	$10.00
Admission fee to Associate membership	5.00
Annual dues for Active membership	20.00
Annual dues for Associate membership	10.00
Transfer fee, Associate to Active	5.00

Advertisements in the Journal.—In order to assist in the financial operations of the Society, the Board of Governors, at a meeting held on May 8th at Washington, authorized the Editor-Manager to solicit advertisements for the JOURNAL, beginning immediately. Information concerning the placing of advertisements in the JOURNAL may be obtained from the General Office of the Society, together with a schedule of rates and other data concerning the Society and its activities. The assistance of the membership in securing advertisements for their JOURNAL will be greatly appreciated.

COMMITTEE ON MOTION PICTURE EXHIBITION

In order to spread knowledge concerning the S. M. P. E. among exhibitors, to promote the support and approval of the exhibitors of the activities of the S. M. P. E., to obtain from exhibitors statements of their problems, and to seek and propose solutions for these problems and ultimately to bring about an organic relation between motion picture engineers and exhibitors, the Board of Governors decided to establish a committee to be known as the Committee on Exhibition, whose function it would be to deal with the problems outlined above. Announcement of the personnel of this committee will be made at a later date.

SUSTAINING MEMBERS

Agfa Ansco Corp.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Case Research Laboratory
Du Pont Film Manufacturing Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Mole-Richardson, Inc.
National Carbon Co.
RCA Photophone, Inc.
Technicolor Motion Picture Corp.

HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN

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Society of Motion Picture Engineers

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